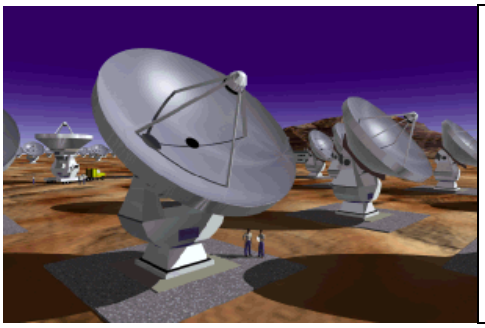

Atacama Large Millimeter Array	ALMA-SW-0011 Revision:3 2002-03-13 *Requirements* Robert Lucas

ALMA Software Science Requirements and Use Cases

Requirements

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Contents

1 Introduction

This document intends to define science-driven software requirements of the ALMA project. In a first report (ALMA Memo 293) we had given an overview of these requirements. In the present report we consider in more detail the requirements of the various components of ALMA software.

The operation of ALMA will have to deal with a larger variety of projects than previous instruments: on one hand at long wavelengths (1-3 mm) due to the high sensitivity and quality of the site, and based on long experience with millimeter-wave interferometry, we can predict with reasonable certainty the observing modes that will be used, the relevant observing strategies to schedule the instrument, and the data reduction techniques. On the other hand at the highest frequencies ($\sim 300\mu$m) no array has been operational yet; we plan to rely on techniques such as radiometric phase correction, fast phase switching and phase transfer between frequency bands, that have been demonstrated, but not applied on the operational scale that we foresee for ALMA. We thus will have to combine in the software a high level of automation, needed to deal with the large information rate that will be available, with a high level of flexibility at all levels to be able to develop and implement new observing methods and reduction procedures. For simple projects the astronomer with little or no experience of radio techniques should be able to use the instrument and obtain good quality results; however experts should easily be able to perform experiments we do not even foresee today.

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

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

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

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

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

The instrument should produce images, aiming to be final for most projects, even when projects are spread over several sessions and configurations, and/or include short/zero spacings. For this purpose an on-line pipeline is required. It will include calibration of the array itself, to reduce measurements of baseline, delay offsets, and determine pointing models during specific sessions. During standard observing sessions

reference pointing and focusing measurements will have to be reduced, with fast loopback of results to the observing process; the phase fluctuations on the phase calibrators must be evaluated, with a feedback to both the real time process and the scheduler. Calibration will be applied on-line and maps/datacubes will be produced according to data processing parameters input by the observer. Single-dish observing sessions will also be reduced on-line. The pipeline must be able to reduce on line the quasi totality of the data, which is expected to be produced at an average rate of 6 MB/s, with a peak rate of 60 MB/s for some observing sessions.

For most projects the data pipeline will produce results in a form suitable for quality evaluation, and astronomical processing, hopefully leading to fast publication. Uncalibrated *uv* data will be archived together with the calibration curves and the resulting images. The archive should enable fast access to the observing parameters and full reprocessing of the data set with improved processing algorithms.

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

In Section 2 we introduce the main entities, used to manage the whole observing process, that are referred to in the Requirements and the Use Cases. In Section 3 we enumerate requirements in a formal way; these are grouped in sub-sections corresponding to the main software components outlined in the present Introduction. In Section 4 we give the main *Use Cases* for ALMA Software, as well as, in a more detailed way, for what we believe will be the main observing modes. Use Cases are a very important way of providing input to the 'Unified Process' method of software design, which has been chosen by the ALMA Software Group, as it is now getting more and more recognized as an efficient method of producing software in large projects.

Appendix A give some examples of Scheduling Blocks in order to precise their meaning. Appendix B lists the main quantities that describe how the ALMA hardware is controlled to perform a basic, individual observation. A Glossary is included as Appendix C.

2 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 and the Use Cases. These entities have some kind of hierarchical structure that will be further refined at the analysis stage of software development.

Proposal:

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

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

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

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

Project:

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

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

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

— A project identification code
— A list of requested bands (possibly subset of those in proposal)
— A list of requested configurations (possibly subset of those in proposal)
— A scientific rating assigned by the observing programme 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).

Programme:

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

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

A Programme is a set of Scheduling Blocks and Break Points.

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

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

Break Point:

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

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

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

Scheduling Block: (SB)

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

- An observing script to be executed.
- `Deleted: A maximum repeat count.`
- 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.
- Conditions on the antenna positions: ranging from a required configuration name to a required angular resolution, i.e. a domain of the uv plane to be filled with reasonable uniformity (depending of the array configuration policy, TBD).
- An optional, observer assigned logical condition to be satisfied before scheduling. This is used for dependencies between SBs.
- A maximum pointing error (systematic and random components)
- A maximum surface error / beam error (from thermal gradients in antenna structures).
- 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 blocks have several possible functions. They may collect data for use in the data reduction phase:

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

There is at least one case in which one would like a preamble block to feed back information to the observing system: It may observe a list of calibrators, picking one or two which meet defined characteristics (mainly, a combination of calibrator strength and proximity to the target source), using data fed back by the calibrator data reduction programme. These may then be referred to symbolically in the following SBs.

Observing Session:

The time continuous execution of one or more scheduling blocks in a programme constitutes an observing session. In addition to the SBs it will include preamble and postamble observations attached to them.

The observing session is a key object for the data processing since data taken in a session will have some technical coherence (e.g. no receiver tuning inside a session) which allows calibrations to be shared for that data.

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. Whether OTF mosaicing observations are considered a single scan or a scan per point is rather a matter of how you would like to define it.

Observation:

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

— a simple driving pattern for each antenna,
— a simple driving pattern for nutating subreflector
— a simple driving pattern for the array phase center
— a single receiver band
— a single position for any slow receiver calibration mechanical device (vane) or a simple switching pattern for any fast receiver calibration mechanical device (chopper)
— a single frequency or a simple frequency switching pattern
— a single correlator configuration

Integration:

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

Dump:

A Dump corresponds to the minimum available integration time. Its duration is 16ms if all correlator data is written. It can go down to 1ms if only autocorrelation data is recorded, or 2ms if only total power detectors are recorded.

Switching Cycle:

A Switching Cycle is needed when a fast switching device, such as a nutating subreflector, is used to cancel atmospheric noise. The Switching Cycle is the time sequence of several States, each of which is an integer number of Dumps.

If such a fast switching device is used, an Integration is an integer number of Switching Cycles; for each Integration, the average of all data taken in each State of the switching device are kept separately.

3 Requirements

Requirement priorities in the following have four values:

0 Essential feature: Must be present from the start.

1 Must be there for Interim Science period, when the system is commissioned to produce meaningful science results.

2 Must be there when the system is widely open for Science as an operational (though not hardware completed) instrument.

3 Desirable feature for the final, complete system.

These priorities should be reflected in the order of implementation of the features involved.

3.1 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 **Graphical User Interfaces** (GUIs) except for the low level Command Control Language.

Priority: 1

1.0–R6 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.

Priority: 1

1.0–R7 The ALMA final product shall be images for the large majority of projects. The data shall be calibrated and processed in pipelines.

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 `to be updated` 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 times higher. See page 17 and ALMA Software Note NNN. The full data rate will be needed only when all baselines are present.

Priority: 2

1.0–R10 An Alarm System shall allow hardware and software faults to be uniquely identified and suppress error cascades. Identification of the faults shall be available to the operator and used in operating ALMA. The faults shall be logged and used as input for system maintenance and for the dynamic scheduling.

Priority: 0

1.0–R11 Poorly behaving system hardware components detected by the data pipelines will also be managed at the system level; their status will also be made available to the system maintenance staff and to the dynamic scheduler.

Priority: 1

3.2 Real time software

3.2.1 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. This will be done under the responsibility and with the assistance of the Operator.

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. They shall include:

1. Interferometric
    1. Single Field Mapping.
    2. Multi Field Mosaics
    3. On-The-Fly Mosaics
    4. Phased Array
2. Total Power
    1. On the Fly Mapping
    2. Position Switched Mapping
    3. Frequency Switched Mapping
3. Special observations
    1. Pulsar observations
    2. Solar flare tracking.
4. Project Calibrations
    1. Temperature Scale Calibration
    2. Gain Calibration (amplitude and phase)
    3. Bandpass calibration
    4. Pointing/Focus calibration
    5. Flux calibration
    6. Polarization calibration
5. Array Calibration
    1. Pointing calibration session
    2. Baseline calibration session
    3. Delays calibration
    4. Beam shape calibration

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 above modes.

However there should be only one programme in the dynamically scheduled mode at any time (see 2.1R11 below).

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 in the scheduling, unless otherwise decided by the staff, e.g. to make the best possible use of exceptional observing conditions.

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

2.1–R11 As a baseline plan there shall be only one dynamically scheduled research programme at a time, using all available antennas while some antennas have been taken out by the staff as one or several interactively controlled subarrays, for calibration or research. Remaining antennas shall be made available to filler science programmes, either through a functionality of the scheduler, or by manual action of the operator. The filler programmes must be able to release these antennas on short notice as soon as they are needed by the main (dynamically scheduled) research programme.

Priority: 1

3.2.2 Control Command Language

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

Priority: 0

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 including a time out

— interruption facility in procedure execution

Priority: 0

3.2.3 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). This means that for long integration times (tens of seconds), being able to blank a single correlator dump is not necessary.

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 kept along with data, in addition to the flagging information).
  — 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 `to be updated` The average data rate shall allow the recording of one million complex visibilities per second (1.0 MVPS) and one-half million image pixels per second (0.5 MPPS). These are the average over long periods of time and different programmes. These can be used to determine the archive size. The visibility data rate 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 could be done automatically on each spectrum and baseline (for a spectrum normalized by its maximum channel, the number of bits should be at least $1/2 \log_2 B\tau$, where B is the channel bandwidth and τ the integration time). Alternately one may choose to always use 32-bit integers and rely on standard data compression techniques.

Priority: 0

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

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

Priority: 0

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 also be computed from the stored system noise spectra.

Priority: 0

2.3–R12 When a band is equipped with a double sideband receiver, it shall be possible to process and store data from both sidebands using software sideband separation or to store data from a single sideband using sideband suppression by local oscillator offset.

Priority: 0

3.3 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: I: prior to scientific evaluation, and II: 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 I to judge technical feasibility and observing time needed; The remaining input shall be optional at phase I but required at phase II to fully specify the observations to be done.

Priority: 1

3.0–R4 The scientific justification shall be provided (at Phase I) 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:

— full source identification and coordinates (whatever the size of the source list).
— 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 I the observing tool shall perform certain calculations, e.g. of integration time required under average conditions, using velocity width and resolution information, 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 warning 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, in order to better assess the validity of the amplitude and phase calibrations. The system shall optionally automatically choose a test source at execution time.

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. Observations after the breakpoint will have to stay within the project scope, as defined in the observing proposal and accepted by the reviewers.

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.

The dependency rule for a scheduling block shall be a logical expression involving the execution status parameters of one or several among the other scheduling blocks in the programme:

— SB execution started
— SB execution failed
— SB execution successfully terminated
— number of SB executions
— SB sensitivity reached

There shall be at least one SB in the programme with a dependency rule that evaluates as `false` (i.e. SB is independent) when the program is started.

Priority: 2

3.3.1 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: 2*).

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

Priority: 1

3.1–R3 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

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.

However some projects may be only allocated a total integration time.

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: 2*). 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: 1-2

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

3.1–R13 Based on the simulation 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 whether image deconvolution needs to be executed after each breakpoint.

Priority: 1

3.4 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. A SB can be executed again (in order to reach the required sensitivity level, or if it had failed for hardware reasons), but cannot be restarted in the middle of its execution.

Priority: 1

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

— 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 (see 3.0-R15)
— 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
— Preamble/postamble execution times
— Hardware availability and status (from quality control)
— Stringency factor: SBs requiring rare conditions should get a preference whenever these conditions do occur.

The actual formula and coefficients must be tuned for optimum overall efficiency, and agreement with observatory policy, 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, in each range of observing conditions.

Priority: 1

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

Priority: 1

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

Priority: 0

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 recorded historical weather data, or model atmospheric data, as input.

Priority: 1

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

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

Priority: 1

4.0–R10 At all times two receiver bands are active (used in turn for target observations and calibration), and a third one is kept on standby, ready to become an active band when the next project is observed. Consequently, during the execution of a SB, the scheduler shall periodically (e.g. every 15 min) select the SB that would be elected if the currently executed SB would finish at this time, and change the receiver band on standby accordingly, if needed (whether this evaluation may use extrapolation of observed environmental parameters should be considered during design). When the SB actually finishes, only the SBs making use of receiver bands either active or on standby are to be considered.

Priority: 1

3.5 Operator Interface

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

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

Priority: 0

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

Priority: 0

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

Priority: 0

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

— a top level monitor to show integrated information, including the current observing plan, the array status, and telescope status.
— a second level to show important monitoring items for the current observations.
— a third level with on-demand monitoring.

Priority: 0

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

Priority: 1

3.6 Pipeline Data Processing

3.6.1 Introduction

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

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

3.6.1.1 Pipeline Operations The pipeline executes four different kinds of operations: *Real-time Calibration*, *Quick Look*, *Science Calibration*, and *Science Imaging*. Each of these groups has different functions; those related to interferometric data are summarized in the following list:

- **Real-time Calibration Operations**
  Occurence: (quasi) real time
  - Atmospheric Model
  - Astronomical Calibration
    — reduce and archive astronomical calibrations:
      – side band ratio determination
      – atmospheric calibration
      – bandpass calibration
      – preliminary phase rms
      – preliminary phase and amplitude calibration
    — make results available to the dynamic scheduler
  - Telescope/Array Calibration
    — reduce and archive telescope/array calibrations
      – pointing
      – focus
      – delay
      – baselines
      – holographies
    — make results available to the sequencer

- **Quick Look Operations**
  Occurence: during and after observing session
  - Monitoring
    — display subsets of the current properties of the observations and/or array
    ⇒ needs results of Real-time Calibration Operations
  - Quick Calibration
    — works on subsets [channel ranges] or pre-processed data [resampled or integrated]
    — apply preliminary phase and amplitude calibration
    ⇒ needs results of Real-time Calibration Operations
  - Quick Imaging
    — produce images (no or simplified deconvolution)
    ⇒ needs results of Quick Calibration
  - Display Tools
    — Display current observations to allow checks of data quality to operator/astronomer
    ⇒ needs results of Quick Calibration/Quick Imaging

- **Science Calibration Operations**
  Occurence: after completion of observing session
  - derive and/or apply the calibration curves
    - — bandpass calibration
    - — final phase and amplitude calibration
    - — flux scale

- **Science Imaging Operations**
  Occurence: after Science Calibration Operations; results are preliminary after completion of observing session, final after completion of project
  - produce *uv* tables of temperature-calibrated visibilities
  - ⇒ need results of Science Calibration Operations
  - extract from Archive previous observations
  - produce and archive deconvolved images

3.6.1.2 Sources We use the following terms in this document:

— *Astronomical Source*: any astronomical object in the sky observed by the ALMA. This excludes arbitrary positions observed for calibrations (OFF positions, skydips, etc).

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

— *Calibration Source*: astronomical source observed for calibration purpose. It could be a a point-like source (quasar) or any source of known flux or structure (including planets).

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

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

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

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

The first two categories are real-time calibration operations, as described in section 3.6.3.

The third category will be handled partly as Real-time Calibration Operations (for calculating quantitites like phase noise up to a certain point or as function of time, to assess the data quality and interact with the scheduler), partly as Quick Look Operations (for producing intermediate images), and partly as final Science Calibration Operations. It will probably be sufficient to include only the simple modes 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 the observed spectra on a given bandwidth. Similarly, polarization data are not distinguished, but are included in all steps, the model that we consider being the processing of one or more Stokes parameter; primary beams are polarized.

3.6.2 Pipeline General Requirements

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

Priority: 1

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

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

Priority: 1

6.2–R3 The Pipeline shall operate through readable and comprehensible data reduction scripts (*Priority: 1*). Those scripts shall be automatically generated from templates, on the basis of the observing mode being use (*Priority: 2*).

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

Priority: 1

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

Priority: 1

6.2–R6 Sufficient recording of operations performed and control parameters shall be carried out so that any step can be reversed and redone if needed, without recourse to repeating an entire series of previous operations or resorting to a copy of the dataset at the intermediate state.

Priority: 2

6.2–R7 A manual, interactive mode of operations shall be available for debugging, technical developments, inspection by qualified ALMA staff. In this mode, both a Command Line Interface (CLI) and a Graphical User Interface (GUI) shall be available.

Priority: 1

6.2–R8 The Pipeline (especially the Science Calibration and Imaging Operations) shall also be runnable at the Regional Centers. Some of the actions described below are not relevant in that case, as the interactions with the Dynamic Scheduler and with the Sequencer.

Priority: 2

6.2–R9 Antenna-based determination of calibration quantities shall be the primary form of calibration. Baseline-based calibration shall also be available.

Priority: 1

3.6.3 Real-time Calibration Operations

6.3–R1 The Real-time Calibration Operations shall be activated after each observation.

Priority: 1

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

Priority: 1

3.6.3.1 Astronomical Calibration: Atmospheric Model

6.3.1–R1 Atmospheric modelling shall be available in the Pipeline. The model shall be able to predict the absorption, emission and pathlength on the line of sight through the atmosphere at all ALMA bands. The prediction will be based on the following data:

— measured atmospheric parameters at the site: temperature, pressure, humidity;
— measured atmospheric emission in the observed ALMA bands;
— measured WVR data;
— measured atmospheric profiles of temperature and water content if available from atmospheric sounders;
— measured optical depths from tipper meters and/or FTS, if available.

Priority: 1

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

Priority: 1

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

Priority: 1

3.6.3.2 Astronomical calibration: Interferometric Data

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

6.3.2–R1.1 the receiver sideband ratios;
Priority: 1

6.3.2–R1.2 the temperature scale calibration data, using the Atmospheric Model; in real-time mode, the result must be passed to or made available for access by the Dynamic Scheduler;
Priority: 1

6.3.2–R1.3 the bandpass calibration data;
Priority: 1

6.3.2–R1.4 the instrumental polarization.
Priority: 1

6.3.2–R2 For all observations of an astronomical source, the Pipeline shall convert the raw data into temperatures, or, alternatively, store the conversion factor ($T_{\rm sys}$) and defer the actual conversion to each step that requires calibrated data.

Priority: 1

6.3.2–R3 For suitable observations of a calibration source, the Pipeline shall:

6.3.2–R3.1 compute the phase rms over the observed time;
Priority: 1

6.3.2–R3.2 compute the antenna efficiencies using the known source flux;
Priority: 1

6.3.2–R3.3 do the previous operations both with and without the atmospheric phase correction, and deduce from the comparison whether the atmospheric phase correction improves the results or not; this may involve trying different parameters for the atmospheric phase correction;
Priority: 2

6.3.2–R3.4 derive amplitude and phase time-dependent variations by fitting smoothed curves (e.g. polynomials, splines) using all observations of calibrators since the beginning of the session; fast-swtiching observations shall be supported; this derivation shall be done either per antenna or per baseline or both.
Priority: 2

In real-time mode, these results shall be passed to the Dynamic Scheduler. They must also be made available to later Science Calibration Operations for gain transfer to target sources.

Priority: 1

3.6.3.3 Astronomical Calibration: Single Dish Data

6.3.3–R1 The Pipeline shall reduce the atmospheric calibration, using sideband ratios determined from the most recent interferometric calibration, and pass the results to the Dynamic Scheduler.

Priority: 1

6.3.3–R2 For all observations of an astronomical source, the Pipeline shall convert the raw data into temperatures, or, alternatively, store the conversion factor ($T_{\rm sys}$) and defer the actual conversion to each step that requires calibrated data.

Priority: 1

3.6.3.4 Telescope/Array Calibration

6.3.4–R1 The Pipeline must reduce:

6.3.4–R1.1 the pointing measurements;
Priority: 1

6.3.4–R1.2 the focus measurements;
Priority: 1

6.3.4–R1.3 the delay measurements.
Priority: 1

The results must be archived. They must be passed or made available to the Sequencer.

Priority: 1

6.3.4–R2 The Pipeline shall determine the baselines from the observations of several calibration sources. The results must be made available to the Sequencer.

Priority: 1

6.3.4–R3 The Pipeline shall be able to determine pointing (*Priority: 1*) and focus (*Priority: 2*) models from the observations of several calibration sources.

6.3.4–R4 The Pipeline shall reduce holography measurements.

Priority: 1

6.3.4–R5 The Pipeline shall derive the primary beam properties, half-power beam size and the main-beam efficiency from the observations of planets or point sources of known fluxes or small sources of known visibility model and aperture efficiency.

Priority: 2

6.3.4–R6 Single Dish data – The Pipeline must reduce:

6.3.4–R6.1 the pointing measurements;
Priority: 1

6.3.4–R6.2 the focus measurements;
Priority: 1

6.3.4–R6.3 the skydip measurements;
Priority: 1

6.3.4–R6.4 the holography measurements.
Priority: 3

The results must be archived. They must be passed or made available to the Sequencer. Note however that in most cases these determinations will be done interferometrically.

3.6.4 Quick Look Operation

6.4–R1 The Quick Look Operations shall be activated automatically after each occurence of the Real-time Calibration Operations, or under given conditions (e.g. after a certain time interval, if a rms has been reached, etc.). It must also be possible to start the Quick Look Operations whenever requested by the staff astronomer or operator.

Priority: 1

6.4–R2 The results of the Quick Look Operations must be made available to PI/CoIs astronomers of the project, via the Internet.

Priority: 2

3.6.4.1 Monitoring

6.4.1–R1 A Monitoring Tool shall be available, plotting and archiving in a log file various real-time calibration results, including:

6.4.1–R1.1 the results of the last pointing or focus scan;
Priority: 1

6.4.1–R1.2 the phase rms computed over the last scan and computed over the current session.
Priority: 1

6.4.1–R1.3 the corresponding seeing.
Priority: 1

6.4.1–R1.4 the atmospheric opacity.
Priority: 1

This tool shall include a variety of options, to control the display parameters, to plot the variation of these results with time, to allow the staff astronomer and operator to monitor one antenna or baseline in particular, etc. Since it is required that the ALMA 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.

6.4.1–R2 Automatic checks shall be available to detect bad or degrading results, triggering alarms if necessary.

Priority: 1

6.4.1–R3 A Monitoring Tool shall be available to plot the current properties of the array, such as:

6.4.1–R3.1 the current instantaneous *uv* coverage;
Priority: 2

6.4.1–R3.2 the corresponding weight distribution (natural weighting);
Priority: 2

6.4.1–R3.3 the corresponding dirty beam;
Priority: 2

6.4.1–R3.4 the previous quantities, integrated since the beginning of the session;
Priority: 2

6.4.1–R3.5 the thermal noise rms reached since the beginning of the observing session (from theory, using actual system temperatures).
Priority: 2

3.6.4.2 Data processing: Interferometric Data

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

6.4.2–R1.1 apply the current bandpass calibration;
Priority: 1

6.4.2–R1.2 apply the current amplitude and phase correction (using the scaling factor between the calibration and observing frequencies);
Priority: 1

6.4.2–R1.3 apply the flux conversion factor based on standard antenna efficiencies.
Priority: 1

6.4.2–R2 The spectra observed on an astronomical target shall be displayed (amplitude and phase) with various options such as:

6.4.2–R2.1 time integration;
Priority: 1

6.4.2–R2.2 choice of the baseline(s);
Priority: 1

6.4.2–R2.3 baselines summation, with and without shifting phases to a specified position;
Priority: 2

6.4.2–R2.4 intensity (amplitude and/or phase) as function of baseline and time (for a frequency), or time and frequency (for a baseline);
Priority: 1

6.4.2–R2.5 phase and amplitude closure for calibrators.
Priority: 1

6.4.2–R3 The Quick Look Pipeline shall compute the dirty image of astronomical targets, by computing the Fourier Transform of the visibilities, using the fastest algorithm. The resulting map shall be displayed. Alternatively, the actual Fourier Transform of each new visibility point can be computed and added to the current image. This shall be done for:

6.4.2–R3.1 the continuum data;
Priority: 1

6.4.2–R3.2 the line-averaged spectra, over a pre-defined velocity range, or possibly a velocity range defined by the staff astronomer or operator.
Priority: 1

6.4.2–R4 Mosaic and self-calibration projects shall be supported.

Priority: 2

6.4.2–R5 For the observations of point-like, bright sources (e.g. quasars) the Pipeline shall produce a map of the continuum emission and compare it to the clean beam, in order to estimate the seeing of the observations.

Priority: 2

3.6.4.3 Data processing: Single Dish Data

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

6.4.3–R1.1 on/off;
Priority: 1

6.4.3–R1.2 nutator switch;
Priority: 1

6.4.3–R1.3 frequency switch;
Priority: 1

6.4.3–R1.4 raster maps using one of the above modes;
Priority: 1

6.4.3–R1.5 OTF maps using one of the above modes.
Priority: 1

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

6.4.3–R2.1 time integration;
Priority: 1

6.4.3–R2.2 antenna summation;
Priority: 1

6.4.3–R2.3 baseline fit, excluding a window automatically determined, or pre-defined, or defined by the Operator or Staff Astronomer;
Priority: 1

6.4.3–R2.4 spectra on a grid corresponding to actually observed positions on a raster (a "stamp" or "profile" plot).
Priority: 1

3.6.5 Science Calibration Operations

6.5–R1 The Science Calibration Operations shall be activated after reaching a break-point (either user-defined or end of observing object or end of observing session).

Priority: 1

6.5–R2 The Pipeline shall find in the Archive all data observed during the session. It shall use the atmospheric-calibrated data (temperature scale and phase).

Priority: 1

3.6.5.1 Interferometric Data

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

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

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

Priority: 1

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

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

3.6.5.2 Single Dish Data

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

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

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

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

Priority: 1

3.6.6 Science Imaging Operations

6.6–R1 The Science Imaging Operations shall be activated after reaching a break-point (either user-defined or corresponding to the end of the subproject). It shall run after the Science Calibration Operations have been completed.

Priority: 1

6.6–R2 The manipulation of data cubes shall be the default mode of operation of the Science Imaging Pipeline. The final product will be the deconvolved images.

Priority: 1

6.6–R3 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

6.6–R4 The results of the Science Imaging Operations must be made available to PI/CoIs astronomers of the project, via the Internet.

Priority: 2

3.6.6.1 Interferometric Data

6.6.1–R1 The Pipeline shall find in the Archive all data observed during the session. It shall use the calibrated data produced by the Science Calibration Operations.

Priority: 1

6.6.1–R2 The Pipeline shall find in the Archive the visibilities and calibration data obtained during all previous observing sessions, and check whether the data are compatible with the current dataset (in terms of instrumental setup, noise rms, etc.)

Priority: 2

6.6.1–R3 Careful cross checks of the flux scales between the data sets shall be performed.

Priority: 2

6.6.1–R4 Direct comparison of the redundant data (obtained simultaneously or not) shall also be performed.

Priority: 2

6.6.1–R5 The Pipeline shall extract the visibilities with the appropriate frequency resolution, plus the continuum measurement if required.

Priority: 1

6.6.1–R6 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

6.6.1–R7 The images shall be deconvolved using the most appropriate algorithm. In case of a complex image, it should be possible to have several algorithms running in parallel, the best (according to criteria TBD) image being eventually selected. The algorithms supported shall include:

6.6.1–R7.1 CLEAN and its various flavors;
Priority: 1

6.6.1–R7.2 multi-resolution and multi-scale CLEAN;
Priority: 2

6.6.1–R7.3 Maximum Entropy Method (MEM).
Priority: 1

6.6.1–R8 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 be possible to make trial subtractions and select the best solution in an automated manner.

Priority: 2

6.6.1–R9 Designated modes shall be supported, including:

6.6.1–R9.1 mosaic observations;
Priority: 1

6.6.1–R9.2 on-the-fly mosaics;
Priority: 2

6.6.1–R9.3 wide-field imaging;
Priority: 2

6.6.1–R9.4 self calibration projects;
Priority: 1

6.6.1–R9.5 combination of single dish and interferometer data.
Priority: 1

3.6.7 Single Dish Data

6.7–R1 For single dish data, the Pipeline shall find in the Archive all data observed during the session; it shall use the calibration data produced by the Science Calibration Operations.

Priority: 1

6.7–R2 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

6.7–R3 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

6.7–R4 Provision shall be taken to allow running appropriate algorithms (deconvolution, destriping), if required by the data or by the experience gained using ALMA.

Priority: 2

3.7 Archiving

3.7.1 Introduction

7.1–R1 The archive enables astronomers and engineers to access and use data which has been obtained with ALMA.

Priority: 0

7.1–R2 We distinguish the "observational archive," which contains the observational data and related header information, and the "technical archive", which contains all technical and environmental data recorded by the ALMA systems.

Priority: 1

3.7.2 Observational Archive

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

Priority: 1

7.2–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.

7.2–R1.2 The quick-look data is not stored in the final archive by default (see requirements for quick-look and scientific imaging pipelines).

7.2–R2 The observational archive shall also include as header data:

— all user (observer) input including the scientific justification of the project
— high-level observing scripts as they have been used to obtain the data
— the low-level actual observation descriptors which are made by expanding the high-level observing scripts and (time-variable) instrumental/environmental parameters
— technical data relevant to data reduction (cf. 1.3-R2)
— the pipeline or offline software versions and data reduction scripts
— dataquality information (e.g. noise level and dynamic range, based on pipeline results)
— whether it 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

7.2–R3 In case of irreversible on-line data corrections such as the atmospheric phase correction on time scales shorter than the integration time, the default action is to archive both the corrected and the uncorrected data. This may be overridden by the user, however, and this must be reflected in the archive contents and header information.

Priority: 1

7.2–R4 A user or staff member may submit the results of off-line reduction and imaging for attachment to the archive. Other data products, such as the scientific paper resulting from the observations, or catalogs derived from the data, might also be attached to the archive at a later date.

Priority: 2

7.2–R5 The observational archive shall extract the database information for efficient data search, from the header of the observation data.

Priority: 1

7.2–R6 The observational raw data shall be archived in SOC/OSF immediately after they are taken, and the results from the Science Pipeline shall be archived after it runs.

Priority: 1

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

Priority: 1.

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

Priority: 2.

7.2–R9 There shall be a backup for the archive.

Priority: 1

7.2–R10 There shall 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

7.2–R11 The data within each scan shall be identifiable by its goal (phase calibrator, target observation, pointing scan ...)

Priority: 1

7.2–R12 The archive shall provide the appropriate link to all the technical data/table which is necessary to make off-line analysis, if there is any technical data/table which is not included in its header.

Priority: 1

7.2–R13 Images produced by the pipeline are stored in the archive when appropriate:

- **7.2–R13.1** For long integrations or large numbers of channels, the images are stored in the archive.
- **7.2–R13.2** For short integrations or small datasets, images shall be generated on-the-fly from the visibilities upon extraction from the archive.
- **7.2–R13.3** 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.
- **7.2–R13.4** Images must always be archived if the pipeline cannot generate them upon extraction.

Priority: 1

7.2–R14 Updates to the calibration must be transparently incorporated in the archive.

Priority: 1

- **7.2–R14.1** The archive should always contain and provide the most up-to-date calibration. (*Priority: 1*)
- **7.2–R14.2** If recalibration by using better calibration algorithm and/or better calibration data is recommended by ALMA, then the science archive system should inform the observer or registered archive users. (*Priority: 1*)
- **7.2–R14.3** It shall be possible for an archive user to recalibrate the data on extraction on a case-by-case basis. This should not affect the state of the archive, which should use the standard calibration. (*Priority: 2*)

3.7.3 Technical Archive

7.3–R1 The archive shall include all technical/environmental data recorded by the ALMA system (including times when the array was not observing), logged by timestamp.

Priority: 1

7.3–R2 The technical archive shall include:

- environmental data (e.g. weather data)
- the water vapor radiometric raw data and derived pathlength correction, on $\sim 1s$ timescale

— the monitor data

Priority: 1

7.3–R3 The archive shall record all high- and low-level scripts, not only of the Dynamic Scheduler but also of interactive observing or other manual operation, whether they are made during observation or not.

Priority: 1

7.3–R4 The archive shall include an electronic logbook to record the notes of the observer and/or telescope operator.

Priority: 2

3.7.4 User Interface

7.4–R1 The archive shall be accessed through a GUI, the **Archive Search Tool**.

Priority: 1

7.4–R2 The Archive Search Tool shall allow searching the database to see if observations have been previously done. It shall also be used as a front end to the **Data Extractor Tool**, which manages the data extraction and delivery.

Priority: 1

7.4–R3 The Archive Search Tool shall operate on supported platforms as designated by the project.

Priority: 1

7.4–R4 Comprehensive help facility shall be provided for the Archive Search Tool.

Priority: 1

7.4–R4.1 Interactive context-based help shall be provided in the GUI. (*Priority: 2*)

7.4–R4.2 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: 2*)

7.4–R5 The Archive Search Tool shall have two interfaces: one mainly for observational archive, the other mainly for technical archive.

Priority: 2

7.4–R6 The search criteria shall include:

— Object name
— Position on the Sky (Equatorial, Galactic, Ecliptic coordinates)
— Hour angle
— Elevation
— Observation Date
— Integration Time
— Molecular transition
— Frequency
— Array Configuration
— Observation mode
— Whether observation is for target or calibration
— Angular resolution
— Spectral resolution
— Weather condition
— Name of Principal Investigator
— Project name

— Project number
— Title of the proposal
— Observing Programs (OPs)
— Scheduling Blocks (SBs)
— Telescope operator or Astronomer on Duty
— Reduction date
— Data quality (noise level or dynamic range).
— Any other header info

Priority: 1

7.4–R7 Some regular expressions including wild card and ranges shall be available in search.

Priority: 1

7.4–R8 The query statements used for database search shall be shown with search results.

Priority: 2

7.4–R9 For the Observational Archive, 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*)

7.4–R10 A preview image (e.g. a small image cube) of the data found in the search shall be made available before actual data transfer.

Priority: 1.

7.4–R10.1 The preview image cube of the images and dirty beams shall be made either on-the-fly upon request or produced by the pipeline in advance (using the same criteria as for full images). (*Priority: 1*)

7.4–R10.2 If a user requests a preview image without specifying the frequency/velocity information in the line data search, the Data Extractor Tool shall provide a sensible default velocity integrated intensity map (e.g. 10 km/s for Galactic, 300 km/s for extragalactic, centered on the observer-specified rest frequency and tracking velocity, or the intensity-weighted velocity of the detected line emission from the pipeline). (*Priority: 1*)

7.4–R10.3 A simple image viewer for preview image shall be also provided. (*Priority: 2*)

7.4–R11 An archive user shall be able to browse all of the header information for requested data.

Priority: 1

7.4–R12 An archive user as well as the Dynamic Scheduler, shall be able to use calibration data immediately after the calibration observation.

Priority: 1

7.4–R13 The Data Extractor Tool shall attach a hyperlink to external archives and catalogs (e.g. DSS image) of the corresponding sky area upon request.

Priority: 2

7.4–R14 The Data Extractor Tool shall accept external archive search request to get the file like, http://archive.stsci.edu/cgi-bin/hst?ra=16%2052%2055.75 &dec=%2B02%2024%2001.88&radius=1.0&equinox=J2000&action=search

Priority: 1

7.4–R15 The Data Extractor Tool shall be invoked from the Offline reduction package (cf. OL-3.8-R1 to R3 of the Offline Requirements document).

Priority: 1

7.4–R16 The archive user can select network transfer or the physical data delivery (disk/tape) for data retrieval. The Data Extractor Tool shall have upper limits in total data size for each of them, which shall be determined by the ALMA project by taking into account the network bandwidth and the I/O speed.

Priority: 1

7.4–R17 If an archive user requests a file transfer operation, then the Data Extractor Tool shall put data in the user-accessible directory. If preparation takes more than 3 minutes, the Tool shall inform the user and send an e-mail when data are ready.

Priority: 1

7.4–R18 In any ALMA supported data transfer method, the data shall be delivered to a user within the ALMA project defined maximum time.

Priority: 1

7.4–R19 The Data Extractor Tool shall use login identification to secure access to proprietary data

Priority: 1

3.7.5 Relationship with the Virtual Observatory Projects

7.5–R1 The archive shall be designed to meet the requirements for on-going virtual observatory projects so that the ALMA data can be used more efficiently.

Priority: 2

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

7.5–R2.1 the first ALMA catalogues, which also serve as the index of the archive (*Priority: 1*)
7.5–R2.2 data quality information (cf. 1.2-R2) (*Priority: 1*)

7.5–R3 The interface shall be designed to meet the requirements for virtual observatories, when they are ready.

Priority: 1

4 Use Cases

4.1 Observe With Alma

Use Case: ObserveWithAlma

This Use Case outlines the basic process of astronomical observations with ALMA.

Role(s)/Actor(s):
Primary: Observer
Secondary: The Operator, the Staff Astronomer, the Reviewer

Priority: Critical

Performance: hours to months

Frequency: hours

Preconditions:

1. The ALMA System has reached at least partial operational state and accepts observing proposals from astronomers.

Basic Course:

1. The Observer creates a detailed Observing Programme (UC_ Create Observing Programme). This includes submission of a Phase I Observing Proposal, peer review, and submission of a detailed Phase II Observing Programme.
   Exception Course: The Proposal is rejected by the reviewers.
   Postcondition: The Phase II Observing Programme is stored as one or more Scheduling Blocks in the Scheduling Block Repository. Its SBs are ready to be queued for observing.
2. The Programme's SBs are dynamically scheduled for observing, whenever the optimal conditions apply for best efficiency of the ALMA System. Observations are scheduled in units of Scheduling Blocks. Further scheduling for a programme is halted when a Breakpoint is reached. (UC_ScheduleSB).
   Alternate Course: The programme may be observed interactively.
   Alternate Course: The programme may have to be scheduled at a fixed time, in the case of VLBI and of unusual events.
3. The ALMA Observing System executes Scheduling Blocks (UC_ExecuteSB): if necessary the system allocates requested resources and initiates pipeline data reduction, or releases those resources after execution.
   Postcondition: The raw data goes into the archive.
4. The Data Pipelines reduce observing scans as they are written into the archive.
   1. The Calibration Pipeline writes reduced Calibration Data into the archive, and makes relevant results and data quality evaluation available to the scheduling and observing processes (UC_ProcessCalibrations).
   2. The Quick Look Pipeline displays calibration data and applies it on the fly to science data in order to display interim science results.
   3. The Science Data Pipeline processes science data, writes reduced science data into the archive, optionally displays results, and optionally makes data quality evaluation available to the scheduling process (UC_ProcessScienceData).
5. When allowed, the Observer can update the SBs of his/her Observing Programme in the frame set by the reviewers. This affects the content of the SBs that have not yet been executed and their relative priorities (UC_CreateSchedulingBlocks).
6. At any time, the Observer or the Staff Astronomer may inspect the archived raw or science data, and initiate an off-line pipeline data reduction. (UC_RetrieveArchivedData)

Postconditions:

1. The science goals are reached so that the results may be published for the improvement of human knowledge.

Issues to be Determined or Resolved: ...

Notes:

1. Occasions when the Observer is allowed to update the SBs are:
    1. At Phase II Preparation,
    2. After a Breakpoint is reached,
    3. Whenever a specific authorization is granted by the staff person responsible of scheduling.

Owner: Robert Lucas

Last modified: $Id: ObserveWithAlma.html,v 1.5 2001/04/11 09:38:40 lucas Exp lucas $

4.2 Create Observing Programme

4.2.1 Create Observing Programme

Use Case: Create Observing Programme

This use case describes the creation of a validated Observing Programme. The goal of the Observer is to create an approved Phase I Observing Programme, and to deliver the complete technical specifications of the Observing Programme to the Phase II Scheduling Block Repository. The Observing Programme consists of one or more Scheduling Blocks. Creation/Preparation of the Phase I and the Phase II proposals is done using Proposal Tool as part of the Observing Tool.

Role(s)/Actor(s):
Primary: Observer
Secondary: Reviewer, ALMA Proposal Repository, Scheduling Block Repository, ALMA Archive

Priority: critical

Performance:
Depending on the actual submission policies, the process will take a couple of weeks to a couple of months between Phase I Proposal Submission and delivery of the Phase II Scheduling Blocks.

Frequency:
The system must be able to cope with one or more Phase I submission periods and with around 2000 proposals on a yearly basis. Most of these proposals will be submitted within 24 hours before the submission deadline. Similarly, the system must be able to cope with one or two Phase II Proposal submission periods (see Notes). In the case of Phase II, the amount of interaction with the system is lower.

Preconditions:

1. The most recent version of the Observing Tool should be available, either locally installed, or via the network.
2. Catalogues needed by the tool should be available, either locally (limited scope) or via the network.
3. For actually submitting the Phase I Proposals and Phase II Scheduling Blocks, the Observer must have network access to the ALMA system
4. Optionally, the Observer has access to the ALMA User's Manuals, simulator and Archive.
5. On-line access to databases and additional catalogues (those not required to run the tool) is desirable, not mandatory.

Basic Course:

1. Observer starts up the ALMA Observing Tool
2. Observer creates a new Phase I Observing Proposal
   Alternate Course: Observer retrieves a previously locally stored Phase I proposal
3. Until the Observer completes the Phase I Proposal
   — Observer enters or modifies the Phase I information, including the scientific justification with figures and graphs (see UC Create Phase I Observing Proposal)
   — Observer saves completed Phase I Proposal
   — Observer locally validates Phase I Observing Proposal (see UC Validate Phase I Observing Proposal)
4. Observer submits (or re-submits) Phase I Observing Proposal (see UC Submit Phase I Observing Proposal)
   Exception Course: Phase I proposal cannot be submitted now (for whatever reason)
5. System validates Proposal (see UC Validate Phase I Observing Proposal) and stores it in the ALMA Proposals Repository.
   Exception Course: Phase I Observing Proposal validation fails
6. The Observer is informed of the Proposal validation status

7. Reviewer evaluates (incl. feasibility) and OPC approves Phase I Proposal (see UC Review Phase I Observing Proposal). The proposal becomes an ALMA Observing Programme.
   Exception Course: OPC rejects Phase I Proposal
8. The Observer is informed about the outcome of the review
9. Until the Observer completes all Phase II Information
   — The Observer enters/modifies the Phase II technical specs. The tool creates Phase II Scheduling Blocks, and optionally defines breakpoints (see UC Create Scheduling Blocks)
   — Observer saves completed Phase II Scheduling Blocks
   — Observer validates Phase II Scheduling Blocks (see UC Validate Scheduling Blocks)
10. Observer submits Phase II Scheduling Blocks (see UC Submit Scheduling Blocks)
11. System stores validated Phase II Scheduling Blocks in the Phase II SB Repository
12. The Observer is informed of the Scheduling Blocks validation status

Postconditions:

1. The Observing Programme is granted observing time on ALMA.
2. Phase II Scheduling Blocks are stored in the Phase II Scheduling Block Repository.
3. The Observer is informed that the Phase II Scheduling Blocks were successfully validated and stored, ready for scheduling/execution.

Issues to be Determined or Resolved:

— Policies concerning Phase I/II submission review procedures and deadlines are to be defined.
— Basically, ALMA will guarantee an minimum data quality which depends on the amount of observing resources granted. Additional policies concerning the products to be delivered needs to be defined.
— There will be one Observing Tool that support Phase I and Phase II. A decision has to be taken concerning Phase I and II validation and if there are distinct versions for Observer and System validation. Validation of the Phase I and II Proposal is considered to be part of the Observing Tool.

Notes:

— It is assumed that various tools (incl. the Proposal Preparation Tool) are packaged together (Simulator, Correlator setup, Validator) in the Observer Tool. Within this OT data can be passed from the Proposal Preparation Tool to the other tools.
— The actual implementation of the Observing Tool is uncertain/unclear. However, in addition to on-line access, it is thought that the Tool should be available locally as well. In the use cases for the Proposal Preparation the latter situation is assumed. In the case of a completely WWW based tool (Phase I/II Preparation , Simulator, Correlator Setup, etc) are available, a locally installed Tool can still be useful for off-line Phase I and Phase II preparation work.
— At any time during the Phase I or Phase II submission process, the Observer can consult the on-line ALMA simulators, ALMA User Manuals, ALMA Observing Catalogues, and other foreign data bases to retrieve technical of scientific information needed for creating validated Phase I and Phase II Observing Proposals. However, the Observer should be able, using the tool off-line, to create Phase I/II Proposals without these on-line services.
— It is assumed that the Phase I validation is reasonably light and only checks the most basic instrument settings. However the information should be sufficient to check feasibility. The emphasis is on the scientific justification. Phase II submission and validation should focus on instrument settings only. Passing the validation means that the Scheduling Blocks should be executed at ALMA without problems.

— After a Phase I Proposal has been validated and accepted, the Observer shall be able to cancel it (not modify). When allowed (see UC_ObserveWithAlma), Scheduling Blocks can be revised until they have been scheduled (check-out, modify, check-in). Once a block has been scheduled it cannot be modified (execute or cancel only), unless a breakpoint has been reached.
— It is assumed that Target of Opportunity (ToO) or DDT proposals will be evaluated by the Director or his/her delegate. Phase II preparation will go through the normal channels.

— The actual responsibility of assessing the technical feasibility of proposals may be left to the science reviewers or given to technical reviewers (operational issue).

Owner: Rein Warmels
`Last modified by $Author: lucas $ on $Date: 2001/04/11 14:47:58 $.`

4.2.2 Create Observing Proposal

Use Case: Create/Edit Phase I Observing Proposal

The goal of this use case is to create an optionally validated Phase I Proposal to be submitted to the ALMA Observatory for review. The Observer can either create a new or retrieve a locally existing Phase I Proposal. The submitting observer works off-line. Network access is required for consulting the on-line ALMA Observer manuals, catalogues. The proposal will be stored on a local storage device of the observer. Phase I proposal preparating via the Proposal Tool within Observing Tool.

Role(s)/Actor(s):
Primary: Observer

Priority:
critical

Performance:
Creation of (template) proposals should take of the order of seconds. Filling in /modifying the template can take several hours, depending on the experience of the the observer. The Observing Tool shall react in real time on the Observer's input.

Frequency:
On average, observers will create more than one proposal per proposal submission period. It should be possible to prepare proposals over the whole year, independent from any proposal submission policies. Target of Opportunaty (ToO) and Director Discretionary Time (DDT) proposals shall be possible during the whole year.

Preconditions:

1. On the Observer's system the most recent version of Observing Tool is available.
2. In case the Observer retrieves a Phase I Proposal, this proposal should be available locally.
3. The Observer should be able to store proposal technical specifications and scientific justification.
4. Access to the ALMA archive is desirable.
5. On-line access to Observer User Manuals and Observing Catalogues is available/desirable.

Basic Course:

1. Start the Proposal Tool (within the Observing Tool)
2. Request creation of a new Phase I Proposal. An empty/template form for the Phase I Proposal is created.
   Alternate Course: Observer retrieves previously saved Phase I Proposal
3. Observer specifies User Mode (novice/experienced/expert)
4. Observer specifies personal and institutional information.
5. Observer enters/modifies a minimal amount (to be defined) of Phase I technical data
   1. Observer enters Phase I data:
      - For single sources, specifies source co-ordinates, optionally using source catalogue(s)
        For snapshots (if there are more than 10 sources) selection criteria can be sufficient.
      - Specify line name/central velocity/frequency, velocity/frequency resolutions and spacings
      - Specify angular resolution
      - Specify size of sky area to be mapped
      - Specify polarization information
      - Specify RMS sensitivity, or S/N
      - Specify minimal image dynamic range
6. On the basis of the previously entered data the tool proposes one or several standard observing modes.
7. Observer chooses an observing Mode and tool fills in the default specs for this mode

8. Tool translates novice/experienced input data into expert data
9. If User Mode is experienced/expert Observer enters/modifies expert mode parameters:
   — Specify Array configurations
   — Specify Observing time
   — Specify Correlator setup (optionally, use separate Correlator Tool)
   — ...
10. Create a file containing scientific justification. If needed the Observer may create other files containing additional information (e.g. figures);
    Specify information about related projects (i.e. if proposal is continuation)
11. In the Proposal Tool, enter the list of all files that are to be attached (minimum the scientific justification)
12. Optionally, the Observer validates the scientific justification and the other attachments, if any. (see UC Validate Phase I Observing Proposal)
13. Save Phase I Proposal locally.

Postconditions:

1. Phase I Proposal is saved on local storage with/without status **validated.**
2. In case of successful validation the proposal is ready for submission.

Issues to be Determined or Resolved:

— The Proposal Tool should have at least two user modes, novice, experienced. A third expert mode can be considered. Depending on the user level less or more detailed information about the observational requirements can be filled in.
— At several instances the Tool could do checks on the feasibility and or provide feedback to the Observer (e.g. correlator setup, array configuration, calibrators). The user can set this check to done on the fly or on request only (see UC_ValidatePhaseIObservingProposal).
— The Proposal tool requires to enter information concerning the scientific justifications attachments. This allows a complete validation, including a check that all documents are available.

Notes:

— Proposal may contain more than one configuration (e.g. more than one object/frequency). Hence there can be more than one set of observing parameters
— At any time the Observer can consult the on-line ALMA User Manuals, ALMA Observing Catalogues, and other catalogues to retrieve technical of scientific information needed for the Observing Proposal. Similarly, it is desirable that a simulator is available., either locally or on-line.
— It will be possible to select mapping areas with a graphical interface.
— The Observer's validation of the Phase I Proposals is not mandatory during the creation and editing of the Proposal. However, the ALMA Proposal Handling system will only accept Observer validated Phase I proposals.

— At any time during the editing process the Observer can save his proposal session locally.
— It has to be decided which formats the scientific justification and additional attachments are supported. Most obvious formats are: PostScript, Adobe PDF, MS Word, ASCII, ...
— It is suggested that the file names of the scientific justification and additional attachments be entered in the Proposal tool. This allows: a) validation can be done on the complete Phase I Proposal and get it ready for submission; b) ensures that the user does not forget any relevant files.
— It is assumed that the scientific justification is a separate document that can be created by any standard WYSIWIG or ASCII editor. The format and content of this document is subject to a minimal set of requirements (language, max. length, etc.)
— The system should have a (password-protected) data base of user information so that the PIs do not need to enter these things every time.

Owner: Rein Warmels
`Last modified by $Author: lucas $ on $Date: 2001/05/03 13:32:41 $.`

4.2.3 Validate Observing Programme

Use Case: Validate Phase I Observing Proposal

In this use case the Observer validates the Phase I proposal which is checked on technical specifications. The Validator also checks if all additional documents relevant for the Proposal are available and can be handled. Validation can be done locally as well by the ALMA Phase I Proposal Handling System.

Role(s)/Actor(s):
Primary: Observer
Secondary: Proposal Validator, ALMA Phase I Proposal Handling System

Priority: Critical

Performance: Local validation takes a couple of seconds. . If the ALMA system is performing the validation (on-line validation, or after Proposal Submision), it can take longer.

Frequency: Locally, the Observer can validate the Phase I Proposal several times before its final submission. The validation by the ALMA will be done for every Proposal that is received. A total of about 2000 proposals are expected for each submission period. At peak submission times the frequency can be minutes.

Preconditions:

1. If the validation is requested by the Observer:
   — a Phase I Proposal is available
2. If the validation requested by the ALMA Proposal Handling System
   — The system has received a new Phase I proposal
3. For on-line validation by the ALMA System a network connection is required

Basic Course:

1. The Observer or the Phase I Proposal Handling System requests validation. In case the Observer request validation this can be locally or via the net. In the latter case the latest version of the ALMA validator is used.
2. The validator determines the type of validation request (Observer/PHS)
3. If the validation request comes from the Observer:
   — System starts validation (see Subflow Validation)
   — System notifies the Observer that the proposal is successfully validated
   Exception Course: validation fails

   — Optionally, Observer saves the Phase I information

4. If the validation request comes from the System:
   — The system checks the version of the Observing Tool used by the Observer to prepare the Phase I proposal
   — The system checks the observer validation flag
   — System starts validation (see Subflow Validation)
   — System notifies the Observer that the proposal is successfully validated
   Exception Course: The validation fails. The Observer receives a complete validation report. The Proposal is rejected by the system (not included in the Proposal Repository)
   — The System stores the Proposal in the Proposal Repository

Subflow: Phase I Validation

1. The validator checks the following Phase I specifications:

— TBD
— ...

2. In case the validation is done by the ALMA Proposal Handling System the validator checks the ALMA archive for objects that have already been observed (or proposed) with e.g. same observing mode, frequency, array configuration, ...
3. In case of overlap (see Issues) with previously observed objects, notify observer and flag the proposal
4. In case of overlap with other proposals, enter note for reviewer (do not inform observer)
5. The validator checks for the completeness of the Phase I Proposal
   — Scientific Justification attached in a recognizable format
   — Graphs and figures included
6. If validation is successful, the validator sets validation flag

Postconditions:

— The Proposal is locally validated.
or
— The Proposal is validated, and stored in the Proposal Repository ready to be reviewed (see UC Review Phase I Observing Proposal).
— The Observer is given the validation results.

Issues to be Determined or Resolved:

1. Is there a time cycle for submitting proposals or will we have continuous submission? This affects the validator requirements (deadline to be checked).
2. We should clearly define what we mean by overlapping programmes.
3. In case of an overlapping with other submitted programmes it is suggested to flags the proposal and to draw it to the attention to the Reviewer(s). Should the Observer be informed at this point?
4. In case of overlap with other executed or completed programmes (proprietary data) the proposal should be flagged as well and draw it to the attention of the reviewers. Should the Observer be informed at this point already?

Notes:

1. In case of overlap with publicly available data the observer shall receive a summary of the available observation. Submission should then be confirmed by the Observer, and the proposal should be flagged to the PC.

Owner: Rein Warmels
`Last modified by $Author: lucas $ on $Date: 2001/04/11 14:45:49 $`

4.2.4 Submit Observing Programme

Use Case: Submit Phase I Observing Proposal

This use case concerns the submission of a user-validated Phase I proposal to the ALMA Proposal Handling System (APHS), which will check the proposal for completeness and integrity. If validation is successful the Proposal is stored in a database for reviewing.

Role(s)/Actor(s):
Primary: Observer
Secondary: ALMA Proposal Repository

Priority: Critical

Performance: Minutes

Frequency: Submission can occur up to several times per minute

Preconditions:

1. The system is available to receive Phase I Proposals
2. The Observer is connected to the network.
3. The Observer has a validated Phase I Proposal

Basic Course:

1. In the Proposal Tool the Observer performs an action to submit the Phase I proposal
2. Tool checks if Proposal is locally validated
   Exception Course: Proposal is not sent if not locally validated
3. Proposal Tool sends Phase I specs, scientific justification and documents to the ALMA PHS
4. In case the proposal is already in the ALMA Proposal Repository, Observer is asked if he wants to replace it.
5. ALMA Proposal Handling System puts the Proposal in the queue for validation.
   Exception Course: Phase I Proposal is not validated by the Observer.
6. The ALMA PHS validates the Proposal (see UC Validate Phase I Observing Proposal)
7. The System stores the Phase I Proposal in the Proposal Repository and the Observer received a confirmation message (incl. validation report, number, etc.)
   Exception Course: The ALMA validation of the Proposal failed; the Observer receives validation report. Proposal is not stored in the Proposal repository.

Postconditions:

1. The Phase I proposal is received by the ALMA Proposal Handling System and validated
2. The Observer receives an acknowlegment of reception and validation.
3. In case of successful validation, the Proposal is stored in the Proposal repository.

Issues to be Determined or Resolved:

1. Is there a deadline for submitting proposals or continuous submission?
2. Are proposals reviewed continously or will there be deadlines?

3. There should be a software-based mechanism to cancel/replace proposals that are already in the ALMA Proposal Repository.

Notes:

1. It is assumed that all Phase I Proposal information is sent and stored in the ALMA Proposal Repository.

Owner: Rein Warmels
Last modified: January 23, 2001/Rein Warmels

4.2.5 Review Observing Programme

Use Case: Review Phase I Observing Proposal

This use case describes the Phase I Review Process. After a Phase I Proposal is submitted it will be reviewed. The Proposal will either be accepted, and given a priority, or rejected. The Observer is informed of the review outcome and receives a Phase I Review Report.

Role(s)/Actor(s):
Primary: Reviewer(s) , Observing Program Committee (OPC)
Secondary: Observer

Priority: Critical

Performance: The review process may take a couple of days or longer, depending on review procedures. Reviews of proposals that apply for special observing time allocation (e.g. Director's time, Target of Opportunity) may take less time and may not go through the standard review process.

Frequency: The frequency heavily depends on policies and procedures. It can be short (when the review process runs the whole year) or longer (when a review process takes place once or twice a year). Review of a Phase I Proposal by the reviewer shall take up to one hour, on average less than 0.5 hours.

Preconditions:

1. A submitted and validated Phase I Proposal is available
2. Reviewer is assigned for proposal review

Basic Course:

1. Reviewer receives a validated Phase I Proposal for review
2. Reviewer makes judgement of scientific value of the Proposal
3. Reviewer checks possible overlap with other observing programmes
4. Reviewer makes judgement of the technical feasibility of the Proposal
   Alternate Course: Reviewer runs validator and/or simulator to get better view of technical feasibility and scientific output
5. Reviewer rates scientific value and feasibility of Phase I Proposal
   Alternate Course: Reviewer requests additional information from Observer and/or from ALMA Staff
6. OPC meets (face-to-face or electronically) to assign ratings to all programmes taking into account policies and procedures.
7. Phase I Proposal is accepted and gets assigned observing priority
   Alternate Course: Proposal is accepted subject to modification(s) of technical specification(s).
   Alternate Course: Proposal is rejected
8. Observer is informed and receives Phase I Review Report

Postconditions:

1. Proposal is accepted (with/without certain conditions) or rejected
2. The Observer is informed.

Issues to be Determined or Resolved:

— Most, if not all, review procedures and policies are to be defined. Does the Time Allocation Committee meet face-to-face?

— Policy Issue: Does the whole proposal get one priority, or is it an option for different parts of it to get different priorities.
— It is assumed that there will be technical reviewers (feasibility) and scientific reviewers.
— Reviewers should take into account the percentage of time available for excellent, good, average and poor observing conditions and accept proposals accordingly. There should be a sufficient number of accepted proposals in each range of observing conditions, in case large weather fluctuations occur, so that the array does not run out of accepted proposals.

Notes:

— To review the technical aspect and the science goals, validating and simulator tools should be available

— The stringency factor (percentage of time when the programme may be observed) should be computed for each proposal against recorded historical weather data.
— In the case of complex proposals, comporting different identified parts (sub-programmes making use of different observing modes, different frequencies or different astronomical objects not handled in the same scheduling block), the reviewer may want to assign different priorities to these parts.

Owner: Rein Warmels
`Last modified by $Author: lucas $ on $Date: 2001/05/03 16:17:46 $`

4.2.6 Create Scheduling Blocks

Use Case: Create/Edit Scheduling Blocks

In Phase II Proposal Preparation the technical specs of the Observing Programme are defined, consisting of at least one ALMA Scheduling Block. The goal of this use case is to create an optionally validated Scheduling Block or Blocks. The Observer can either create new or retrieve a locally existing Scheduling Block(s). The observer works either on- or off-line. On-line access to ALMA Observer manuals and to tools for observing simulation is desirable. The Scheduling Blocks will be stored on a local storage device of the observer. Scheduling Blocks are created via the Phase I/II Proposal Tool as part of the Observing Tool.

Role(s)/Actor(s):
Primary: Observer
Secondary: SB Validator

Priority:
critical

Performance:
Creation of a (template) Scheduling Block should take of the order of seconds. Filling in /modifying the template can take several hours, depending on the experience of the the observer. The Phase I/II Proposal Tool shall react in real time to the Observer's input

Frequency:
On average, 2000 proposals per year will be submitted. A limited number will make it to Phase II. It should be possible to prepare Phase II Scheduling Blocks over the whole year, independent from any Phase II submission policies.

Preconditions:

1. On the Observer's system the most recent version of the Observing Tool is available

Basic Course:

1. Start the Proposal Tool (part of the Observing Tool)
2. The Observer retrieves from the ALMA Proposal database the Phase I Proposal for which (s)he is granted time, the OPC response, and approved observing time allocation.
3. The Tool informs the user what has been approved.
4. The User is then prompted for general science parameters and options like, e.g. for mapping:
   — Field name.
   — Coordinate system.
   — Field center coordinates (either by absolute coordinates or offsets from a direction specified by its absolute coordinates).
   — Desired synthesized beam size
   — Field width
   — Desired sensitivity.
   — Desired dynamic range.
   — Number of IF bands.
   — Line names and/or frequencies
   — Center velocities.
   — Velocity reference systems.
   — Velocity bandwidths.
   — Velocity resolutions.

   All these fields have defaults values (the ones entered at Phase I). Some may only be changed in a limited range in order not to conflict with approved proposal scope.
5. On that basis the system proposes one or more standard observing modes.
6. The Observer chooses one of the proposed modes.

7. The User Interface for that observing mode is opened with reasonable defaults for the technical parameters, based on the science parameters (see the setup of the individual Observing Modes).
8. The Observer edits the parameters to meet the specific goals of the project.
9. The system proposes a group of SB's, Preamble, Postamble, and lists the programme's needed resources (e.g. data rate and volume).
10. The Expert Observer may select to examine the script content of the SBs, preamble, postamble, and to edit the scripts themselves, in order to better meet the specific needs of the project.
11. Optionally, the Observer validates the SB or group of SBs (see UC Validate Scheduling Blocks)
12. Steps 4-11 may be repeated for complex programmes, resulting in several groups of SBs with different sources, frequencies, observing modes.
13. For each group of SBs the Observer may define additional conditions for the SB execution as dependencies between/among SBs (e.g. execute some blocks only after other blocks have been executed).
14. If required, the Observer defines breakpoints to inspect the data and to take action depending on the results (online data pipeline results, environmental data)
15. *Alternate Course:* the Observer checks out SB or groups of SBs from the ALMA SB Repository and makes modifications in one or more *(see above),* and checks the SB(s) in again.

16. Optionally, validate the Scheduling Blocks (see UC Validate Scheduling Blocks)
17. Optionally, run the simulation tool to check the scientific output

Postconditions:

1. The Observing Block is saved on local storage with/without status **validated.**
2. In case of successful validation the Observing Block is ready for Phase II submission.

Issues to be Determined or Resolved:

1. Phase II submission policies are to be determined
2. It is assumed that the collection of all Scheduling Blocks defines the complete Phase II Programme.
3. Which limitation do SBs have (e.g. no change of Observing Mode within a SB; maximum limit in time; e.g. max. angular distance between targets within a SB; ...).
4. At several instances the tool could do checks on the feasibility and or provide feedback to the Observer (e.g. correlator setup, array configuration, calibrators). The user can have this functionality on the fly or on request only (see UC Validate Scheduling Blocks).
5. What kind of input does the simulator expect (a single block, or any number of blocks belong to the programme, and that maybe interrelated)?
6. What determines the 'expert' status of the Observer? Probably an authorization needs to be requested at Phase I and granted by the staff.

Notes:

1. At any time the Observer can consult the on-line ALMA User Manuals, ALMA Observing Catalogues, and other catalogues to retrieve technical or scientific information needed for the Observing Programme. Similarly, it is desirable that a simulator is available..
2. The Observer's validation of the Scheduling Block(s) is not mandatory during the creation and editing of the Block(s). However, it is mandatory at submission of the Scheduling Blocks.

3. At any time during the editing process the Observer can save the Scheduling Block(s) locally.

Owner: Rein Warmels
`Last modified by $Author: lucas $ on $Date: 2001/05/03 13:43:05 $.`

4.2.7 Validate Scheduling Blocks

Use Case: Validate Scheduling Blocks

In this use case the Observer validates the ALMA Scheduling Blocks. The validating covers all technical specifications that are relevant for successful execution of the SB at the telescope. Validation can be done locally as well by the ALMA Phase I Proposal Handling System.

In this use case the Observer or the ALMA system validates one or more Scheduling Blocks created in the Phase II Proposal Preparation.

Role(s)/Actor(s):
Primary: Observer
Secondary: Scheduling Blocks Repository

Priority: Critical

Performance: Minutes

Frequency: Locally, the Observer can validate the Scheduling Block(s) several times before its final submission. The validation by the System will be executed after receiving an Scheduling Block(s) or its/their modification.

Preconditions:

1. If the validation request comes from the Observer:
   — at least one Scheduling Block is available
2. If the validation request comes from the Phase II receiving system
   — a new (modified) Scheduling Block has been (re-)submitted

Basic Course:

1. The Observer or the system requests the validation.
2. The validator determines the type of validation request (Observer/ALMA)
3. If the validation request comes from the Observer
   — System starts validation (see Block Validation subflow)
   — The validator checks the relationships between the SBs and breakpoints defined
   — System notifies the Observer that the Scheduling Block(s) is/are successfully validated
   Exception Course: The Scheduling Blocks is/are rejected, the Observer is notified.

4. If the validation is to be done by the ALMA System
   — The system checks version number of the Proposal Tool by which the block(s) is/are created
   — Systems starts validation (see Block Validation subflow)
   — System notifies the Observer that the Scheduling Block(s) is/are successfully validated
   Exception Course: The Scheduling Blocks is/are rejected, the Observer is notified, and the Scheduling Block(s) is/are flagged as not-validated and left in checked out state.
   — The system flags the SBs as validated and checked in.

Subflow: Block Validation

1. Validator checks consistency between Scheduling Block and Phase I information and OPC response.
   Exception Course: Scheduling Block does not match Phase I information. In case the validation is done by the ALMA system, the Block is left in the checked out status.

2. The validator checks the Scheduling Block (see also UC Create Scheduling Blocks). For standard observing modes the validity of the Phase II input parameters for each SB group should be enough. For observing modes customized by experts the scripts themselves have to be validated, by a syntax checker or a simulator.

Postconditions:

— The Scheduling Blocks are locally validated and the Observer is given the results
or
— The Scheduling Blocks are validated and checked-in in the ALMA SB repository.

Issues to be Determined or Resolved:

1. How strongly should we insist on having the Scheduling Blocks match the Phase I Proposal? I assume software will do the checking. Flagging can be done in case of clear differences.
2. Will each Scheduling Block be reviewed by the Operator/Astronomer before it goes to the scheduler?

Notes:

Owner: Rein Warmels
`Last modified by $Author: lucas $ on $Date: 2001/05/02 14:13:09 $`

4.2.8 Submit Scheduling Blocks

Use Case: Submit Scheduling Blocks

This use case concerns the submission of one or more user-validated ALMA Scheduling Blocks to the System. The submitted SBs are validated. If validation is successful the SBs are stored in the Scheduling Blocks Repository.

Role(s)/Actor(s):
Primary: Observer
Secondary: ALMA Scheduling Blocks Repository

Priority: Critical

Performance: Minutes

Frequency: Submission can occur up to several times per minute

Preconditions:

1. The system is available to receive Phase II Scheduling Blocks
2. The Observer is connected to the network.
3. The Scheduling Block(s) has been validated by the Observer

Basic Course:

1. The Observer performs an action to submit the Scheduling Block(s)
2. Proposal Tool connects to the system and sends the Block(s) to the ALMA system
   Exception Course: The Scheduling Block(s) is/are not validated by the Observer.
3. Observing Block(s) is/are validated (see UC Validate Scheding Blocks) and stored in the ALMA Scheduling Block Repository
   Exception Course: The validation of one or more Scheduling Block(s) fail(s) and the Observer is informed. The Scheduling Block(s) is/are left in the checked out state
4. The SBs are checked in and ready to be executed

Postconditions:

1. The SBs are received by the system, validated and checked into the Scheduling Block Repository.
2. The Observer receives an acknowledgement of reception and validation.

Issues to be Determined or Resolved:

1. Should the initial SBs submission cover the entire approved proposal so that the global programme values can be checked against the submitted SBs values?
2. This use case assumes that Phase II submission is done via Scheduling Blocks. In case of more than one SB that are interrelated, they should be submitted in one go. Is this a reasonable assumption?
3. Is there a time cycle for submitting Phase II data or continuous submission?
4. What about special proposals (Targets of Opportunity, Discretionary Time)?
5. The Scheduler should not schedule SBs that have a dependency relationship with one or more checked-out SB.

Notes:

— The Observer should be able to checkout one or more SBs, make changes to them, and check them in again (after which the SBs are validated again).

Owner: Rein Warmels
Last modified: January 23, 2001/Rein Warmels

4.3 Schedule Scheduling Blocks

4.3.1 Schedule Scheduling Blocks

Use Case: ScheduleSB

Retrieve SBs from Phase II SB Repository, assign priorities to Observing Programme SBs and return prioritized list of SBs to the caller (here represented by the DispatchSB Use Case).

The Phase II Repository for a given Programme contains SBs as well as their associated configuration and calibration requirements. The system will take account of the time required to bring the array to the necessary calibration state when assigning a rank to each SB.

In "local scheduling mode", the system will consider each SB independently. In "global scheduling mode", on the other hand, the system will attempt to look ahead, building a queue of SBs – possibly from different Programmes – that can share a significant (in terms of observing time needed) amount of calibration operations. The main goal here is to accommodate "snapshot" programmes, short observing programmes that would be inefficient to schedule independently because of their relatively high calibration time-to-target time ratios.

The Programme may contain relational links between SBs, in the sense that a given SB may only be scheduled if specified other SBs have been previously executed, and if some condition on their results (as indicated by the Observing Programme's status) is fulfilled.

The programme may contain Breakpoints, *i.e.* conditions in the Observing Programme's status which will inhibit further execution of SBs in that Programme, pending release of the Breakpoint by the Observer.

Role(s)/Actor(s):
Primary: DispatchSB Use Case
Secondary: Phase II Repository, Array Observing System

Priority: major

Performance: order of seconds

Frequency : order of minutes

Preconditions :

1. The Repository of active Programmes from Phase II

Basic Course :

1. The system determines the current array configuration, in particular, that part that is available for use
2. The system determines the receiver bands that are available for immediate use
3. The system determines the current observing conditions
4. The system acquires all Phase II SBs that can be run with the current:
   1. Array configuration
   2. Receiver band(s)
   3. Observing conditions
   4. LST range

   and that:
   1. fulfill any conditions imposed by their Programme (relational links between SBs).
   2. are not on hold because of a breakpoint.
5. The system determines the starting calibration requirements of each ready-to-run SB and the time necessary to fulfill them.
6. System calculates SB priorities based on rules involving:

   1. Initial scientific priority rating.
   2. Environmental parameters (weather, LST, UT, ...)
   3. System parameters (is the Programme started, is it currently in execution, ...)
   4. Pipeline results (current phase rms if available from calibrators, possibly science results, ...)
   5. Time to execute SB and all necessary calibrations.
7. System returns priority-ordered list of SBs.
8. Whenever an SB makes it into the list of (TBD) ten top ranked ones, an e-mail is sent to the PI.

Alternate Course : "Global scheduling mode"

1. The system matches SBs that can share time-consuming calibration operations and constructs separate queues for groups of these.
2. The system returns these queues

Postconditions:

1. SBs have been returned to the requester.

Issues to be Determined or Resolved :

1. The actual set of rules to calculate priorities.
2. How to resolve the conflict between the "local" way of ranking SBs (considering each one individually) and the "global" scheduling mode (where the assumption is made that the observing conditions will remain constant enough to allow more than one SB to be executed using a common set of calibrations).
3. When calibrations are shared among programmes, their time cost should not be entirely attributed to the first SB, but shared with the SBs in the repository that would benefit from them (in fact only those that may be executed during the validity period of that calibration). That might be difficult to compute. A policy decision to charge time for shared calibrations to the observatory rather than to individual observers might be worthwhile for the simplification it would bring, and for the incentive it might give observers to propose "snapshot" observations.

Notes:
Owner: Robert Lucas, Joe Schwarz
`Last modified by $Author: lucas $ on $Date: 2002/03/12 21:06:55 $`

4.3.2 Dispatch SB

Use Case : Dispatch Scheduling Block

The goal of this use case is to obtain a ranked list of Scheduling Blocks (SBs) from the Dynamic Scheduler or from an interactive observer (via the Observing Tool) and pass this to the Sequencer. When a group of SBs from the same Observing Programme is executed contiguously, an observing session is said to have been executed. The system may initiate some data processing activities at the end of a session.

Role(s)/Actor(s) :
Primary: Operator, Scheduler, Sequencer
Secondary:

Priority : Critical

Performance : Seconds to hours

Frequency : Several times per minute/hour/day; One at a time per Sub-Array

Preconditions :

1. Need to have Scheduling Block(s) available in the Phase II SB Repository

Basic Course :

1. System requests a priority-ordered list of SBs from the Dynamic Scheduler in either "atomic" or "snapshot" dynamic scheduling mode. (see UC_ ScheduleSB)
   Alternate course: System requests an SB from the Observing Tool in Interactive mode.
2. The system displays this list to the Operator, who can choose to override it, moving a different SB to the top of the list and furnishing a reason for this decision to the log.
3. The system passes the SB at the top of the list to the Sequencer for execution
   1. During execution of the above SB, the system periodically determines the SBs most likely to be highly-ranked at expected time of completion of current SB. If SBs are considered to have a duration of typically 30 minutes, this would be done every 15 minutes. How the general case is to be handled is TBD.
   2. System ensures that the receiver band appropriate to this "most likely SB" is set to standby.
4. Upon return from the Sequencer, the system updates persistent SB / OP (Observing Program) parameters that have changed and saves SB / OP status
5. The system repeats Steps #1 and 2. If the newly selected SB requires that the previous session be ended (because it is from a different Observing Programme, for example), the system may initiate session processing activities on the Science Data Pipeline, *e.g.,* to produce a fully calibrated and deconvolved image–this is likely to be done only if a breakpoint in the OP has been reached or if all data for the final image has been accumulated.
6. The system loops on Steps #3, #4 and #5 as long as the Scheduler or the Observer can furnish an executable SB.

Exception Course : No more SBs are available to be scheduled.

1. Stop SB execution
2. Notify operator / observer; request repopulation of SB-Repository
   Postcondition: System waiting for input of SB or observing commands

Postconditions:

1. SB's have been successfully dispatched

Issues to be Determined or Resolved :

- Which calibrations can be shared across SBs from different programs?
- What happens in snapshot mode when conditions change rapidly?
- How is selection of the standby-receiver to be made in the case of SBs of arbitrary (usually << 15 minutes) duration?

Notes:

- Must have access to persistent program parameters.

Owner: Joseph Schwarz
`Last updated by $Author: lucas $ on $Date: 2002/03/12 21:27:11 $`

4.4 Execute SB

Use Case : Execute Scheduling Block

The goal of this use case is to execute Scheduling Blocks (SBs) that have been scheduled by the Dynamic Scheduler. SBs are the building blocks of Observing Programs (OPs). They include descriptions of configurations and the initial and final calibrations needed for an Observing Session (an uninterrupted sequence of SBs sharing the same calibration requirements). SBs are the smallest units to which the Dynamic Scheduler assigns priorities. The Dispatcher sends the SB with the highest priority (previously assigned by the Scheduler) to the Sequencer for execution on a Sub-Array. Alternatively, in Interactive Mode, SBs are sent directly from the Observing Tool to the Sequencer. Each SB includes all the project-level calibrations necessary for its output to be processed autonomously. Calibrations that have been performed prior to this SB but that are still valid for this SB's desired hardware configuration/setup are used and not repeated unnecessarily.

Role(s)/Actor(s) :
Primary: Dispatcher, Sub-Array (all hardware available to this SB)
Secondary:

Priority : Critical

Performance : Seconds to hours

Frequency : Several times per minute/hour/day; One at a time per Subarray

Preconditions :

1. Need to have Scheduling Block(s) to execute

Basic Course :

1. SB is received for execution (see UC_ DispatchSB)
2. Perform initial setup and calibration operations. If existing calibrations are still valid for this setup, do not repeat them.
   1. Perform necessary system initializations and/or calibrations, *e.g.,* a bandpass calibration (see UC_ Observe˙Interferometric˙AstroBandpassCal)
   2. Notify the PI that his/her observations have been started if a previous warning has not been sent within the last 96 (TBD) hours for the same programme.
3. Execute standard Scans by interpreting the corresponding observing procedures with the given user parameters (Observation Descriptors) and controlling the antennas, the receiver and the correlator accordingly
   Alternate course 1: For non-standard scan modes interpret the user supplied observing procedure (aka Script)
   Alternate course 2: Alternatively, in manual mode, the user types in commands to be executed directly via a Command Line Interface (CLI).
   Exception course: An existing calibration becomes invalid, either because its validity has expired, or because a change of hardware configuration has made it inapplicable. In either case, perform the necessary calibration and proceed.
   Exception course: The execution of an observation fails
4. Archive data with time and project tags continuously, *i.e.,* while an observation is being executed (see UC_ArchiveData)
5. For standard observing modes send standard Reduction Script to Calibration Pipeline (see UC_ProcessCalibrations)
6. Perform final calibrations necessary to complete SB; if this SB turns out not to be the last one in a session, these calibrations will still be valid and will not be repeated when the next SB begins execution.
7. Return status to caller (usually the Dispatcher).

Exception Course : The execution of an observation fails

1. Stop SB execution

2. Notify operator / observer; save status of OP
   Postcondition: Execution of SB halted; operator / observer notified; status saved

Postconditions:

1. SB has been successfully executed

Issues to be Determined or Resolved :

— Which calibrations can be shared across SBs from different programs?
— The Observing Tool must know about the possible default scan modes and the necessary Observing Descriptors.

Notes:

— Must have access to persistent program parameters.
— Interactive observing will be setup via SBs that will be directly transmitted to the Sequencer.

Owner: Dirk Muders
`Last updated by $Author: lucas $ on $Date: 2002/03/12 21:22:08 $`

4.5 Process Data

4.5.1 Process Calibrations

Use Case: ProcessCalibrations

The Calibration Pipeline reduces calibrations in quasi-real time, in an automatic way, taking input data from the Raw Data Archive, and putting calibration results into the Science Archive.

Those results are made available to the AOS and/or to the Scheduler. The reduction of calibrations should not be a bottleneck for the array operation.

Action is taken after each Observation to recompute e.g. system temperatures, and/or update incremental displays; after each Scan to reduce e.g. pointing scans, focus scans with a feedback to the AOS, or phase calibration scans with a feedback to the Scheduler (computed phase noise).

Role(s)/Actor(s):
Primary: Array Observing System
Secondary: Operator, Staff Astronomer, Observer

Priority: Major

Performance: from seconds (such as pointing/focus measurements) to minutes for array calibrations (baseline, pointing model).

Frequency: minutes

Preconditions:

1. Data is available from the Correlator and Total Power detectors, either in the Archive or in temporary storage.
2. Reduction scripts are available, as defined in the observing programme.

Basic Course:

1. The AOS initiates the Calibration Pipeline when the Preamble of the first SB of a new Observing Session is executed.
   Alternate Course: Off-line execution.
2. The Pipeline executes reduction script commands whenever observations are written into the archive. These commands retrieve data from the raw data archive, manipulate data, optionally display results, store results in science archive.
   Exception Course: the operator is notified if the script fails.
3. The Calibration Pipeline makes results available to the AOS
4. The Calibration Pipeline makes quality check results available to the scheduler

Alternate Course: Off-line execution

1. The Observer initiates the Calibration Pipeline off line
2. The Calibration Pipeline executes script commands sequentially

Postconditions:

1. Parameters are fed back to either the AOS or the Scheduler;
2. Calibration data are written into the Science Archive
3. Data reduction scripts and logs are written into the Science Archive

Issues to be Determined or Resolved:

1. How the ACS and the Scheduler retrieve Pipeline results.

Notes:

1. The Calibration Pipeline shall be run either at or near the telescope, or at the places where the archives are kept.
2. If the pipeline of a previous session is still active, the pipeline of the current observing session has priority for allocation of computing resources, as quick feedback on calibration of current session is more urgent than the 'final' science data processing of previous sessions.
3. An Observer must be able to look at the Calibration Pipeline results of recently observed Programmes without downgrading the Pipeline performance on the currently observed Programme.

Owner: Robert Lucas
`Last modified by $Author: lucas $ on $Date: 2001/05/03 13:45:39 $`

4.5.2 Process Quick Look Data

Use Case: ProcessQuickLookData

The Quick Look Pipeline reduces data in quasi-real time, in an automatic way, taking input data from the Raw Data Archive, and putting results into the Science Archive. The Quick Look data reduction should not be a bottleneck for the array operation.

Quick Look data processing will take place after each scan to produce a live display, of the data as they are obtained, such as total power spectra, but also incremental raw maps (not deconvolved) of selected channels or channel averages. This will need applying the calibration data after they are computed by the Calibration Pipeline. A copy of the display will be made available on the Web to the Observer.

Role(s)/Actor(s):
Primary: Array Observing System
Secondary: Operator, Staff Astronomer, Observer

Priority: Major

Performance: from seconds to a few minutes for imaging.

Frequency: minutes

Preconditions:

1. Data is available from the Correlator and Total Power detectors, either in the Archive or in temporary storage.
2. Calibration Data are available from the Calibration Pipeline running in parallel (see UC_ProcessCalibrations).
3. Reduction scripts are available, as defined in the Observing Programme.

Basic Course:

1. The AOS initiates the Quick Look Pipeline when the first SB of a new Observing Session is executed.
   Alternate Course: off-line execution.
2. The System informs the Observer (by email) when data processing starts.
3. The Quick Look Pipeline executes reduction script commands at the end of every scan. These commands retrieve data from the Raw Data Archive, manipulate data, display results, store interim results in Science Archive.
   Exception Course: the Operator is notified if the script fails.
4. Optionally: the Pipeline makes quality check results available to the Scheduler
5. The pipeline makes a representative display of the science interim results available to the Observer on a Web page.

Alternate Course: Off-line execution:

1. The Observer initiates the Pipeline off line.
2. The Pipeline executes script commands sequentially, using previously obtained calibration data.

Postconditions:

1. Science data (images) are written into the Science Archive. The images will be marked as quick look data to distinguish them from final images.
2. Data reduction scripts and logs are written into the Science Archive.
3. Parameters may be fed back to the Scheduler (on-line execution). This can be e.g. quality (dynamic range, SNR) evaluation on a test source.

4. The Observer is kept informed of the progress of Quick Look data reduction.

Issues to be Determined or Resolved:

1. How the Scheduler retrieves pipeline results.

Notes:

1. If the Pipeline of a previous Session is still active, the Quick Look for the current Observing Session has priority for allocation of computing resources.
2. An Observer must be able to look at the Pipeline results of recently observed Programmes without downgrading the Quick Look performance on the currently observed Programme.

Owner: Robert Lucas
`Last modified by $Author: lucas $ on $Date: 2001/05/03 13:48:47 $`

4.5.3 Process Science Data

Use Case: ProcessScienceData

The Science Data Pipeline reduces data in an automatic way, taking input data from the Raw Data Archive, and putting results into the Science Archive. The science data Pipeline reduction should not be a bottleneck for the array operation.

Science data processing will take place after the end of an Observing Session to perform 'final' imaging and deconvolution. Image deconvolution will be performed only if a break point is reached, or if the program has reached the point where no further visibility data needs to be obtained to complete the image.

Image deconvolution after a breakpoint must also have been requested by the proposer at Phase II of Proposal preparation.

The Science data processing will use the calibration data after they are computed by the Calibration Pipeline, and the interim results as computed by the Quick Look Pipeline.

Role(s)/Actor(s):
Primary: Array Observing System
Secondary: Operator, Staff Astronomer, Observer

Priority: Major

Performance: from seconds to tens of minutes for imaging.

Frequency: minutes

Preconditions:

1. Data is available from the Correlator and Total Power detectors, in the Archive or on temporary storage.
2. Calibration Data are available from the Calibration Pipeline running in parallel (see UC_ProcessCalibrations).
3. Reduction scripts are available, as defined in the Observing Programme.

Basic Course:

1. The AOS initiates the Science Data Pipeline when the first SB of a new Observing Session is executed.
   Alternate Course: off-line execution.
2. The Science Data Pipeline executes reduction script commands whenever observations are written into the Archive. These commands retrieve data from the Raw Data Archive, manipulate data, optionally display results, store results in Science Archive.
   Exception Course: the Operator is notified if the script fails.
3. Optionally: the Pipeline makes quality check results available to the Scheduler
4. The System informs the Observer by e-mail when science data processing is complete.

Alternate Course: Off-line execution:

1. The Observer initiates the Pipeline off line.
2. The Pipeline executes script commands sequentially, using previously obtained calibration data.

Postconditions:

1. Science data (images) are written into the Science Archive.
2. Data reduction scripts and logs are written into the Science Archive.
3. The Observer is kept informed of the completion of pipeline data reduction.

Issues to be Determined or Resolved:

Notes:

1. The Science Data Pipeline shall be run either at or near the telescope, or at the places where the Archives are kept.
2. If the Pipeline of a previous Session is still active, the Pipeline of the current Observing Session has priority for allocation of computing resources.
3. An Observer must be able to look at the Pipeline results of recently observed Programmes without downgrading the Pipeline performance on the currently observed Programme.

Owner: Robert Lucas
`Last modified by $Author: lucas $ on $Date: 2001/05/03 13:50:32 $`

4.6 Manage Archive

4.6.1 Archive Data

Use Case: Archive Data

The goal of this use case is to store given data into the ALMA data archive / database. The archive will contain a variety of time tagged data streams such as:

- Proposals
- Observation Programs with their Scheduling Blocks (including Pre-, Postamble, Observing and ImageProduction Scripts) and their persistent data (program data and program related system data)
- Program related observational data:
  - Source name, coordinates and velocity
  - Line name and frequency
  - Continuum frequency (band) and bandwidth
  - Correlator bandwidth and resolution
  - Phase corrected and uncorrected raw uv data
- Environmental data:
  - Water vapor content from WVR, opacity measurements
  - Weather data
- Monitoring data:
  - Instrument status (astromical receiver)
  - Antenna status
- Logs:
  - Observation log
  - Operator log
- Errors
- Warnings
- Online Calibration and Image Pipeline products:
  - Pointing and focus corrections
  - Calibration Data
  - Images
  - Data quality parameters
- Data base related information:
  - Archive access / request logs

Role(s)/Actor(s):
Primary: ALMA System (role of Proposal Handling System, Dynamic Scheduler, ALMA Observing System (AOS), Calibration Pipeline, Image Pipeline)
Secondary:

Priority: Critical

Performance: Faster than the time it takes to perform an observation, typically seconds to minutes; Archive system must be able to cope with peak data rates (currently expected to be 60 MB/s), but the average data rates should be 10 times lower.

Frequency: Continuously

Preconditions

Basic Course:

1. ALMA System sends data to Archive System
2. Archive System saves data stream in archive
   Exception course: Saving the data fails
   1. Notify ALMA System

   Postconditions:

   1. Data not saved
   2. ALMA System is notified
3. Archive System maintains indexes of the various archived data streams

Subflow:

Alternate Course:

Exception Course:

Postconditions:

1. Data stored

Issues to be Determined or Resolved:

— Will offline data reduction products also be stored in the ALMA archive ?
— How long will intermediate data pipeline results be stored in the archive ? One approach would be to keep images above a given image size and/or image production time and to recalculate on the fly below it.

Notes:

Owner: Dirk Muders
`Last modified by $Author: lucas $ on $Date: 2001/05/03 13:52:25 $`

4.6.2 Retrieve Data

Use Case: Retrieve Archived Data

The goal of this use case is to retrieve selected data from the ALMA archive and optionally reduce it using the ALMA Science Data Pipeline. The ALMAarchive will be available for the whole astronomical community to allow data mining of existing ALMA observations. There are proprietary periods for the data but the data headers are always available for everyone.

Role(s)/Actor(s):

Primary: ALMA User (Role of Operator, Observer, Technician, Offline User, Data Pipeline)
Secondary:

Priority: Critical

Performance: Seconds to minutes

Frequency: Seconds to hours

Preconditions:

Basic Course:

1. ALMA User identifies him-/herself to the ALMA Archive System
2. ALMA User defines criteria for data selection (using a GUI for human user access):
   — Project name(s) / number(s)
   — Source name(s)
   — Coordinates
   — Line names / frequency ranges
   — Date(s)
   — Proposals
   — Observing Programs (OPs)
   — Scheduling Blocks (SBs)
3. ALMA User requests data under given constraints from archive
   Exception Course I: Requested data is not accessible to the user.
   Exception Course II: No data is available under the given constraints.
4. Data set is made available to ALMA User
5. Optionally reduce the data set using the ALMA Science Data Pipeline
6. Save access / request log in archive

Subflow:

Alternate Course:

Exception Course I: Requested data is not accessible to the user.

1. System delivers only data headers.

Exception Course II: No data is available under the given constraints.

1. System notifies ALMA User.
   Postcondition: No data delivered.

Postconditions:

1. Requested data is made available to ALMA User

Issues to be Determined or Resolved:

- The access to the ALMA archive is supposed to be easy and fast. What exactly does that mean ?
- What are the policies concerning data access for reviewers, ALMA staff and general users ?
- Are there any restrictions concerning the usage of the Offline Science Data Pipeline or is anybody allowed to use as much computing power / time as they want ? A policy statement on this point will be needed.
- Will products of the Offline Science Data Pipeline be stored in the ALMA archive ? One approach would be to keep images above a given image size and/or image production time and to recalculate on the fly below it.

Notes:

Owner: Dirk Muders
`Last modified by $Author: lucas $ on $Date: 2001/04/12 11:18:57 $`

4.7 Main Observing Modes

The Use Cases for Observing Modes are included here not as a final description of ALMA Observing and Calibration Modes, but as examples of practical uses of the array, which we describe here as a means to achieve a better characterisation of the software.

4.7.1 Single Field

Use Case: SetupSingleField

Starting from user's scientific input, determine all parameters necessary to perform single field interferometric observations.

In this mode, the array is used in Interferometric Mode to synthesize a map which is entirely contained inside the primary beam of the antennas. All antennas, while on source, point towards the Field Center, while in general the interferometer is tuned to maintain a zero delay and zero phase for that same position (the Phase Center).

The source observations are interspaced with observations of phase calibrators, amplitude calibrators, pointing and focus calibrators (See UC_SetupGainCalibration, UC_PointingCalibration).

Role(s)/Actor(s):
Primary: Observer
Secondary: Line Catalog, Source Catalog, Array Configuration Catalog

Priority: Major

Performance : seconds.

Frequency: 100/hour

Preconditions:

Basic Course:

1. User indicates the Project aim: detection, high fidelity mapping, ... This information will be used later to select reasonable defaults in data taking and reduction.
2. User specifies:
   — Field name.
   — Coordinate system.
   — Field center coordinates (either by absolute coordinates or offsets from a direction specified by its absolute coordinates). This is both the Phase Center and the Pointing Center.

   Alternate Course: A Phase Center is specified which is different from the Pointing Center.
3. System checks the declination.
   Exception Course: The source is not observable from the ALMA site.
4. User specifies:
   — Desired synthesized beam size
   — Field width
5. User specifies:
   — Number of IF bands.
   — Line names; the frequencies are obtained from the line catalog.
   Alternate Course: User enters line name and line frequencies.
   Alternate Course: User enters continuum setup name and continuum frequency.
6. For line observations, the user specifies:
   — Center velocities.
   — Velocity reference systems.
   — Velocity bandwidths.
   — Velocity resolutions.

Alternate Course: For continuum (or line in specific cases), the user specifies:
— Frequency bandwidths.
— Frequency resolutions.

7. User optionally specifies phase calibrator choice policy:
   — calibrator to be selected in preamble by direct observation: closest with given minimum flux, or strongest with maximum distance
   — calibrator named explicitly from the instrument catalog.

   Alternate Course: The Observatory default policy is used.
8. User specifies phase calibration observing frequency and phase rms goal on calibrators translated at target observing frequency.
9. User specifies whether the radiometric phase correction is to be used, and in which mode (keep corrected data, both corrected and uncorrected, or best as determined in real time).
10. User specifies that the integration times of the phase calibration cycle are optimally determined at run time from measured phase rms
    Alternate Course: the integration times are given explicitly
11. User specifies the parameters of bandpass calibration:
    1. The calibrator is to be chosen at observing time.
       Alternate Course: the calibrator is explicitly specified.
    2. The goal in rms phase is specified.
12. User specifies the performance goals: final rms and/or maximum total integration time
13. The system evaluates the proposed setup:
    1. The field size is compared to the primary beamwidth at the observing frequency.
       Alternate Course: if larger a mosaic observation is suggested.
    2. Beam information is computed (ellipticity, actual size).
    3. The system computes maximum and minimum baseline lengths needed, and makes some comments about configuration availability (TBD).
    4. Map cell size and number of pixels are computed.
    5. A warning is given if time averaging smearing in the *uv* plane leads to significant sensitivity reduction at primary beam edge.
    6. The correlator setup is explicitly computed from the spectral information. Warnings are given if the spectral coverage is affected by Doppler effect variations.
    7. The system proposes splitting into SBs based on observatory policy (max. SB length). If the synthesis requires several array configurations, there will be one SB for each configuration.
14. The User may either refine its input parameters, modify the deduced setup parameters, or accept the system provided values.

Postconditions:

1. The Programme consists of a single SB per array configuration, of fixed duration (typically 15-30 min.) which will be repeated until the Project sensitivity goals are obtained, in one or more Observing Sessions. It will ensure phase, amplitude, pointing and focus calibration at regular intervals. Programme execution is described in UC_ObserveSingleField.

Issues to be Determined or Resolved ...

Notes:

— Coordinates may be also graphically determined from a user provided map or image.
— Calibrator choice: there is usually a trade-off between distance and calibrator strength. There should be several different rules to select the optimum calibrator.
— The map cell size entered here is to be used mainly for on-line display and reduction of single configuration data. Including previously obtained long baseline data should force the pipeline to produce maps at the right sampling.

Owner: Robert Lucas
`Last modified by $Author: lucas $ on $Date: 2001/04/12 12:48:41 $`

Use Case: ObserveSingleField

Describe the actual observing actions needed to obtain data in the Single Field Interferometric Mode. The mode and the corresponding observing setup are described in UC_SetupSingleField.

The Programme consists of a single SB, of fixed duration (typically 15-30 min.) which will be repeated until the Project sensitivity goals are obtained, in one or more Observing Sessions. It ensures phase, amplitude, pointing and focus calibration at regular intervals.

The data reduction for this mode is described in UC_ReduceSingleField.

Role(s)/Actor (s)
Primary: The AOS
Secondary:

Priority: Major

Performance: real-time; overhead should be minimal and dominated by hardware.

Frequency: This mode is likely to be the most frequently used.

Preconditions: All the user parameters have been properly entered and checked (UC_SetupSingleField)

Basic Course:

1. The Preamble is executed (only once in the Session):
    1. Doppler effect is initially calculated for the target source and current time. This value is used for the initial setting of the correlator.
    2. The receivers are set up and tuned at each of the frequencies foreseen (target frequency, calibration frequency.
    3. The correlator is initially setup.
    4. The pipeline is started.
    5. The bandpass calibration is executed, after automatic selection if so specified. This includes observing this source at both the target frequency and the calibration frequency.
    Alternate Course: The bandpass is calibrated using a hardware calibration scheme.
    6. The phase calibrator is selected if necessary by observing a few candidates in the source vicinity, according to the selection policy as specified in the setup. Its flux is measured.
    7. If the phase calibrator is not suitable (too weak) as a pointing/focus reference, a pointing and focus calibrator is selected.
    8. If the phase calibrator is not suitable (too weak) as a flux reference, a stronger flux calibrator is selected to be regularly observed at the target frequency. Its flux is measured.
2. For each scheduled SB:
    1. Check whether the time elapsed since the pointing corrections have been last measured is larger than a specified time. That specified time must depend on observing frequency, required pointing accuracy, and current observing conditions.
    2. If needed, measure pointing and focus offsets on the pointing calibrator using the standard procedures. Update the pointing and focus corrections using feed back from the calibration pipeline.
    3. Record correlator output on the phase calibrator at the calibration frequency then at the observing frequency (TBD) for a specified or calculated time.
    4. Record correlator output on the target source at the observing frequency for a specified or calculated time. This calculation is based on the current phase rms or phase structure function (TBD). The Doppler effect is recalculated and the time-varying increment (since the Preamble calculation) is applied on the first LO phase rotators.
    5. Repeat steps 3 and 4 until the SB time is exhausted or the goals are achieved (e.g. minimum rms reached).
    6. The phase calibrator is reobserved one last time.

    Exception Course: If:
    — the phase rms increases over a specified limit,

— the pointing accuracy as monitored over the repeated measurements increases over a specified limit,
— the system noise increases over a specified limit,

the SB is terminated (the data observed so far is kept, with an appropriate flag).

3. The System executes the associated Postamble:
   1. The pointing and focus are checked one last time on the pointing calibrator to validate the latest observations.
   2. Optionally (if specified by the astronomer or if automatically determined) the pipeline is instructed to make the final image and is closed.

Postconditions:

Issues to be Determined or Resolved:

1. An amplitude calibrator may need to be observed at some rate if the phase calibrator is not strong enough.
2. That calibrator may also be used to monitor the relative phases at the observing and the calibration frequency
3. The policy to choose the bandpass calibrator is to be defined.
4. The algorithm to determine the dwell time for phase calibration is TBD.
5. Measuring the sideband gain ratios could be needed in the Preamble if both sidebands can be measured.
6. This use case might be extended to include a calibrator as a test source at regular intervals, for quality evaluation.
7. The optimal phase calibrator may change during a Session. If so foreseen, the Preamble must include selecting and testing calibrators for various hour angle ranges ...

Notes:

1. The Doppler effect cannot be tracked continuously because if the finite steps allowed for LO1 tuning. The fine tracking of the Doppler effect (inside a given day) is performed using the phase rotators.

Owner: Robert Lucas
`Last modified by $Author: lucas $ on $Date: 2001/04/12 12:52:38 $`

Use Case: ReduceSingleField

This Use Case describes the on-line data reduction operations specific to the Single Field interferometry mapping mode.

Selection of Reducing Scripts as well as that of observing parameters for this Mode is described in UC_SetupSingleField.

The data reduction operations presented here are performed by the Calibration Pipeline and the Science Data Pipeline. General operation of these are described in UC_ProcessCalibrations and UC_ProcessScienceData.

Role(s)/Actor (s)
Primary: The AOS, or the observer
Secondary:

Priority: Major

Performance: Need to feed back data nearly in real time.

Frequency: At least once per program, possibly after Breakpoints, after a session or for every scan.

Preconditions: The user input parameters have been input and have been made available to the Pipeline, preferably in the data headers

Basic Course:

1. For each available observation, the current system temperatures are computed using total power on sky and ambient load (previously measured: See UC_ TemperatureScaleCalibration)
2. When the bandpass scan is available, the bandpass calibration is computed (See UC_ ReduceAstroBandpass-Calibration)
3. Whenever a new phase calibrator scan is available, the phase rms is computed, the antenna based amplitudes are checked against the known calibrator flux.
4. At the end of the session:
    1. The phase calibration is computed and applied to all target scans by interpolation.
       Alternate Course: The phase calibration is computed and applied on the fly, as soon a sufficient number of calibration scans are available.
    2. The amplitude calibration is computed and applied to all target scans by interpolation.
       Alternate Course: the amplitude calibration is computed and applied on the fly, as soon a sufficient number of calibration scans are available
5. Optionally, the *uv* data is
    1. Gridded
    2. Fourier transformed into a dirty map
    3. Deconvolved
6. Optionally the data cube is archived

Postconditions: Issues to be Determined or Resolved: ...

Notes:

1. Processing of the calibrations (pointing, focus, phase, flux ...) and processing of science data are performed by distinct Pipelines.
2. The pointing and focus scans reduction is/will be described in other Use Cases (UC_ObservePointingCalibration, ...)
3. We assume that online displays to be regularly updated are described in another Use Case.
4. If resources allow maps may be computed and displayed at more frequent intervals, for diagnostic purposes.
5. Interim results are probably not stored in the archive or at least they should be flagged as being only intermediate results.

6. Data is automatically flagged for various detected situations (large pointing errors, ...)
7. The WVR-based phase corrected or uncorrected data are used according to the options in the setup.

Owner: Robert Lucas
`Last modified by $Author: lucas $ on $Date: 2001/04/12 13:07:06 $`

4.7.2 Multi Field

Use Case: SetupMultiField

Starting from the User's scientific input, determine all parameters necessary to perform multi-field interferometric observations.

Setup is done as part of the Phase II process to specify the details of the observations and is done with the Observing Tool (OT) GUI. The OT will simplify the setup procedure by providing sensible automatic parameter values derived from high level user input. These automatic values can be overridden by more expert users. The most common use of multi-field interferometric observations is to create a mosaic, but in the most general case this Observing Mode can create an arbitrary sequence of different pointing centers with different nominal noise levels. There is one pointing center per field, coincident with the field center. The user may set a preferred order of pointing centers that considers the scientific priorities and the effects of common pointing errors between fields. This setup usually creates multiple SBs.

See also UC_ObserveMultiField and UC_ReduceMultiField.

Role(s)/Actor(s):
Primary: The User (Observer, Staff Scientist, Array Operator), the ObservingTool
Secondary: Line Catalog, Source Catalog, Array Configuration Catalog

Priority: Major

Performance: Interactive

Frequency: Many per hour.

Preconditions: None

Basic Course:

1. User specifies the scientific intent from the following:
    1. Detection in multiple separate fields.
    2. Imaging of multiple separate fields.
    3. Detection in a mosaic .
    4. Imaging a mosaic.
2. User fully specifies mosaic parameters:
    - Noise level in final mosaic
    - A coordinate system and a center position for the mosaic
    - A pattern or area from the following:
        - Rectangular area
        - Oval (including circular) area
        - Region defined by mouse on a sky overlay
        - Spiral pattern
3. The OT selects an angular spacing between pointing centers based on the frequency and then generates the list of pointing centers. The OT generates a nominal noise level for each field based on the specified noise level in the final mosaic. The OT generates a default name for each field based on the sequential order of the field and the source name assigned to the center position.
   Alternate Course: User specifies that a mosaic is not the Program goal and enters an array of field centers and noise levels. The field centers may be specified either by absolute coordinates or offsets from a position specified by absolute coordinates.
4. User optionally edits the sequence of field names, field center coordinates, and noise levels.
5. User optionally assigns a preferred order to the fields that considers the scientific priorities and the effects of common pointing errors between fields.
6. System checks the declination for all fields.
   Exception Course: Any field is not observable from the ALMA site.

7. User specifies the desired spatial resolution in the mosaic or field maps.

8. User specifies number of IF bands, line names; the frequencies are obtained from the Line Catalog.
   Alternate Course: User enters line name and line frequencies
   Alternate Course: User enters continuum frequency

9. User specifies center velocities, velocity reference systems, velocity bandwidths, velocity resolutions.
   Alternate Course: For continuum, the user specifies frequency bandwidths and frequency resolutions

10. In the case of double sideband receivers, User specifies whether to use software sideband separation or sideband suppression by offset LO.
11. User specifies phase calibrator choice policy (closest with given minimum flux, strongest with maximum distance, calibrator named explicitly from the ALMA catalog)

12. OT determines phase calibration observing frequency and phase rms goal on calibrators based on scientific intent.

13. User optionally modifies phase calibration observing frequency and phase rms goal.

14. OT determines the parameters of the phase calibration cycle based on the scientific intent.

15. User optionally modifies the parameters of the phase calibration cycle, either explicitly, or by requesting that those parameters be optimally determined at run time from measured phase rms.

16. User specifies the parameters of bandpass calibration: the calibrator is either to be chosen at observing time or explicitly specified; the goal in rms phase is specified.

17. The OT and User specify the parameters for pointing calibration. See UC_SetupPointingCalibration for the details.
18. The OT and User specify the parameters for focus calibration.
19. User specifies atmospheric pathlength correction selection for visibility archiving:
    — Uncorrected
    — Corrected
    — Both
20. User specifies atmospheric pathlength correction selection for the Science Data Pipeline and image archiving:
    — Uncorrected
    — Corrected
    — Best of uncorrected or corrected
21. The OT evaluates the proposed setup:

    1. Examines field spacing to determine if they are close enough to create mosaic image.
       Alternate Course: Inform user that fields are too far apart for mosaic.
       Alternate Course: Recognize that scan goal is not a mosaic and skip examining field spacings.
    2. Beam information is computed (ellipticity, actual size)
    3. The OT computes maximum and minimum baseline lengths needed, and makes some comments about configuration availability (TBD).
    4. Map cell size and number of pixels are computed.
    5. The correlator setup is explicitly computed from the spectral information. Warnings are given if the spectral coverage is affected by Doppler effect variations.
    6. Compute visibility data rate and data volume and warn User if it exceeds proposal allocation.

22. User may either refine the input parameters, modify the deduced setup parameters, or accept the setup.
23. OT creates pipeline data reduction script.
24. User optionally edits pipeline data reduction script.
25. OT computes image data rate and data volume and warns User if it exceeds proposal allocation.
26. OT generates Preamble Block, Postamble Block, and SBs for the scans.
27. User optionally edits Preambles, Postambles, and SBs.
28. User specifies a unique name to attach to the final results (Preambles, Postambles, SBs, pipeline reduction script).
29. OT automatically saves the results at the completion of the setup.

Postconditions:
A set of Preambles, Postambles, SBs, and pipeline data reduction script.

Issues to be Determined or Resolved
When not creating a mosaic, can the shape and/or size of the fields vary between different fields?

Notes:

— The User may save partial results from the setup at any time and exit, assigning a unique name to the results.
— The User may start the OT with previously saved partial results.
— The User may start the OT with a previous setup, using it as a template.

Owner: Steve Scott

Last modified: 2001/01/22 Steve Scott

Use Case: ObserveMultiField

The observing actions needed to obtain data in the multi-field interferometric mode. The Observing Mode and the corresponding setup are defined in UC_SetupMultiField.

This Observing Mode usually consists of several SBs, with each SB containing multiple pointing centers. The size of the SBs (the number of pointing centers contained in each) is determined by the optimal temporal duration of an SB at the requested atmospheric conditions and the requested sensitivity. Several operations are done in both the Preamble and the SB so that looping can be done within the SB, always ending with a phase calibration and evaluation of the progress in the data collection. Data are collected with all antenna and interfermometric beams centered on each pointing center.

Role(s)/Actor(s)
Primary: The AOS
Secondary:

Priority: Major

Performance: Realtime; overhead should be minimal and dominated by hardware.

Frequency: Frequently used.

Preconditions: All the user parameters have been properly entered and checked (UC_SetupMultiField), and the Preamble Blocks, Postamble Blocks, and SBs have been created.

Basic Course

1. The Program is scheduled for the first time or it is resumed to begin another Observing Session and execute more SBs.
2. The Preamble for the next SB is executed, unless it is the same as the Preamble for the preceeding SB.
    1. Doppler effect is calculated for the target source and current time.
    2. The receivers are set up and tuned.
    3. The correlator is set up.
    4. The bandpass calibration is executed, after automatic selection if so specified. This includes observing this source at both the target frequency and the calibration frequency.
    5. The phase calibrator is selected if necessary by observing a few candidates in the source vicinity, according to the selection policy as specified.
    6. If the phase calibrator is not suitable (too weak) to use as a pointing reference, a pointing calibrator is selected.
    7. Select which atmospheric pathlength corrected data will be archived based on earlier input (see UC_SetupMultiField).
    8. Measure pointing and focus offsets on the pointing calibrator using the standard procedures.
    Alternate Course: Pointing and focus are already up to date; skip this step.
    9. Update the pointing and focus corrections using feedback from the Calibration Pipeline.
    Alternate Course: Pointing and focus are already up to date; skip this step.
    10. The phase calibrator is observed for the first time (collect and archive correlator output).
3. For each scheduled SB:

    1. Measure pointing and focus offsets on the pointing calibrator using the standard procedures.
    Alternate Course: Pointing and focus are already up to date; skip this step.
    2. Update the pointing and focus corrections using feedback from the Calibration Pipeline.
    Alternate Course: Pointing and focus are already up to date; skip this step.
    3. Collect and archive correlator output on a sequence of the specified fields at the observing frequency for a specified or calculated time. This calculation is based on the current phase rms or phase structure function (TBD).
    4. Collect and archive correlator output on the phase calibrator at the calibration frequency then at the observing frequency (TBD) for a specified or calculated time.

5. Obtain estimate of the rms noise in the field from the Calibration Pipeline.
6. Repeat steps 1 through 5 until all of the fields have been observed and the goals are achieved (e.g. minimum rms reached), or the SB time is exhausted.

Exception Course: If the phase rms increases over a specified limit, the SB is terminated (keep the data observed so far, with appropriate flag).

4. The associated Postamble is executed, instructing the Science Data Pipeline to make any requested preliminary images.

5. If all SBs for the Program are not complete, loop back to Preamble for the next SB.
6. The Science Data Pipeline is instructed to make the final images and is closed.
   Alternate Course: The Program is not complete: make any requested preliminary images.

Postconditions:

1. Data is stored in the archive.
2. Completion status of observed fields is updated.

Issues to be Determined or Resolved:

— The policy to choose the bandpass calibrator is TBD.
— The algorithm to determine the dwell time for phase calibration is TBD.

Notes:

— An amplitude calibrator may need to be observed at some rate if the phase calibrator is not strong enough.
— The amplitude calibrator may also be used to monitor the relative phases at the observing and the calibration frequency.
— Focus and pointing are done before the phase calibrator in the Preamble to ensure that instrument sensitivity is maximized before the phase calibrator is observed.
— Any change in focus will cause a phase change that will be automatically corrected.
— Measuring the sideband gain ratios could be needed in the preamble if both sidebands can be measured.
— This use case might be extended to include a calibrator as a test source at regular intervals, for quality evaluation.

Owner: Steve Scott

Last modified: 2001/01/22 Steve Scott

Use Case: ReduceMultiField

This Use Case describes the on-line data calibration and reduction operations for the multi-field interferometric Observing Mode. This Observing Mode is described in UC_SetupMultiField.

Data calibration and reduction is performed by the Calibration Pipeline during the Observing Session and by the Science Data Pipeline after the session or on user request. Calibration is applied to the target data as new calibration becomes available, allowing calibrated visibility data to be displayed at any time. Calibrations are applied on an integration data level. The Calibration Pipeline also provides estimates of noise in data products that are fed back to the AOS to control successful completion of Schedule Blocks. The presence of calibrated data does not prevent display of raw data. See also UC_ObserveMultiField.

Role(s)/Actor(s):
Primary: The AOS, the User (Observer, Staff Scientist, Array Operator); the Calibration and Science Data Pipelines.
Secondary:

Priority: Major

Performance: Need to feed back data nearly in real time.

Frequency: At least every scan.

Preconditions: The user input parameters have been input and have been made available to the pipeline, preferably in the data headers. A standard data reduction script has been selected.

Basic Course:

1. An atmospheric pathlength corrected data set is selected for the pipelines as specified in UC_SetupMultiField.
2. At the completion of every scan:
    1. The current system temperature spectra are computed using autocorrelation spectra and total power on the sky and on the ambient load (previously measured) and applied to the data.
    2. At completion of the bandpass scan, the bandpass calibration is computed as specified in (UC_Reduce˙Interferometric˙AstroBandpassCalibration.
    3. The bandpass calibration is applied to all new integrations.
    4. At the completion of every target scan, all available calibrations are applied to the target data.
    5. At the completion of every phase calibrator scan:
        1. The phase rms is computed.
        2. The antenna based amplitudes are computed and checked against the known calibrator flux.
           *Exception Course:*Only two antennas are available so the baseline amplitude is compared.
        3. The map noise is estimated and fed back to the AOS for use in control of data collection.
        4. The phase calibration is computed and applied to all target scans by interpolation with time.

    6. At the completion of every amplitude calibrator (or phase calibrator strong enough to be used as an amplitude calibrator), amplitude calibration is computed and applied to all target scans by interpolation with time.
3. At the end of an Observing Session, the calibrated data from all fields are handled together as the UV data are gridded, Fourier transformed into a dirty map, and deconvolved.
   Alternate Course: A mosaic was not requested: the individual fields are processed using the same steps as for a mosaic, except on a field by field basis.

4. At the end of the Observing Program, the data cube is archived.

Postconditions:

1. An archived image data cube is produced.
2. The project status is updated to reflect completion of archiving.

Issues to be Determined or Resolved: None at this time.

Notes:

Owner: Steve Scott
`Last modified by $Author: lucas $ on $Date: 2001/04/12 13:17:11 $`

4.7.3 OTF Mosaic

Use Case: SetupOTFMosaic

Starting from user's scientific input, determine all parameters necessary to perform On The Fly (OTF) Mosaic interferometric observations.

In such a mode, the antennas are synchronously scanned across the area to be mapped, while the correlation data is being recorded. In the end the maps obtained during each integration will be simultaneouily deconvolved using a mosaicing algorithm and a full scale map will be obtained.

Note that this is a mode which has **not been used in any millimeter array so far** (to my knowledge).

Role(s)/Actor(s):
Primary: Observer
Secondary: Line Catalog, Source Catalog, Array Configuration Catalog

Priority: Major

Performance: seconds.

Frequency: 100/hour

Preconditions:

Basic Course:

1. User indicates the Project aim: detection, high fidelity mapping, ... This information will be used later to select reasonable defaults in data taking and reduction.
2. User specifies field name, coordinate system, and field center coordinates (either by absolute coordinates or offsets from a direction specified by its absolute coordinates);
3. System checks the declination.
   Exception Course: The source is not observable from the ALMA site.
4. User specifies the desired synthesized beam size and field width.
5. User specifies number of IF bands, Line names; the frequencies are obtained from the line catalog.
   Alternate Course: User enters line name and line frequencies
   Alternate Course: User enters continuum setup name and frequency
6. User specifies center velocities, velocity reference systems, velocity bandwidths, velocity resolutions
   Alternate Course: for continuum, the user specifies frequency bandwidths and frequency resolutions
7. User specifies phase calibrator choice policy (closest with given minimum flux, strongest with maximum distance, calibrator named explicitly from the instrument catalog)
8. User specifies phase calibration observing frequency and phase rms goal on calibrators at target observing frequency, and whether the radiometric phase correction is to be used.
9. User specifies the parameters of the phase calibration cycle, either explicitly, or by requesting that those parameters are optimally determined at run time from measured phase rms.
10. User specifies whether the radiometric phase correction is to be used, and in which mode (keep corrected data, both corrected and uncorrected, or best as determined in real time).
11. User specifies the parameters of bandpass calibration: the calibrator is either to be chosen at observing time or explicitely specified; the goal in rms phase is specified.
12. User specifies the performance goals: total integration time and/or final rms.
13. The system evaluates the proposed setup:
    1. The field size is compared to the primary beamwidth at the observing frequency.
       Alternate Course: if field size is too small single field or pointed mosaic observation is suggested
    2. beam information is computed (ellipticity, actual size)
    3. the system computes maximum and minimum baseline lengths needed, and makes some comments about configuration availability (TBD).

4. map cell size and number of pixels are computed.
5. the correlator setup is explicitly computed from the spectral information. Warnings are given if the spectral coverage is affected by Doppler effect variations.
6. proposes subdividing mosaic field into OTF scans with scan length and slew rate determined from the maximum baseline length, size of field to be mosaiced .... following hardware limitations.
7. proposes splitting into SBs based on observatory policy (max SB length). Depending whether the map is small enough to fit in one SB, there will be one SB or several SBs corresponding to different map areas that can each be scanned in a standard SB duration. If several array configurations are needed, there will be one or several SB for each array configuration.

14. The User may either refine its input parameters, modify the deduced setup parameters, or accept the system provided values.

Postconditions:

1. The Programme consists of one or several SBs, of fixed duration (typically 15-30 min.) which will be repeated until the Project sensitivity goals are obtained, in one or more Observing Sessions. It will ensure phase, amplitude, pointing and focus calibration at regular intervals. Programme execution is described in UC_ObserveOTFMosaic.

Issues to be Determined or Resolved ...

Notes:

1. Coordinates may be also graphically determined from a user provided map or image.
2. *The scheme currenly envisioned for phase tracking* is the following (D. Emerson):
   - — We apply, on one of the LO's, the phase and fringe frequency needed to track the center of the antenna beam (taken at the center of the integration period),
     - — an additional phase, constant during the integration, as needed to obtain a continuous phase at the beginning of the integration.
   - — this phase value is kept and later subtracted from that of visibilities obtained during that integration.

   This scheme should not unneededly restrain the final data rate.
3. The beam information (Basic Course 2) is approximate, expecially for snapshots, and highly stretched arrays.

Owner: Robert Lucas
`Last modified by $Author: lucas $ on $Date: 2001/04/12 13:24:28 $`

Use Case: ObserveOTFMosaic

Describe the actual observing actions needed to obtain data in the On-The-Fly Mosaic interferometric mode.

See UC_SetupOTFMosaic for a description of this mode and of the way the relevant parameters are selected by the Observer. Relevant data reduction procedure will eventually be described in UC_ReduceOTFMosaic.

Role(s)/Actor(s):
Primary: The AOS
Secondary:

Priority: Major

Performance: real-time; overhead should be minimal and dominated by hardware.

Frequency: if successful, this mode will be commonly used for large mosaics.

Preconditions: all the user parameters have been properly entered and checked (UC SetupOTFMosaic.html)

Basic Course

1. The preamble block is executed (only once in the session).
    1. Doppler effect is calculated for the target source and current time.
    2. The receivers are set up and tuned.
    3. The correlator is set up.
    4. The pipeline is started.
    5. The bandpass calibration is executed, after automatic selection if so specified. This includes observing this source at both the target frequency and the calibration frequency.
    6. The phase calibrator is selected if necessary by observing a few candidates in the source vicinity, according to the selection policy as specified. Determine the calibration integration time from the flux density.
    7. If the phase calibrator is not suitable (too weak) as a pointing reference, a pointing calibrator is selected.
2. For each scheduled SB:
    1. Check whether the time elapsed since the pointing corrections have been last measured is larger that a specified time. That specified time must depend on observing frequency, required pointing accuracy, and current observing conditions.
    2. If needed, measure pointing and focus offsets on the pointing calibrator using the standard procedures. Update the pointing and focus corrections using feed back from the calibration pipeline.
    3. Record correlator output on the phase calibrator at the calibration frequency then at the observing frequency (TBD) for a specified or calculated time.
    4. Set the fringe rate for the mid point of the OTF scan or the map center (see Note in UC_SetupOTFMosaic).
    5. OTF scan: Record correlator output on the target source at the observing frequency whilst synchronously slewing the antennas for a specified time at a specified slew rate.
    6. Repeat steps 4 and 5 until the calibration interval , then re-observe the phase calibrator.
    7. Repeat until the SB time is exhausted or the goals are achieved (e.g. minimum rms reached).

    Exception Course: If the phase rms increases over a specified limit, the SB is terminated (keep the data observed so far, with appropriate flag).

3. The system executes the associated postamble SB: the phase calibrator is reobserved one last time. The pipeline is instructed to make the final image and is closed.

Postconditions: Issues to be Determined or Resolved:

— An amplitude calibrator may need to be observed at some rate if the phase calibrator is not strong enough.
— That calibrator may also be used to monitor the relative phases at the observing and the calibration frequency
— The policy to choose the bandpass calibrator is to be defined.

— The algorithm to determine the dwell time for phase calibration is TBD.
— Measuring the sideband gain ratios could be needed in the preamble if both sidebands can be measured.
— This use case might be extended to deal with more than one target source.
— This use case might be extended to include a calibrator as a test source at regular intervals, for quality evaluation.

Notes:

Last modified: $Id: ObserveOTFMosaic.html,v 1.4 2001/04/12 13:26:32 lucas Exp lucas $

4.7.4 AutoCorrelation On-The-Fly Mapping

Use Case: Setup AutoCorrelation OTF-Map

Starting from user's scientific input, determine all parameters necessary to perform Auto Correlation On-The-Fly (=Total Power On-The-Fly) Mapping observations. An Auto Correlation On-The-Fly map is the continuous scanning of an area on the sky, in a predefined pattern, and the taking of data during this scanning. One needs to occasionally observe emission-free areas (OFF-Positions) for some time. In some cases, these OFF-positions can be the edges of the map, in other cases, they may be further away from the mapping region.

Role(s)/Actor(s):
Primary: Observer
Secondary: Line Catalog, Source Catalog, Array Configuration Catalog

Priority: Major

Performance: Seconds

Frequency: Several/hour

Preconditions:

Basic Course:

1. User specifies field name, coordinate system and field center coordinates (either by absolute coordinates or offsets from a direction specified by its absolute coordinates);
2. System checks the declination.
   Exception Course: The source is not observable from the ALMA site.
3. User specifies
   - number of IF bands,
   - Line names, the frequencies are obtained from the line catalog.
     Alternate Course: User enters line name and line frequencies
     Alternate Course: User enters continuum frequency
   - observing mode:
     - Position switching
     - Beam switching using the wobbler
     - Frequency switching (only applicable for line observations)
4. For line observations, the user specifies
   - center velocities
   - velocity reference systems
   - velocity bandwidths
   - velocity resolutions

   Alternate Course: e.g. for continuum, the user specifies
   - frequency bandwidths
   - frequency resolutions
5. System calculates beam size.
6. User specifies the desired geometric mapping details:
   - the map size, shape (rectangular, circular, etc.).
   - the mapping strategy (zig-zag, spirals, etc.).
7. User specifies the desired time and / or scanning speed details for each observing frequency:
   - the desired RMS noise for a given velocity resolution (which may be larger than the specified correlator channel width) per OTF point.
     Alternate Course: User specifies the integration time per OTF point.
   - System calculates and displays step sizes between OTF scanning points according to the beam size and the Nyquist sampling theorem.
     Alternate Course: User specifies the step size between subsequent OTF scanning points and the distance between scan lines perpendicular to the scan axis.

Alternate Course: User specifies scanning speed and total time per basic geometric OTF map element.

8. User specifies sky reference position(s) in absolute or relative coordinates for On-Off OTF map for each observing frequency.
   Alternate Course I: User specifies nutator / wobbler offset(s) for Beam Switched OTF map.
   Alternate Course II: User specifies to use edges of OTF map as reference positions.
   Alternate Course III: frequency throw for frequency switching observations
9. User specifies time intervals for alternation between reference and target for each observing frequency.
10. User specifies time intervals between amplitude calibrations during the OTF map to be determined at run time depending on changes in elevation and atmospheric water vapor content.
    Alternate Course: User specifies time intervals explicitly, optionally as upper limits, for each observing frequency.
11. User specifies desired pointing and focus accuracy.
    Alternate Course: User specifies time intervals between pointing and focus calibrations.
12. The system evaluates the proposed setup:
    1. The system calculates the estimated time for completion of the specified map
    2. The system compares the given OTF step sizes to the beam size at the specified frequency, notifies user and suggests changes if the sampling theorem is violated or the beam smearing is too large.
    3. the correlator setup is explicitly computed from the spectral information. Warnings are given if the spectral coverage is affected by Doppler effect variations.
    4. The system suggests to split the given OTF map into smaller pieces to be executed in parallel by software-subarrays.
    5. The system proposes splitting into SBs based on observatory policy (max SB length) .
13. The User may either refine its input parameters, modify the deduced setup parameters, or accept the system provided values.

Postconditions:

1. Set of SBs describing the OTFMap. For large maps, the mapping is separated into sub-maps (one per SB) whose observing takes at most the maximum allowed SB time. Each sub-map must be begun with an amplitude calibration (see UC_AmplitudeCalibration) to ensure that SBs can be calibrated individually.

Issues to be Determined or Resolved:

— Projects may ask for maps of the same area at different frequencies, which implies different beam sizes and therefore a different mapping step sizes etc. This has to be addressed somewhere.
— It is unclear if there will be software-subarrays.
— It is unclear if there will be LO / frequency subarrays which would allow simultaneous mapping of different lines within one subarray.

Notes:

— Coordinates may be also graphically determined from a user provided map or image.
— For performance reasons, all allowed OTF mapping patterns should use only continuous movements of the antennas, e.g. in a rectangular zig-zag pattern the rows should be connected by half circles.
— Time intervals both for observing reference positions and for performing calibrations should, in case of mapping patterns with identifiable subpatterns (e.g. a row in a zig-zag pattern) be expressible in time units needed to complete a subpattern (e.g. Off after each row).

Owner: Dirk Muders
`Last modified by $Author: lucas $ on $Date: 2001/04/12 13:17:11 $`

Use Case: Observe Auto Correlation OTF-Map

This use case describes the actual observing actions needed to obtain data in the Auto Correlation On-The-Fly Mapping mode. For a detailed description of this Observing Mode refer to UC_Setup˙AutoCorrelation˙OTF˙Map.

Role(s)/Actor(s):
Primary: The AOS
Secondary:

Priority: Major

Performance: real-time; overhead should be minimal and dominated by hardware.

Frequency: Several / hour.

Preconditions: all the user parameters have been properly entered and checked (UC_Setup_AutoCorrelation_OTF_Map)

Basic Course

1. If this is the beginning of an Observing Session, the Preamble Script is executed:
    1. The receivers are set up and tuned.
    2. The correlator is setup.
    3. The pipeline is started.
    4. A pointing calibrator is selected.
2. For each scheduled SB:
    1. Calculate the trajectories specified in the OTF map setup.
    2. Optionally calculate integration time per OTF point from current receiver and atmospheric conditions
    3. Calculate the scanning speed from the OTF map setup (step size along scanning trajectory divided by dwell time per OTF point).
    4. Execute until map is finished:
        1. Perform pointing and focus calibrations
        2. Update the pointing and focus corrections using feed back from the calibration pipeline, if applicable.
        3. Execute for time calculated or specified between pointing calibrations:
            1. Perform temperature scale calibration.
            2. Execute for time specified between calibrations:
                Observe reference position.
                Alternate course I: For beam switch: switch on nutator
                Alternate course II: For frequency switch: initiate frequency switching
                Execute for time specified between reference positions:
                Move telescope(s) with given speed along trajectory.
                Update Doppler effect for the target source and current time continuously.
                Record autocorrelator output on the target source at the observing frequency and observed position(s) for a specified or calculated time. This calculation is based on the current weather conditions.

    Exception Course: If the weather conditions deteriorate to a given limit (opacity, anomalous refraction) the SB is terminated (keep the data observed so far, with appropriate flag).
3. If this is the end of an Observing Session, the AOS executes the associated Postamble Script: a pointing is performed one last time. The image pipeline is instructed to make the final image and is closed.

Postconditions:

1. OTFMap data has been collected.

Issues to be Determined or Resolved:

— Measuring the sideband gain ratios could be needed in the preamble if both sidebands can be measured.

— This use case might be extended to deal with more than one target source.

Notes:

— Pointing may be performed at a different frequency.

Owner: Dirk Muders
`Last modified by $Author: lucas $ on $Date: 2001/04/12 13:40:07 $`

Use Case: Reduce Auto Correlation OTF-Map

This Use Case describes the on-line data reduction operations for the AutoCorrelation On-The-Fly Mapping mode. For a detailed description of this Observing Mode refer to UC_Setup˙AutoCorrelation˙OTF˙Map.

Role(s)/Actor(s):
Primary: The AOS, or the observer
Secondary:

Priority: Major

Performance: need to feed back data nearly in real time for display purposes.

Frequency: For each scan on source.

Preconditions: The user input parameters have been input and have been made available to the pipeline, preferably in the data headers

Basic Course:

1. For each available observation, the current system temperatures are computed using total power on sky and ambient load (previously measured).
2. Calculate spectrum for each observed OTF point.
3. Grid data observed so far for online display.
4. Display image.

Postconditions:

1. Image data cube produced.

Issues to be Determined or Resolved: ...

Notes:

1. we assume that the pointing and focus scans reduction is described in another Use Case.
2. we assume that online displays to be regularly updated are described in another Use Case.
3. we assume that data reduction for On-Off observations, Beam switching and Frequency switching are described in other Use Cases.
4. the reference data for each OTF point may be interpolated between adjacent reference positions.
5. if resources allow maps may be computed and displayed at more frequent intervals, for diagnostic purposes.

Owner: Dirk Muders

Last modified: January 22, 2001, D. Muders, P. Schilke

4.7.5 Position Switched Mapping

Use Case: SetupPositionSwitchedMapping

Starting from user's scientific input, determine all parameters necessary to perform Position Switched Mapping (total power) observations. This observing mode requires moving the antenna(s) between source and blank sky; it should be possible from all antennas, since it does not use the nutating subreflector that will be available on only a few (if any) antennas in the ALMA array.

Role(s)/Actor(s):
Primary: Observer
Secondary: Line Catalog, Source Catalog

Priority: Major

Performance: seconds.

Frequency:

Preconditions:

1. This mode is not expected to be used for continuum observations.

Basic Course:

1. User specifies coordinate system, and 1..n source names and coordinates (either by absolute coordinates or offsets from a position specified by its absolute coordinates); note that these positions must be close together in the sky (separation less than ~5 degrees, exact value TBD)
   Alternate Course: User gives map center and its dimensions; system chooses absolute positions
2. System checks the declination.
   Exception Course: The source is not observable from the ALMA site.
3. User specifies the position to be used as "blank sky", *e.g.*, from an optical image or a map previously obtained in a representative molecular transition. Both absolute and offset coordinates will be accepted. Default coordinate system is that indicated in Step 1 above, but user may choose a different system.
4. User specifies number of IF bands, Line names; the frequencies are obtained from the Line Catalog.
   Alternate Course: User enters line name and line frequencies
5. User specifies center velocities, velocity reference systems, velocity bandwidths, velocity resolutions
   Alternate Course: User specifies center frequencies and bandwidths
6. System will allow the user to examine expected line transitions that could come from image sidebands and, as a result, tune the correlator (or receivers?) appropriately.
7. User specifies the performance goals: final rms.
   Alternate Course: User specifies the total integration time desired. In this case, he/she may specify the desired system temperature or maximum opacity, or may allow the system to determine these quantities (default).
8. The system evaluates the proposed setup and:
   1. suggests frequencies of amplitude calibration and of blank sky observation
      Alternate Course: If requested, the system will choose the frequency of calibrations based on actual conditions at time of observation
   2. computes map cell size and number of pixels if user has requested a map
   3. computes the correlator setup explicitly from the spectral information. Warns the user if the spectral coverage is affected by Doppler effect variations.
   4. proposes splitting into SBs based on observatory policy (max SB length) ...
9. The User may either refine the input parameters, modify the deduced setup parameters, or accept the system provided values.

Issues to be Determined or Resolved ...

1. How can we help the user to determine what to use as "blank sky"? Possibilities:
    1. The observatory generates a catalog of blank sky positions
    2. The user proposes a list of candidate blank sky positions which are then observed via frequency switching to determine whether they are really blank
    3. Some amount of human intervention in near-real-time may be required (depends upon the–missing–ALMA operations concept)
2. "Beam Switched Mapping" UC is needed to describe observations using nutating subreflector. This is the mode that will be needed, together with OTF, for many continuum observations.
3. If the Compact Array becomes a reality, the user will need to specify the desired angular resolution, and the system will need to choose between the smaller compact array antennas and the 12m ones
4. How many antennas to use will be a scheduling issue (e.g., 12 antennas for 1 hour or 1 antenna for 12 hours?). If the atmospheric transmission at different antennas is uncorrelated, then there is a simple tradeoff between number of antennas used and integration time.
5. We should consider allowing the user to specify a rotated coordinate system, *e.g.*, to map an elongated object.

Notes: Coordinates may be also graphically determined from a user provided map or image.

Owner: Joe Schwarz.
`Last modified by $Author: lucas $ on $Date: 2001/04/12 14:04:10 $`

Use Case: Perform Position Switched Mapping (Total Power)

Describe the actual observing actions needed to obtain data in the position switched mapping mode.

Role(s)/Actor(s)
Primary: The AOS
Secondary:

Priority Major

Performance real-time; overhead should be minimal and dominated by hardware.

Frequency: this mode is likely to be used less often than on-the-fly total power modes, but is important for commissioning

Preconditions: all the user parameters have been properly entered and checked (UC_SetupPositionSwitchedMapping).

Basic Course

1. If necessary, the following initialization steps are executed (only once in the session).
    1. A subarray of antennas is assigned to this session
    2. Doppler effect is calculated for the target source and current time.
    3. The receivers are set up and tuned.
    4. The correlator is setup.
    5. The pipeline is started.
    6. If user has requested, current atmospheric conditions are used to set initial frequencies of amplitude calibration and blank sky observation
2. For each Schedule Block (SB):
    1. Measure pointing and focus offsets on the pointing calibrator using the standard procedures.
    2. Update the pointing and focus corrections using feed back from the pipeline.
    3. Perform amplitude calibration
    4. Record (auto) correlator output on the blank sky at the observing frequency for a specified or calculated time.
    5. For each target position:
        1. Record (auto) correlator output at the observing frequency for a specified or calculated time. Integration time will be determined by a TBD algorithm whose objective is to arrive at the total integration time desired for this SB
        2. Every m targets, record (auto) correlator output on the blank sky as in Step 3 (m was either specified by the user or calculated in near-real-time based on atmospheric conditions). Integration time will be determined by an algorithm similar to that used on-source.
        3. Every n minutes, perform an amplitude calibration. The default value of n is calculated at run-time based on observing frequency, sky stability and opacity; the minimum integration time depends on the interval between amplitude calibrations.
    6. Repeat last step until the SB time is exhausted or the goals are achieved (*e.g.*, minimum rms reached).
3. The system ensures that the last scans were blank sky and amplitude calibration.
4. If the last SB has been executed, the pipeline is instructed to make the final spectra (and image, if a map was specified) and is closed.

Postconditions:Issues to be Determined or Resolved:

— The algorithm to decide when to do an amplitude calibration is to be defined.
  — This will depend on the observing frequency, and on parameters determined by other parts of the system, *i.e.*, sky stability and opacity
— The algorithm to determine the dwell time on blank sky and on sources is TBD. There will be some minimum (~1 sec), but some observations will require much longer times.

— Measuring the sideband gain ratios could be needed as an initialization step if both sidebands can be measured.

Notes:

Last modified: PerformPositionSwitchedMapping.html,v 2.1 2001/01/22 jschwarz

4.7.6 Frequency Switched Mapping

Use Case: SetupFrequencySwitchedMapping

Starting from user's scientific input, determine all parameters necessary to perform Frequency Switched Mapping (total power) observations. Can be observed using a single map field or multiple fields.

Role(s)/Actor(s):
Primary: Observer
Secondary: Line Catalog, Source Catalog

Priority: Major

Performance: seconds.

Frequency:

Preconditions: Basic Course:

1. User specifies coordinate system, and 1..n source names and coordinates (either by absolute coordinates or offsets from a position specified by its absolute coordinates); note that these positions must be close together in the sky (separation less than ~5 degrees, exact value TBD)
   Alternate Course: User gives map center and its dimensions; system chooses absolute positions
2. System checks the declination.
   Exception Course: The source is not observable from the ALMA site.
3. User specifies the frequency switch rate and throw (frequency difference between "signal" measurement and "reference" measurement) for each IF band. Two symmetric reference measurements can be used for better baseline stability.
4. User specifies number of IF bands, Line names; the frequencies are obtained from the line catalog.
   Alternate Course: User enters line name and line frequencies
5. User specifies center velocities, velocity reference systems, velocity bandwidths, velocity resolutions
   Alternate Course: User specifies frequency bandwidths and resolutions.
6. System will allow the user to examine expected line transitions that could come from image sidebands and, as a result, tune the correlator (or receivers?) appropriately.
7. User specifies the performance goals: final rms.
   Alternate Course: User specifies the total integration time desired. In this case, he/she may specify the desired system temperature or maximum opacity, or may allow the system to determine these quantities (default).
8. The system evaluates the proposed setup and:
   1. suggests frequencies of amplitude calibration and of frequency switching rate
      Alternate Course: If requested, the system will choose the frequency of calibrations based on actual conditions at time of observation
   2. computes map cell size and number of pixels if user has requested a map
   3. computes the correlator setup explicitly from the spectral information. Warns the user if the spectral coverage is affected by Doppler effect variations.
   4. proposes splitting into SBs based on observatory policy (max SB length) ...
9. The User may either refine the input parameters, modify the deduced setup parameters, or accept the system provided values.

Issues to be Determined or Resolved ...

1. How can we help the user to determine what to use as the frequency switch rate and throw? Some possibilities include:
   1. Frequency switch throw decision based on knowledge of standing wave properties of ALMA antennas
   2. Frequency switch rate based on knowledge of stability of receiver phase lock

2. If the Compact Array becomes a reality, the user will need to specify the desired angular resolution, and the system will need to choose between the smaller compact array antennas and the 12m ones
3. How many antennas to use will be a scheduling issue (e.g., 12 antennas for 1 hour or 1 antenna for 12 hours?). If the atmospheric transmission at different antennas is uncorrelated, then there is a simple tradeoff between number of antennas used and integration time.
4. We should consider allowing the user to specify a rotated coordinate system, *e.g.*, to map an elongated object.

Notes: Coordinates may be also graphically determined from a user provided map or image.

Owner:Jeff Mangum
`Last modified by $Author: lucas $ on $Date: 2001/04/12 16:31:06 $`

Use Case: Perform Frequency Switched Mapping (Total Power)

Describe the actual observing actions needed to obtain data in the frequency switched mapping mode.

Role(s)/Actor(s)
Primary: The AOS
Secondary:

Priority Major

Performance real-time; overhead should be minimal and dominated by hardware.

Frequency: This mode is likely to be used less often than on-the-fly total power modes.

Preconditions: all the user parameters have been properly entered and checked (UC_SetupFrequencySwitchedMapping).

Basic Course

1. If necessary, the following initialization steps are executed (only once in the session).
    1. A subarray of antennas is assigned to this session
    2. Doppler effect is calculated for the target source and current time.
    3. The receivers are set up and tuned.
    4. The correlator is setup.
    5. The pipeline is started.
    6. If user has requested, current atmospheric conditions are used to set initial frequencies of amplitude calibration
2. For each Schedule Block (SB):
    1. Measure pointing and focus offsets on the pointing calibrator using the standard procedures.
    2. Update the pointing and focus corrections using feed back from the pipeline.
    3. Perform Temperature Scale Calibration
    4. For each target position:
        1. Record (auto) correlator output on the "signal" and "reference" frequencies while switching at the specified rate and throw. Integration time will be determined by a TBD algorithm whose objective is to arrive at the total integration time desired for this SB
        2. Every n minutes, perform a Temperature Scale Calibration measurement. The default value of n is calculated at run-time based on observing frequency, sky stability and opacity; the minimum integration time depends on the interval between Temperature Scale calibrations.
    5. Repeat last step until the SB time is exhausted or the goals are achieved (*e.g.*, minimum rms reached).
3. The system ensures that the last scan is a Temperature Scale Calibration measurement.
4. If the last SB has been executed, the pipeline is instructed to make the final spectra (and image, if a map was specified) and is closed.

Postconditions: Issues to be Determined or Resolved:

— The algorithm to decide when to do an amplitude calibration is to be defined.
  — This will depend on the observing frequency, and on parameters determined by other parts of the system, *i.e.*, sky stability and opacity
— The algorithm to determine the optimum frequency switch rate and throw is TBD. This will depend upon the final ALMA first LO design.
— Measuring the sideband gain ratios could be needed as an initialization step if both sidebands can be measured.

Notes:... **Owner:** Jeff Mangum
`Last modified by $Author: lucas $ on $Date: 2001/04/12 16:52:12 $`

4.8 Project Calibration

4.8.1 Temperature Scale Calibration

Use Case: Temperature Scale Calibration

This Use Case outlines the basic process of Temperature Scale Calibration with ALMA. It is executed within all scheduling blocks. Temperature scale calibration is the process of converting total power measurements from a receiver into system temperatures which have been corrected for the opacity due to the Earth's atmosphere. The system temperatures are used to convert observed correlation coefficients into antenna temperatures.

Role(s)/Actor(s):
Primary: Observer
Secondary: The Operator, the Staff Astronomer, the Reviewer

Priority: Critical

Performance: hours to months

Frequency: seconds

Preconditions:

1. The Alma System has reached at least partial operational state and accepts observing proposals from astronomers.

Basic Course:

1. Temperature Scale Calibration system operates continuously during all observations.
2. Control system measures total power or wide bandwidth autocorrelation signals and physical load temperatures from calibration loads in Temperature Scale Calibration system in synchronization with data acquisition.
3. Find tipping curves appropriate for data to be calibrated and derive zenith opacity at frequency of observation.
4. Calibration scale is derived from difference between calibration load total power measurements, physical load temperature difference, and opacity at current elevation.
5. Calculated calibration scale is stored in accessible area.
6. Derive autocorrelation system temperature versus frequency, used for data calibration and weighting in subsequent processing.

   Postconditions:

   1. Calculated calibration scale is available for application to data.

   Issues to be Determined or Resolved:

   — Exact design for Temperature Scale Calibration system. Could be switching load system located at the prime focus of the antenna or insertable load system located near the top of the receiver system.

   Notes:...

   Last modified: Mon Dec 11 00:25:00 UTC 2000 Jeff Mangum

4.8.2 Gain Calibration

Use Case: SetupGainCal

Starting from user's scientific input, determine all parameters necessary to perform the Gain Calibration in a standard Interferometric Observation. The Gain calibration is obtained by periodically observing a nearby point source.

Gain Calibration is needed for almost every interferometric observing mode. The Gain Calibration is obtained by periodically observing a nearby point source (gain calibrator), either at the same frequency as for the target observations, or at a lower frequency, for better sensitivity, in the case of high frequency target observations. In that case a strong source needs to be observed at both frequencies to calibrate the phase difference between both frequency bands.

Actual observations to perform Gain Calibration are described in UC_ObserveGainCal; the corresponding reduction operations are described in UC_ReduceGainCal.

Role(s)/Actor(s):
Primary: Observer
Secondary: Source Catalog, Array Configuration Catalog

Priority: Critical

Performance: seconds.

Frequency: setup is made for each observing program.

Preconditions:

1. Receiver and correlator setup have been specified
2. The main target source, or a list or nearby target sources have been specified, in SingleField, Mosaic or OnTheFly Mosaic modes

Basic Course:

1. User specifies the amplitude (in per cent) and phase accuracy (in degrees) needed. These numbers will be used at observing time to compute the on-calibrator integration time depending on achieved sensitivity.
2. User specifies the frequency for phase calibration. It may either be the same as that of the target observations, or a lower receiver band may be used. A frequency-dependent default policy may be proposed depending on the accuracies needed.
3. User specifies the number of gain calibrators, and for each one:
   1. whether it is aimed at amplitude or phase calibration
   2. if it is aimed at phase calibration, whether it is to be observed at the target frequency,at the calibration frequency, or at both.
4. User specifies the gain calibrator(s): the gain calibrators are either to be automatically chosen at observing time (in a preamble observation) or explicitely specified. The default is automatic selection.
   Exception Course: In the case of explicit selection, the calibrators are searched for in the calibrator data base; their position and (if known) fluxes in the last few months are read in.
   1. The calibrator directions are compared to that of the main target source. If further than (TBD: 10 ?) degrees, or if the time to move to/from them at full speed at any hour angle exceeds (TBD: 1 min?) a strong warning is issued.
   2. If the calibrator fluxes are unknown or lower than a TBD (frequency dependent) value, a strong warning is issued
5. User specifies the cycle time of gain calibration (i.e. the time between two successive observations of the same calibrator): this time is either to be automatically chosen at observing time (and revised as seeing conditions change) or explicitely specified. The default is automatic selection.
   Exception Course: In the case of explicit selection, a warning is issued if the cycle time is larger that a TBD (frequency dependent) value.

Exception Course: In the case of explicit answers above, this integration time is computed; a warning is issued if the resulting duty cycle exceeds a (TBD:20%?) value.

6. The user may either refine his/her input parameters, modify the deduced setup parameters, or accept the system provided values.

Issues to be Determined or Resolved ...

— The calibrator cannot be far away from the target source. This needs to be considered when setting distance-from-target limits for SBs.
— The limits to issue warnings will have to be determined and periodically reviewed (every deadline at first) as knowledge on the hardware and site weather conditions builds up.
— Those limits will depend on the (hopefully growing) confidence on the radiometric phase correction.

Notes:

— Usually the receiver and correlator setup is the same for the bandpass calibration and the target source; this may not be always the case, switching the correlator to broadband on the calibrator may improve sensitivity considerably.
— If zero calibrators are selected, this means that the user intends to perform fully self-calibrated observations. This may be considered as an expert-only option for the length of the interim science period.
— Example of choice of calibrator includes Flux density, S, distance from target source, theta, and cycle time, deltaT:
Minimize (deltaS/S)**2 + (height_turb*theta)**2 + (vel_turb*deltaT)**2
— Occasionally line sources at specific frequencies may be used as calibrators (masers).

Owner: Robert Lucas
`Last Modified by $Author: lucas $ on $Date: 2001/04/14 07:52:30 $`

Use Case: ObserveGainCal

Describe the actual observing actions needed to obtain data for Gain calibration of standard interferometric observations. There may be several calibrators, each one aimed to amplitude or phase calibration. Each will need to be observed with a given cycle time.

Role(s)/Actor(s)
Primary: The AOS
Secondary:

Priority: Critical

Performance real-time; overhead should be minimal and dominated by hardware.

Frequency: at least once per observing session

Preconditions:

1. All the user parameters have been properly entered and checked (UC_SetupGainCal)
2. Receivers and correlator are set up properly
3. The calibrator catalog is available.

Basic Course

1. **At preamble stage:**
    1. If no user-choice is provided for the **cycle times** (the default) compute them based on the current seeing conditions and phase structure function (for phase calibrators).
    2. If **the list of calibrators is known from setup** (UC_SetupGainCal.html) each one is observed at the required frequencies (calibration/target) to estimate its flux, using known Jy/K calibration factors.
        1. An integration time computed based on the accuracy goal and the measured flux. If an integration time was selected at setup, it may need to be increased.
        2. If the resulting integration time is too large (i.e. implying too large a duty cycle with either user-specified or most probable calibration cycle times), a better calibrator will be searched for as in (2) below.
    3. If **one or more calibrators are to be found:**
        1. A minimum flux is guessed for each based on the accuracy goals, current sensitivity, and allowed integration time (limited by duty cycle in current seeing conditions).
        2. About twice as many candidates as needed calibrators are selected in the calibrator catalog in a (TBD: 5 deg?) circle centered on the target direction. For this the strongest sources are chosen; if there are too few in the catalog, the circle is extended by steps to a maximum of (TBD: 15 deg?) radius.
        3. Each one is observed at the required frequencies (calibration/target) to estimate its flux, using known Jy/K calibration factors.
        4. The final choice is made on the basis of the observed fluxes, and the integration times updated as needed.
2. **In the observing loop, during SB execution**:
    1. Observe each calibrator at the requested frequencies for the determined integration time.
    2. Upgrade the cycle time value (if required) on the basis of the current seeing and phase structure function.
    3. Go back to target source observations for the requested or determined cycle time of that calibrator.

Issues to be Determined or Resolved:

1. Calibrator selection radii
2. What actions if no suitable calibrator can be found?

Notes:

1. Obviously for efficiency the cycle times need to be rounded to multiples of the same basic time.
2. Gain calibrators will also be used as pointing and focus calibrators to save observing time.

Owner: Robert Lucas.
`Last modified by $Author: lucas $ on $Date: 2001/04/14 07:58:13 $`

Use Case: ReduceGainCal

This Use Case describes the on-line data reduction operations for the interferometric Gain Calibration. This is needed for standard interferometric observations.

The description of User-specified input is in UC_SetupGainCal. Actual observations are described in UC_ObserveGainCal.

Role(s)/Actor(s)
Primary: The AOS, or the observer
Secondary:

Priority: Critical

Performance: Need to feed back data nearly in real time.

Frequency: After each Gain Calibration observation.

Preconditions: The user input parameters have been input and have been made available to the pipeline, preferably in the data headers

Basic Course:

1. The time-averaged frequency dependent measured amplitudes of the calibrator in the last observation are converted to Ta* scale using current Tsys as a function of frequency. The weighted frequency average across all bands is the final amplitude (Ta*).
2. The phase-corrected and uncorrected antenna-based amplitude values are compared. If the difference is statistically significant (thermal fluctuations), a validity flag for the phase correction is set or reset in an antenna-based way.
3. Antenna-based efficiencies are computed by comparing the antenna based TA* amplitudes and the flux measured in the preamble observations.
   Exception Course If these are significantly lower than the stored antenna efficiencies (K/Jy) at the relevant frequency, an error message is issued to the operator and logged.
4. If the calibrator is an amplitude calibrator, cubic spline is fitted into the last few amplitude measurements. The corresponding plot can be displayed. The fitted functions are available for further data processing (e.g. quick look display of interim science data).
5. Whatever the calibrator aim, a cubic spline is fitted into the last few phase measurements.
   1. The corresponding plot can be displayed.
   2. The fitted functions are available for further data processing (e.g. quick look display of interim science data).
   3. The residual phase rms are used to evaluate a seeing parameter and phase structure functions. These are made available to the corresponding Observing System session to update the calibration cycle times, and to the Dynamic Scheduler.

Issues to be Determined or Resolved:

1. How the Gain calibration is done in detail (antenna or baseline based, fitting polynomials or other functions ...) needs to be determined.
2. The parametrisation of the phase structure functions is TBD

Notes:

Owner: Robert Lucas.
`Last modified by $Author: lucas $ on $Date: 2001/04/14 08:01:45 $`

4.8.3 Interferometric Bandpass Calibration

Use Case: Setup Interferometric AstroBandpass Cal

Starting from user's scientific input, determine all parameters necessary to perform an interferometric Bandpass Calibration observation using an astronomical source. Observing a strong point source allows determination of the bandpass structure. The bandpass structure is necessary for the calibration of the data taken on the target source.

Role(s)/Actor(s):
Primary: Observer
Secondary: Line Catalog, Source Catalog, Array Configuration Catalog

Priority: Critical

Performance: seconds.

Frequency: at least once per receiver tuning

Preconditions:

1. Receiver and correlator setup has been specified

Basic Course:

1. User specifies the parameters of bandpass calibration: the calibrator is either to be chosen at observing time or explicitly specified
2. If bandpass calibrator is given explicitly, system checks that it has a featureless spectrum at the target observing frequency.
3. User specifies the goal in rms amplitude and phase across the band.
4. User specifies the performance goals: total integration time and/or final rms.
5. User specifies whether to record uncorrected or phase corrected data or both.
6. System checks for atmospheric lines and issues a warning if there are any in this band.
7. The User may either refine her/his input parameters, modify the deduced setup parameters, or accept the system provided values.

Postconditions:

1. A script describing the Bandpass Calibration observation has been created. This script will be part of a Pre- or Postamble Script or an SBScript.

Issues to be Determined or Resolved:

— Bandpass calibrator can be far away from the target source. This needs to be considered if there will be any "distance-from-target limits" for SBs.
— Details of how the bandpass calibration is actually performed (astronomical source only/part of it with noise diode) are not known yet.
— Bandpasses can "age" through Doppler tracking. This should trigger a re-calibration.

Notes:

— The spectral appearance of the bandpass calibrators has to be in the catalog.
— The tool should check that explicitly specified calibrators are visible.
— The signal-to-noise ratio of the bandpass calibrator should normally exceed the expected SNR of the target source significantly.
— Usually the receiver and correlator setup is the same for the bandpass calibration and the target source.

Owner: Dirk Muders

Last modified: January 22, 2001, D. Muders, P. Schilke

Use Case: Observe Interferometric AstroBandpass Cal

Describe the actual observing actions needed to obtain data in the interferometric Bandpass Calibration mode. For a detailed description of this Observing Mode refer to UC_Setup_Interferometric_AstroBandpassCal.

Role(s)/Actor(s)
Primary: The AOS
Secondary:

Priority: Critical

Performance: real-time; overhead should be minimal and dominated by hardware.

Frequency: at least once per observing session

Preconditions:

1. all the user parameters have been properly entered and checked (UC_Setup˙Interferometric˙AstroBandpassCal)
2. receiver and correlator units are set up properly
3. The target frequency and calibration frequency are defined as in UC_SetupGainCal.

Basic Course:

1. System checks water vapor content and calculates atmospheric lines. A warning is issued if the line contribution exceeds given limits.
2. Systems records uncorrected and/or phase corrected correlator output on the bandpass calibrator at the calibration frequency for a specified or calculated time. This calculation is based on the current phase rms or phase structure function (TBD).
3. System records correlator output on the bandpass calibrator at the target frequency for a specified or calculated time. This calculation is based on the current phase rms or phase structure function (TBD).

Postconditions:

1. Astro Bandpass data has been collected and archived.

Issues to be Determined or Resolved:

— What are the limits concerning atmospheric line contributions ?

Notes:

— Sometimes delay and bandpass can be determined from data taken for pointing or focus.

Owner: Dirk Muders
`Last modified by $Author: lucas $ on $Date: 2001/04/14 08:18:47 $`

Use Case: Reduce Interferometric AstroBandpass Cal

This Use Case describes the on-line data reduction operations for the interferometric Bandpass Calibration mode. For a detailed description of this Observing Mode refer to UC_Setup_Interferometric_AstroBandpassCal

Role(s)/Actor(s):
Primary: The AOS, or the observer
Secondary:

Priority: Critical

Performance: may need to feed back data nearly in real time.

Frequency: After each Bandpass Calibration observation.

Preconditions: The user input parameters have been input and have been made available to the pipeline, preferably in the data headers

Basic Course:

1. Calculate bandpass by fitting polynomial (or other functions) through antenna based/baseline based data points, both in phase and amplitude.

Postconditions:

Issues to be Determined or Resolved:

How the bandpass calibration is done in detail (antenna or baseline based, fitting polynomials or other functions or not fitting anything at all) needs to be determined.

Does one need direct feedback from the pipeline to the AOS or the observing program ?

Notes:

— Sometimes delay and bandpass can be determined from data taken for pointing or focus.
Presumably the digital IF bandpass should be stable and well defined and only a relatively smooth RF bandpass needs to be determined astronomically.

Owner: Dirk Muders

Last modified: January 22, 2001, D. Muders, P. Schilke

4.8.4 Flux Scale Calibration

Use Case: Flux Calibration

This Use Case outlines the basic process of Flux Scale Calibration with ALMA. Flux scale calibration is the process of converting total power measurements which have been calibrated to an antenna temperature scale (see the TemperatureScaleCalibration use case) to an absolute flux scale. This is done through comparison with one or more standard flux calibration sources to derive the Jy/K conversion factor. This conversion factor is a function of frequency and time.

Role(s)/Actor(s):
Primary: Observer
Secondary: The Operator, the Staff Astronomer, the Reviewer

Priority: Critical

Performance: hours to months

Frequency: seconds

Preconditions:

1. The Alma System has reached at least partial operational state and accepts observing proposals from astronomers.

Basic Course:

1. Temperature Scale Calibration must have been completed.
2. The monitor data system must be operational and storing flux calibration measurements.
3. Flux calibration scale is derived from either:
   — Measurements of a standard flux calibration source during the observing program, or
   — Flux calibrator measurements made during the past several days.

   Postconditions:

   1. Calculated flux calibration scale is available for application to data.

   Issues to be Determined or Resolved:

   — Determination of standard flux scale calibrators requires examination early in the operation of ALMA. Studies of how accurately the absolute fluxes of planets, asteroids, stars, and other potential flux calibration sources need to be made.

   Notes:...

   Last modified: Mon Dec 15 00:25:00 UTC 2000 Jeff Mangum

4.8.5 Delay Calibration

Use Case: SetupDelayCal

Starting from user's scientific input, determine all parameters necessary to perform an Interferometric Delay Offset Calibration using an astronomical source. Delay calibration makes sure no sensitivity is lost in interferometric continuum observations, in particular for the phase calibration. Residual small delay errors are nevertheless compensated by RF passband calibration.

There is one delay offset for each antenna, frequency band, and baseband.

The observing actions to perform an Interferometric Delay Offset Calibration are described in UC_ObserveDelayCal. The corresponding data processing operations are described in UC_ReduceDelayCal.

Role(s)/Actor(s):
Primary: Staff Astronomer or Operator
Secondary:

Priority: Critical

Performance: seconds

Frequency: at least once per receiver tuning

Preconditions:

1. Receiver and correlator setup have been specified

BasicCourse:

1. User specifies the precision in nanoseconds of delay for the calibration; the calibrator source itself will be chosen at observing time
2. User specifies the range in nanoseconds of delay to be searched.
3. System prepares the correlator setup (bandwidths and resolutions)

Issues to be Determined or Resolved

1. One should (ideally!) be able to separate the delay offsets into:
   1. one stable component (the same for all frequency bands),
   2. one stable component depending on the frequency band,
   3. one variable (frequency band independent) component with small time variations, due to changes in the electrical (or optical) length of the IF transmission system.

   For each setup one would only need to update that third component by observing at the calibration frequency. The relative delays of the various frequency bands would need to be measured on strong sources from time to time. The first component would only need to be measured on antenna moves and other hardware modifications.
2. Calibrator can be far away from the target source. This has no impact on scheduling if we assume that a strong enough calibrator will always be available in the sky.

Notes:

1. The correlator setup need not be the same as for the for the target source.
2. Quite often a specific setup will not be needed; the delay will be easily determined from a pointing or a focus measurement.
3. One should not change the delay offsets during an Observing Session as a phase discontinuity would be produced.

Owner: Robert Lucas
`Last Modified by $Author on $Date: 2001/05/03 13:56:11 $`

Use Case: ObserveDelayCal

Describe the actual observing actions needed to calibrate the delay offsets.

Role(s)/Actor(s)
Primary: The AOS
Secondary:

Priority: Critical

Performance: real-time; overhead should be minimal and dominated by hardware.

Frequency: at least once per observing session

Preconditions:

1. receiver and correlator are set up properly (UC SetupDelayCal)
2. Baseline is known with relatively good accuracy; large errors (1cm) produce small, time varying delay errors.

Basic Course:

1. Compute the minimum flux needed to get to the desired precision in each of the frequency bands to be used (target and calibration), by assuming a TBD integration time (~ 60 sec ?)
2. Find the closest calibrator that meets the minimum flux requirement. If none, increase the integration time.
3. Record correlator output on that calibrator in both target and calibration frequency bands for the specified time.

Postconditions:

1. Data is available to compute the delay offsets

Issues to be Determined or Resolved:

— What is the acceptable integration time range.
— What should be done at high frequencies, if no suitable calibrator is available

Notes:

— The delay precision needed to limit the losses to 1 percent in a 2~GHz band is about 0.03 nanoseconds.
— The delay precision will be improved by repeating the measurement, particularly if the delay error was large.

Owner: Robert Lucas
`Last modified by $Author: lucas $ on $Date: 2001/04/14 08:26:08 $`

Use Case: ReduceDelayCal

This Use Case describes the on-line data reduction operations for the Interferometric Delay offset Calibration scans.

Role(s)/Actor(s):
Primary: The Calibration Pipeline.
Secondary:

Priority: Critical

Performance: need to feed back calibration data nearly in real time.

Frequency: After each delay offset calibration, at least once per observing session.

Preconditions: The raw data of the delay measurement raw data is available to the (calibration) pipeline.

Basic Course:

1. Fit an antenna based, linear dependency of phase versus frequency in each spectrum, taking into account two-pi phase ambiguities.
2. Display the results
3. Make the calibration data (one delay offset for each antenna, baseband and frequency band) available to the observing process.

Postconditions:

1. The delay offsets are used in the correlator for further data taking.

Issues to be Determined or Resolved:

—

Notes:

—

$Id: ReduceDelayCal.html,v 1.2 2001/01/17 17:07:43 lucas Exp lucas $

4.8.6 Polarization Calibration

Use Case: DetermineAntennaPolarization

This pipeline task uses data taken in full polarization mode (with cross-hand products) in quasi-real time, in an automatic way, to determine the instrumental antenna polarizations for a particular band setup. Data is taken from the raw data archive and an antenna polarization "object" is written to the calibration archive.

Role(s)/Actor(s)
Primary: AOS, ALMA Archive System
Secondary: Operator, Staff Astronomer, Observer

Priority: Major

Performance: seconds

Frequency: minutes to hours

Preconditions:

1. correlator data for a potential calibration run is available. It is assumed that the calibration observations themselves were scheduled and carried out as a full-polarization standard observation of an appropriate source with sufficient parallactic angle coverage (see UC: ObserveFullPolarization)
2. either programme dependent or standard system scripts are available for pipeline reduction - in particular system standard scripts might be preferred to ensure conformity of results, however for alternate methods of polarization calibration user-supplied scripts might be preferred

Basic Course: Calibrator of known or unknown polarization is observed for either a single snapshot or over a range of parallactic angle

1. the ALMA Archive system or the AOS initiates pipeline when the observations for a potential polarization calibration are available
2. the script produces a solution for the cross-polarization leakage terms (D-terms) and estimates of robustness, perhaps in comparison to previous solutions in addition to internal error estimates

   Basic Primary Course: Calibrator of known or unknown polarization observed sufficiently over range of parallactic angle to separate instrumental and source polarization

   1. Instrumental D-terms (Jones matrix) can be determined from data with known polarization, up to an arbitrary single D-term over the whole array.
   2. instrumental D-terms (Jones matrix) can be determined from data with unknown polarization, up to a single D-term and arbitrary phase (eg. R-L phase difference for circular, orientation on-sky for parallel linear). This phase can be determined by single scan on source of known polarization (Basic Secondary Course below).

   Basic Secondary Course: Calibrator of known polarization observed for single snapshot at arbitrary parallactic angle

   1. instrumental D-terms can be determined up to an overall distortion corresponding to an overall single unknown matrix, plus and arbitrary phase (eg. R-L phase difference for circular, orientation on-sky for parallel linear).

   Basic Tertiary Course: unpolarized calibrator observed for single snapshot at arbitrary parallactic angle

   1. instrumental D-terms can be determined up to an overall distortion corresponding to an overall single unknown matrix, plus and arbitrary phase (eg. R-L phase difference for circular, orientation on-sky for parallel linear). A snapshot of a source of known polarization (Basic Secondary course) needed to establish this unknown phase.

Exception Course: The script fails to obtain a valid solution (eg. due to insufficent parallactic angle coverage or non-convergence)

1. notification is given to the operator
2. the calibration schedule is resubmitted to the dynamic queue for execution

Alternate Course: on-line execution

1. operator or observer instigates calibration run and expects pipeline to take care of the analysis
2. the pipeline normally executes script commands when complete calibration data is available in archive These commands retrieve data for the raw data archive, manipulate data, optionally display results, store results in calibration archive.

Exception Course: the operator is notified if the script fails

1. the pipeline makes results available to the AOS.
2. the pipeline makes quality check results available to the scheduler.

Alternate Course: off-line execution

1. the operator, observer, or staff scientist initiates the pipeline off line, perhaps with a modified script
2. this behaves in all other ways as the basic course

Postconditions:

1. Parameters are fed back to either the AOS or the Scheduler, and results are written to the Calibration Archive
2. Science data (images) produced as a by-product of the calibration (or perhaps the calibration a by-product of the science observing) are written into the Science Archive
3. Data reduction scripts and logs are written into the Science Archive

Issues to be Determined or Resolved:

1. I am assuming that the physical receiver hardware consists of some sort of ortho-mode transducer to separate out the orthogonal polarizations plus a fixed quarter-wave plate if circular polarization mode is desired (unnecessary if linear), or a quasi-optical device such as a grid diplexer which will send one linear polarization to a different path. Some other scheme with a single rotating grid would complicate things.
2. The possible use of a calibration tone to determine the receiver plus receiver optics polarization would be a separate UC, as it would then be similar to the use of a secondary load or signal for amplitude calibration. This would presumably be applied in quasi-real time (at least as frequently as once per run).
3. In the current optical design, there is significant polarization aberration (squint of ~4%), and the polarization properties will likely vary over the primary beam. I do not know how to deal with this easily, though perhaps the holography measurements of the beam will produce the necessary numbers. See also (9) below.
4. I presume that there is some sort of schedule flag or tag that indicates that a particular observation is intended as or is suitable for determining polarization calibration. This will alert the Archive control to instigate this process. It may be that the operator or staff scientist flags a particular science observation as suitable even though the observer did not indicate it thus. For longer observing programs the observer will likely supply their own calibrator observations, while snapshots will likely rely on cal-transfer for other (possibly system) programs.
5. How do we envision the calibration processes working together (eg. baselines, flux, bandpass, polarization)? In particular the phase calibration and polarization calibration are related by the XY or RL phase difference. In spectral line mode there are probably polarization considerations in the bandpass calibration.
6. There must be a mechanism to notify the Archive Control that a calibration parameter has been updated and needs to be propagated through the Science Archive

7. Where in the data structure does the antenna polarization go? In AIPS this is stored in the Antenna (AN) Table. In aips++ this is stored in a table as part of the measurement set in a Jones matrix form.
8. Is the Archive System the controller of calibration operations? For example, on failure should it resubmit the schedule to the queue, or just notify a human?
9. Just what are the limitations of the various polarization calibration schemes? I guess the papers by Sault, Hamaker et al. are a good place to start (see Notes below). Another question is what parts of polarization calibration must be deferred to the imaging (pipeline) itself, such as the application of wide-field polarization calibration of the primary beam?
10. So far I have only really considered continuum polarization issues. Are there modifications needed for spectral line (eg. Zeeman) polarization observations?

Notes:

— I am assuming that the calibration observations themselves are scheduled and carried out as a full-polarization standard observation of an appropriate source. Suitable parallactic angle coverage must be ensured. I do not see that there need to be a special UC for these observations - in fact for most non-snapshot programs the phase calibrator will serve as a reasonable polarization calibrator.

— Polarization calibration is an example of a "state" calibration where some parameter describing the system is relatively time-independent (assuming no physical changes are made to the array) and thus a global storage of these parameters is effective and can be shared among many observations using the same band setup

— I am assuming that there is a Calibration Archive where the results of the various calibrations (baseline,polarization, bandpass,flux) are stored for access by the on-line system and the pipeline

— The papers by Sault, Hamaker and others are good references for the subtleties of polarization observations and calibration. In particular: Sault, Hamaker & Bregman (1996) A & ASup 117, 149-159; Hamaker (2000) A & ASup 143, 515-534.

There seem to be three main optical geometries:

1. circular - two orthogonal circular poln. R and L each antenna
2. parallel linear - two orthogonal linear poln. V and H oriented the same on all antennas
3. crossed linear - two orthogonal linear poln. V and H oriented at 45 deg w.r.t. half of the antennas

The differences between these cases are mostly in implementation, and we dont really know what ALMA will have yet! There is a claim that a hetergeneous configuration like (3) breaks the degeneracies and thus a simple intensity alignment will determine all parameters. I think WSRT uses some such scheme and it might be useful to look into what they do.

— There seem to be three modes for calibration using celestial sources:

1. a single scan of an unpolarized source
2. a single scan of a source of known polarization
3. several scans spread in parallactic angle of a source of known or unknown polarization

plus obvious combinations, eg. (1+2), (3+2), and multiple sources (n x 2).

Hamaker (2000) splits the polarization errors into a "polrotation" and "poldistortion" (matrices), with the main difference being that the poldistortion couples I into the QUV while the polrotation is a rotation of QUV. It seems that an intensity calibration (a) removes the poldistortion, some assumptions about the instrument can fix 2 of the 3 DOF of the polrotation, and an observation of a polarized source of known polarization can fix the remaining XY or RL phase difference. Thus the combination (1+2) seems to be a good way to calibrate.

If there is no suitable unpolarized calibrator available (as in high-frequency VLBI), then option (n x 2) or (3 + 2) is the way to go.

Owner: Steve Myers.
`Last modified by $Author: lucas $ on $Date: 2001/04/14 08:31:01 $`

Use Case: ObserveFullPolarization

Observations with ALMA in full-polarization mode (a single band and/or sideband with orthogonally polarized IFs at same sky frequency, with correlation of all four cross-products).

Role(s)/Actor(s)
Primary: AOS
Secondary: Operator, Observer

Priority: Major

Performance: real-time; overhead should be minimal and dominated by hardware

Frequency: this observing mode is not likely to be the most-often used (single or dual polarization may be sufficient for most programs), but will be used some non-vanishing (~10-20%?) fraction of the time and thus must be supported

Preconditions:

1. the observation requested requires full-polarization with dual polarization IFs from a single coincident sideband and four polarization cross-products at correlation in interferometer mode - single and dual polarization interferometry (ObserveSinglePolarization, ObserveDualPolarization) and total power observations are not supported by this Use Case. See the Note(3) below
2. all the user parameters have been properly entered and checked (SetupSingleField, SetupMultipleField)
3. the observer has selected a Polarization Calibration Mode for this program/project/session:
    1. Session requires pre-existing valid calibration object. Some mechanism must be provided for to ensure that a calibration is available before exection of the observation - see IssuesTBD(1) below.
    2. This observation is independently calibratable if no valid calibration available. For example, it may contain a single scan on an unpolarized source or source of known calibration and this is deemed sufficient for the purposes of calibration of this session for the science goals.
    3. This observation is intended as a primary polarization calibration itself. It should then be flagged as such and the pipeline results (DetermineAntennaPolarization) fed into the Calibration Archive. correlator data for a target experiment is available, taken in full (cross-hand) polarization mode

Basic Course:

1. The preamble block is executed (only once in the session). This will set up system parameters (eg. Doppler correction, receiver setup, correlator setup) and is mostly identical to that found in the single or dual polarization case (UC-ObserveSingleField, UC-ObserveMultipleField, etc.)
   The choice of dual polarization for IFs from the receiver and full cross-products (x4) in the correlation MUST be chosen.
2. For each scheduled OB, the standard single or multiple field procedure is carried out (eg. UC-ObserveSingleField, UC-ObserveMultipleField).
   Polarization specific tasks might include, but are not exclusive to, observation of a scan on an unpolarized source or source of known polarization, use of an injected test tone signal (if available), hardware interchange of pathways for the polarizations (unlikely to be available). The default procedure is the same as per the non-polarization mode.
3. The system executes the associated postamble OB: the phase calibrator is reobserved one last time if necessary. The pipeline is instructed to make the final image (if requested) and is closed. this task is meant to be carried out by the pipeline as part of an overall reduction sequence and is unlikely to be carried out on its own

Exception Course: preconditions are not met, or the observation must be aborted

1. The observer has requested calibration using pre-determined antenna polarization solutions, and there is no existing valid (ie. same band, sufficient number of antennas) solution in the Calibration Archive. In this case, the observation should be deferred until calibration is available, and the calibration observations themselves should be scheduled at high priority.

2. Abortion of the observing should occur if: weather degrades below the requested quality threshold; array failure occurs that exceeds a tolerance threshold; observations at interrupt priority are inserted into the array queue

Postconditions:

1. The pipeline will reduce the data taken in this mode using the standard procedures (ReduceSingleField, ReduceMultipleFields) with the appropriate application of the polarization calibration (ApplyPolarization-Calibration)

Issues to be Determined or Resolved:

1. How is the requirement that a pre-existing antenna polarization calibration at an observing band implemented?
   One possibility is that when scheduling for the first session for this observation is attempted, the precondition causes failure for this schedule, but a high-priority calibration schedule is inserted in the queue, with the target schedule slated for subsequent observation at high priority.
   Another possibility would be to have a "global schedule model" that is constructed on a weekly to monthly timescale that would include the observation of calibrations that are necessary for the observation of sessions that are forecasted for this period. My guess is that this is the most promising way to work at high efficiency.
2. Can polarization sensitive observations (eg. calibrations on a source for 1 minute every 15 minutes during transit) be "virally" inserted into another session in order to carry out system calibration? Or should dedicated calibration runs be carried out at somewhat lower efficiency but with the advantage of having a more standard composition and less of an impact on the "host" session?
3. What is the break-point in quality where a secondary polarization calibration within the session (ie. a single scan on an unpolarized source or calibrator of known polarization) will be sufficient?
4. What are the tolerances on the validity of previous polarization calibrations for applicability to observations? In particular, is it required only that a continuum calibration at band center be valid for some number of antennas, with the assumption that corrections can be made to line mode and/or the actual observing frequency and bootstrapped to those small number of antennas modified since the last full calibration?

Notes:

— Precision polarization observations at millimeter wavelengths, especially at submillimeter wavelengths, are largely uncharted territory. See the discussion by Crutcher et al. in the report of the September 2000 ASAC meeting

http://www.cv.nrao.edu/~awootten/mmaimcal/asac/asacsep00/

for details of the goals for ALMA polarization observations.

— I am writing this Use Case as an "addendum" to the standard SingleField and MultipleField Use Cases rather than splitting it out as a stand-alone UC (eg. ObserveSingleFieldFullPolarization). I think this is the best approach given that there are only a small number of important differences between the polarization modes. This also preserves the commonality of these modes. Are people happy with this?
— See related UC: ObserveSinglePolarization, ObserveDualPolarization, ObserveSinglePolarizationTotalPower, ObserveDualPolarizationTotalPower. Should these be absorbed into this UC as alternate courses?
— Note also that depending upon the polarization optics (eg. circular, parallel linear, or crossed linear) there may be some similar calibration issues for Single and Dual polarization modes. These will be dealt with in those specific Use Cases.
— The papers by Sault, Hamaker and others are good references for the subtleties of polarization observations and calibration. In particular: Sault, Hamaker & Bregman (1996) A & A Sup 117, 149-159; Hamaker (2000) A & A Sup 143, 515-534. There seem to be three main optical geometries:
  — a. circular - two orthogonal circualr poln. R and L each antenna
  — parallel linear - two orthogonal linear poln. V and H oriented the same on all antennas
  — crossed linear - two orthogonal linear poln. V and H oriented at 45 deg w.r.t. half of the antennas

The differences between these cases are mostly in implementation, and we dont really know what ALMA will have yet!

Created: 2000/10/10 smyers
Last Modified: 2000/10/10 smyers

Use Case: ApplyPolarizationCalibration

This pipeline task calibrates data taken in full polarization mode (with cross-hand products) in quasi-real time, in an automatic way, taking input data from the raw data archive, using antenna polarization objects from calibration archive.

Role(s)/Actor(s)
Primary: ALMA Archive System
Secondary: AOS, Operator, Staff Astronomer, Observer

Priority: Major

Performance: seconds

Frequency: minutes to hours

Preconditions:

1. correlator data for a target experiment is available, taken in full (cross-hand) polarization mode
2. valid polarization calibration objects are available in the Calibration Archive

Basic Course:

1. this task is meant to be carried out by the pipeline as part of an overall reduction sequence and is unlikely to be carried out on its own
2. the antenna polarization calibration parameters are retrieved from the Calibration Archive and applied to the data, likely in the form of a calibration table attached to the dataset Calibrator of known or unknown polarization observed sufficiently over range of parallactic angle to separate instrumental and source polarization

Exception Course:

1. the archive system notifies the appropriate contact about the failure, and possibly a suitable calibration schedule is generated for the dynamic queue
2. processing of this data may be deferred if deemed critical

Postconditions:

1. the calibration is applied in the form of a table attached to the data
2. logs are written into the Science Archive

Issues to be Determined or Resolved:

1. Will calibration be carried out by the attachment of a table to the data?
2. What are the criteria for acceptable calibration data - namely how close bracketed need the observation be (eg. within 7 days, 14 days, 30 days, 60 days), need all antennas have updated calibration (after a recent refit or move)? What is the appropriate action on missing calibration?
3. What feedback mechanisms are there for identifying possible calibration problems (eg. poor polarization images) which might warrant investigation or recalibration?

Notes:

— I am assuming that this UC is carried out as part of a higher-level calibration UC.
— Only calibration suitable for a priori corrections can be applied in this manner - for example the polarized primary beam corrections for extended sources must be done as part of the imaging process. This limits the application of this Use Case to the polarization correction at the center of the beam.

Created: 2000/10/10 smyers
Last Modified: 2000/10/17 smyers

4.8.7 Pointing Calibration

Use Case: SetupPointingCalibration

The User describes a Pointing Calibration so that it can be executed by the system. This is usually done in Phase II proposal preparation using the Observing Tool (OT).

A pointing calibration measurement can be done in one of four pointing modes:

1. Interferometric
2. Auto-correlation (with or without nutator)
3. Total Power with nutator
4. Optical

Nearly all pointing measurements will be made in interferometric mode. The others are mainly used for special cases (phases too unstable, hardware problems). A pointing calibration observation produces an estimated azimuth and elevation offset for each antenna. The interferometric, auto-correlation, and total power observations measure the radio offsets in a single band, while the optical observations measure the optical offsets. These measurements are commonly done conditionally in a Preamble Block and are repeated at regular intervals to compensate for pointing drifts with temperature and time.

See also UC_ObservePointingCalibration.

Role(s)/Actor(s):
Primary: The User (Observer, Staff Scientist, Array Operator), the Observing Tool.
Secondary: Line Catalog, Source Catalog

Priority: Major

Performance: Interactive.

Frequency: Many per hour.

Preconditions: The observing program being prepared has a sub-array consisting of at least:

— Interferometric mode: two antennas (preferably three)
— Auto-correlation mode: one antenna
— Total power mode: one antenna with nutator
— Optical pointing: one antenna with optical telescope

Basic Course:

1. Using the ObservingTool (OT), the User specifies the pointing calibration mode to use for the pointing calibration measurement.
2. If auto-correlation mode is selected, the User specifies the band, the correlator setup, and the frequency range over which to integrate the auto-spectra.
3. The User specifies one of the following intended applications of the pointing calibration:
   — Offset pointing for a specified source at a specified frequency, with one of the following science goals:
      1. Detection in a single or multiple independent fields.
      2. Imaging of single or multiple independent fields.
      3. Detection within a mosaic.
      4. Imaging of a mosaic.
   — Measurement for a pointing calibration session on a specified source, with a goal of measuring:
      1. General radio beam offsets.
      2. Band specific offsets at a specified frequency.
4. The OT automatically specifies the details of the pointing calibration measurement based on the mode and intended use. The details include:
   — Pointing source

- Correlator setup
- Frequency band of pointing calibration measurement
- If interferometric mode, frequencies over which to integrate to achieve maximum sensitivity (e.g. wide continuum bandwidths, or maser lines).
- Desired accuracy of measurement (arc seconds on the sky)
- One of the following pointing calibration patterns:
  - Circular pattern
  - Five point
  - Four point
  - Three point
- Realtime correction of the radio beam pointing offsets:
  - Based on current measurement
  - Based on average over specified time period
  - No realtime correction, just measure and record results
- Maximum amount of time to spend trying to reach goals: this is used in case the required accuracy cannot be reached (the accuracy will be in some cases atmosphere-limited).
- Other details of the pointing algorithm (TBD).

Alternate Course: User specifies the details.

5. User optionally edits the details automatically selected by the OT. The OT will aid with source selection by sorting sources by radio flux in the desired band or optical magnitude, and distance from program source.

Postconditions:
A set of Observation Descriptors and a pipeline data reduction script.

Issues to be Determined or Resolved

- There may be other criteria for prematurely stopping the pointing calibration measurement other than achieving the requested accuracy, e.g. if overall sensitivity loss from pointing errors is less than a fixed amount.
- Other details of the pointing calibration algorithm, starting with ALMA Memo 189 (Lucas).

Notes: Pointing calibration measurements are used to:

- Measure antenna pointing offsets of individual bands (including the optical telescope) with respect to the mount bore sight.
- Dynamically measure the general *radio beam offset*, an offset with respect to the mount bore sight in common to all radio bands that can vary with time. If the radio beam offset is measured and corrected, accurate radio pointing can be used for program source observations. This measurement may be done in a band that is different from the program source observations, and is referred to as *reference pointing*. Reference pointing allows pointing to be done in bands where sources are stronger and the atmosphere is more transparent, but does rely on accurate and stable pointing offsets for the bands with respect to the radio beam.

Owner: Steve Scott
`Last modified by $Author: lucas $ on $Date: 2001/05/03 14:09:40 $`

Use Case: ObservePointingCalibration

The observing actions required for a Pointing Calibration measurement. This calibration mode is described in detail in the UC_SetupPointingCalibration.

The observing cycle is flexible and will continue until the specified goals are attained or until a "do not exceed" time is reached. In the case where time expires before all goals are reached, results are still produced. Any result produced will ***always*** contain an error estimate. All reduction is done using the Calibration Pipeline.

Role(s)/Actor(s):
Primary: The AOS, the Calibration Pipeline
Secondary:

Priority: Major

Performance: Realtime feedback of pointing offsets into the system.

Frequency: Usually once per Preamble Block, and at regular intervals to follow pointing drifts.

Preconditions: AOS has access to a sub-array consisting of at least:

— Interferometric mode: two antennas (preferably three)
— Auto-correlation mode: one antenna
— Total power mode: one antenna with nutator
— Optical pointing: one antenna with optical telescope

User has specified the setup as part of UC_SetupPointingCalibration. which has produced the necessary Observation Descriptors and pipeline data reduction scripts.

Basic Course:

1. Using the Observation Descriptors, the correlator is set up and the receiver band is selected and set up, including band specific pointing offsets.
   Alternate Course: The optical telescope is set up (lens cap removed, etc).
2. Using the Observation Descriptors, pointing calibration measurements are taken and fed to the pipeline.
3. While observations continue, the pipeline separately reduces the data sets containing the phase corrected data and the uncorrected data. Estimates of pointing offsets and errors are produced on both data sets, and the one with the smallest errors is selected for use.
4. If intermediate results indicate that an antenna has large offsets with statistically significant errors, its pointing is corrected so that the measurements are improved by:
   1. Increasing the signal to noise
   2. Reducing systematic errors based on assumptions of the beam shape
5. Observing and reduction continue, looping back to Step 2 until the desired accuracy limit is reached on all antennas. If the pointing on the antenna is not converging, it will not be required to reach the requested accuracy limit.
   Alternate Course: The pointing calibration is terminated because the maximum allotted time has been reached.
   Alternate Course: The pointing calibration is interactively terminated.
6. The accumulated pointing calibration results are archived.
7. The radio beam pointing offsets for all antennas that have achieved the requested accuracy are updated based on the policy selected in the setup:
   1. Use current measurement
   2. Use average over specified time period
   3. No realtime correction, just measure and record results

Postconditions:
A pointing calibration measurement is written to the archive. The measurement contains:

— Azimuth and elevation offsets
— Estimated error in the measured azimuth and elevation offsets
— Azimuth and elevation of measurement
— Frequency of measurement
— Source name
— Time of measurement

The radio beam offsets have optionally been updated.

Issues to be Determined or Resolved
Other details of the pointing calibration algorithm, starting with ALMA Memo 189 (Lucas).

Notes: None at this time.

Owner: Steve Scott

Last modified: 2001/01/22 Steve Scott

4.9 Array Calibration

4.9.1 Baseline Calibration

Use Case: Setup Baseline Cal

Starting from user's input, determine all parameters necessary to perform an interferometric Baseline Calibration observation. A Baseline Calibration is performed to determine the positions of the antennas of a Sub-Array. The calibration session consists of observing a number of point sources with the given Sub-Array. It is important to move the antennas to different azimuth / elevation regions as fast as possible in order to resolve baseline components.

Role(s)/Actor(s):
Primary: Staff Astronomer
Secondary: Line Catalog, Basline Calibration Point Source Catalog(s), Array Configuration Catalog

Priority: Critical

Performance: One to a few hours

Frequency: After moving one or more antennas; maybe more often, and after earthquakes or volcanic eruptions.

Preconditions:

1. If part of the array has been reconfigured, one must have access to a sub-array that consists of the newly moved antennas and at least one (better: a few) antenna(s) of known position. In case of complete reconfiguration (also after earthquakes or volcanic eruptions) one antenna has to be defined as reference antenna.
2. Defaults for frequency and correlator setup is defined.
3. Default performance goals (integration time per source/final rms) are defined.
4. User selects whether to record uncorrected data, phase corrected data or both.

Basic Course:

1. User specifies which Baseline Calibration point source catalog to be used.
2. User specifies required accuracy of antenna positions.
3. System loads default frequency and correlator setup for baseline calibrations (TBD by SSR).
4. Optionally: User modifies observing frequency.

Postconditions:

1. One or more SBs describing the Baseline Calibration session have been created.

Issues to be Determined or Resolved:

> If ALMA is a traveling array (i.e. an array constanly being reconfigured) it may not make sense to perform a baseline calibration every time one or some antennas are moved. One can even observe with antennas, and apply the baseline correction later. This requires a good book-keeping, and would result in these antennas being flagged for the online pipeline reduction, but available for the final image. The frequency of baseline calibrations depends on the details of the array reconfiguration process, which is not determined yet.

Notes:

Owner: Dirk Muders

Last modified: January 22, 2001, D. Muders, P. Schilke

Use Case: Observe Baseline Cal

Describe the actual observing actions needed to obtain data in the interferometric Baseline Calibration mode. For a detailed description of this Observing Mode refer to UC_SetupBaselineCal.

Role(s)/Actor(s)
Primary: The AOS
Secondary: the Calibration Pipeline

Priority: Critical

Performance: real-time; overhead should be minimal and dominated by hardware.

Frequency: After moving one or more antennas; maybe more often, and after earthquakes.

Preconditions:

1. all the user parameters have been properly entered and checked (UC_SetupBaselineCal)
2. A pointing session has been performed on the antennas for which the baseline has to be updated.

Basic Course:

1. The receivers are set up and tuned.
2. The correlator is setup.
3. The pipeline is started.
4. The system selects sources from the baseline calibrator catalog for a homogeneous sky distribution for the current LST.
5. The system calculates the optimum sequence in which to observe the sources.
6. The system records the uncorrected and/or phase corrected cross correlator output at the observing frequency for each source in the sequence for a specified or calculated time. This calculation is based on current phase rms or phase structure function (TBD).
7. The pipeline is instructed to calculate the final solution and is closed.

Postconditions:

1. Baseline session data has been collected.

Issues to be Determined or Resolved:

— Would it be an option to measure antenna positions via GPS instead of a baseline calibration session ? Answer: GPS resolution is about 3 times worse than using astronomical determination but it might help to have initial estimates. NB: For the determination of the position of the SMT for a VLBI experiment the GPS antenna was located behind the subreflector.
— Any surveying method to resolve 2PI ambiguity will help and should be used. Once 2PI ambiguity is resolved, baseline accuracy is just a matter of more measurements.

Notes:

— Optimum sequence means moving the antennas to different regions in azimuth / elevation as fast as possible in order to resolve baseline components.
— Baseline calibrations should be done under very good atmospheric conditions.
— This mode should only be accessible in interactive technical sessions and should not have a time limit.
— The pipeline should be notified that all data (if any) taken with those antennas between the last move and the new baseline determination should be reprocessed.

Owner: Dirk Muders
`Last modified by $Author on $Date:  2001/04/14 09:01:37 $`

Use Case: Reduce Baseline Cal

This Use Case describes the on-line data reduction operations for the interferometric Baseline Calibration mode. For a detailed description of this Observing Mode refer to UC_SetupBandpassCal

Role(s)/Actor(s):
Primary: The AOS, or the observer
Secondary:

Priority: Critical

Performance: A few seconds to minutes.

Frequency: After moving one or more antennas; maybe more often, and after earthquakes.

Preconditions The user input parameters have been input and have been made available to the pipeline, preferably in the data headers

Basic Course

1. Baseline solutions for all antennas relative to reference antenna(s) are computed.

Postconditions:

1. The Sub-Array antenna positions have been determined.

Issues to be Determined or Resolved:

Notes:

— The data reduction is performed after all (today typically 10-20, with ALMA maybe up to 100) baseline calibration point sources have been observed. There is no need for immediate feedback while observing.
— Nominal positions of antennas as known from station survey or historical data and should be used as the starting point for the baseline search. Individual antennas may also have axis intersections that are offset from the mounting points that are measured and carried with the antennas. Then the baseline solution if just offsets from these nominal terms.

Owner: Dirk Muders

Last modified: January 22, 2001, D. Muders, P. Schilke

4.9.2 Pointing Session

Use Case: SetupPointingSession

Starting from Staff Astronomer's input, determine all parameters necessary to perform a Pointing Calibration Session. The goal of a Pointing Calibration Session is to determine the parameters of the pointing models for a sub-array of antennas. The session is performed by making individual pointing measurements in the direction of a set of N sources covering the whole visible sky in a quasi-uniform way; N must be large enough to allow a determination of the pointing model cofficients by the method of least squares; the session must be short enough so that thermal effects are kept to a minimum.
All pointing measurements in a session are performed in the same way, using one of the following pointing modes:

— interferometry mode,
— pseudo-continuum mode (using maser line sources),
— continuum total power mode (with nutators),
— optical mode (with optical telescopes).

Role(s)/Actor(s):
Primary: Staff Astronomer
Secondary: Line Catalog, Pointing Source Catalogs

Priority: Critical

Performance: One to a few hours

Frequency: After moving one or more antennas and/or at regular time intervals (weekly ?).

Preconditions:

1. Must have access to the full sub-array that needs to be calibrated, which consists of:
   — at least two (better three) antenna(s) in interferometry mode,
   — at least one antenna, in pseudo-continuum mode,
   — at least one antenna, equipped with a nutator, in continuum total power mode,
   — at least one antenna, equipped with an optical telescope, in optical mode,

Basic Course:

1. User specifies the number of sources to be observed.
   Alternate Course User specifies accuracy. System will then continue until accuracy is achieved.
2. User specifies the setup parameters to be used for all pointing measurements (UC_SetupPointingCalibration), including which pointing mode will be used.

Issues to be Determined or Resolved

Notes:

Owner: Robert Lucas

Last Modified:$Id: SetupPointingSession.html,v 1.6 2001/01/17 17:31:57 lucas Exp lucas $

Use Case: PerformPointingSession

Describe the actual observing actions needed to perform a Pointing Calibration Session. The User input is described in UC_SetupPointingSession.

Role(s)/Actor(s)
Primary: The AOS
Secondary:

Priority: Critical

Performance: real-time; overhead should be minimal and dominated by hardware.

Frequency: After moving one or more antennas and/or at regular time intervals (weekly ?).

Preconditions: All the user parameters have been properly entered and checked (UC_SetupPointCalSession.html)

Basic Course:

1. The receivers, correlator, optical telescopes, are set up and tuned.
2. The Calibration Pipeline is started.
3. The system calculates a homogeneous sky distribution for the current LST and the time duration of the upcoming session using the specified number of sources, from the appropriate Pointing Catalog
4. The system calculates the optimum sequence in which to observe the sources.
5. The system records data for each source in turn (UC_ObservePointCal).
6. The Calibration Pipeline is instructed to calculate the pointing model and is closed.

Postconditions:

— The pointing model coefficients are fed back from the pipeline and updated in the active pointing models for further observations.

Issues to be Determined or Resolved:

Notes:

— Optimum sequence means a sequence that realizes a good sky coverage in a short amount of time. The effect of time drifts in the resulting pointing model constants must be kept to to a minimum. For instance, to first order, the mean azimuth and the mean elevation in the first and second halves of the session should be equal to mid-range values.
— The requirement on observing conditions depends on the actual pointing mode chosen

Owner: Robert Lucas

Last Modified: $Id: PerformPointingSession.html,v 1.3 2001/01/17 17:36:54 lucas Exp lucas $

Use Case: ReducePointingSession

This Use Case describes the on-line data reduction operations for the Pointing Calibration Session.

Role(s)/Actor(s):
Primary: The (calibration) pipeline, the AOS
Secondary:

Priority: Critical

Performance: A few seconds to minutes.

Frequency: A full pointing session is not necessarily needed each time an antenna is moved. Normally only the Azimut offset should be affected by a move. Nevertheless it is reasonable to remeasure the pointing models at regular intervals, to check for time variations in the mechanics. The frequency of these measurements is not known at present.

Preconditions The raw data of the Pointing Calibration Session scans are made available to the pipeline right after each one is observed.

Basic Course

1. After each scan, the (calibration) pipeline performs the data reduction operations (UC_ReducePointingCalibration), including a display, and saves the pointing offsets.
2. At the end of the Session, the (calibration) pipeline uses the measured pointing offsets and the corresponding antenna coordinates for each scan, to determine by a least square method the pointing model coefficients of each antenna. Other variables than antenna coordinates (time, temperatures) may be used in addition if these affect the pointing model.
3. The results are displayed (including a comparison of new and old model coefficients).
4. Finally the pointing model coefficients are fed back to the AOS.

Postconditions:

1. A new pointing model is available for each antenna used, and available for following observing sessions.

Issues to be Determined or Resolved:

— ...

Notes:

— The data reduction is performed after all pointing sources have been observed. There is no need to feedback the pointing offsets after each individual pointing measurement.

Owner: Robert Lucas

Last Modified: $Id: ReducePointingSession.html,v 1.3 2001/01/17 17:36:32 lucas Exp lucas $

A Examples of Scheduling Blocks

We give here a few examples of Scheduling Blocks, only in order to precise their meaning. Actual implementation of the observing modes we refer to in this Appendix will certainly be different.

- 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 calibrator 20 seconds
    - Target 40 seconds
- Mosaicing, interferometry:
  - Pointing scan
  - Focus scan
  - Up to 30 mosaic points at 30 seconds each
- Mosaicing, single dish, OTF:
  - Pointing scan
  - Focus scan
  - Off source point 1 minute
  - Scan 300 map points at 5s each
  - Off source point 1 minute
  - Scan 300 map points at 5s each

B Observation Descriptor

This Appendix attempts to list the actual hardware control parameters, which are normally derived in quasi real time from high level astronomer input, and should fully describe an Observation. Some fields are still to be defined (TBD). This will obviously need to be refined during the Analysis and Design phases.

Observation Descriptor

1. Project ID
2. Sub-array ID
3. Scheduling Block ID
4. Number of Antennas=NA
5. Antenna(NA)
    1. Antenna ID
    2. Position of Antenna (X,Y,Z)
    3. Antenna Station ID
    4. Pointing Model
        1. Axes Offset
        2. Encoder Zeroes
        3. Collimations
        4. Az Inclinations
        5. Focus Corrections (X0,Y0,Z0, X1,Y1,Z1, ...)
        6. Pointing Offsets of Optical Telescope
        7. ...
    5. Pattern
    6. System (Hor, Eq)
    7. Mode {"None", "Circle", "Points"}
    8. Start coords
    9. Center coords (Circle)
    10. Angular Velocity (Circle)
    11. Number of points (Points)
    12. List of coords, times (Points)
    13. ...
6. Calibration Parameters
    1. Number of frequency points=NPC
    2. Point(NPC)
        1. Frequency
        2. Forward Efficiency
        3. Aperture Efficiency
        4. ... TBD Other Efficiencies (e.g. vane transparency)
    3. Atmospheric Model
    4. ...
7. Frequency Band(NFB)
    1. Pointing offset (Az,El) for H
    2. Pointing offset (Az,El) for V
    3. Focus offset (Z) for H
    4. Focus offset (Z) for V
    5. LO1 Phase offset

    6. Delay offset
    7. BaseBand (NBB)
        1. LO2 Phase Offset
        2. Delay offset
    8. SideBand Gain Ratio
8. Number of Frequency Bands = NFB
9. Frequency Band(NFB)
    1. Frequency Band ID
    2. Mode {Active, Standby}
    3. LO1 Frequency
    4. Number of BaseBands = NBB
    5. BaseBand (NBB)
        1. Setup Mode {EXPLICIT, AUTO}
        2. Polarization {H, V, HH & VV, ALL}
        3. Line ID
        4. Line Rest Frequency
        5. Velocity Interval (min,max)
        6. Velocity Resolution
        7. LO1 SideBand
        8. LO2 Frequency
        9. LO2 SideBand
        10. IF Frequency
        11. IF Frequency Bandwidth
        12. Frequency Resolution
10. Source
    1. Source ID
    2. Catalog {YES NO}
    3. Catalog name
    4. Source Status {Active, Standby}
    5. SolSys Object {YES, NO}
    6. SolSys Name or FileName
    7. Coordinate System {EQ GA HO ...}
    8. Epoch
    9. Lambda at Epoch
    10. Beta at Epoch
    11. Lambda Motion at Epoch
    12. Beta Motion at Epoch
    13. Velocity
    14. Velocity Frame {OBS, GEO, HEL, LSR} ... (EMBar, SSBar ?)
    15. Doppler Track {YES, NO}
    16. Flux
        1. Number of Frequencies
        2. Frequencies
        3. Fluxes
    17. Source Info {PHASE_CAL,FLUX_CAL,BAND_CAL,TEST_TARGET,SCIENCE_TARGET...}
11. Phase Center
    1. Pattern
        1. System (Hor, Eq)
        2. Mode {"None", "Circle", "Points"}
        3. Start coords

        4. Center coords (C)
        5. Angular Velocity (C)
        6. Number of points (P)
        7. List of coords, times (P)
        8. ...
12. Integration
    1. Time
    2. SwitchingMode
        1. Number of States
        2. State
            1. Duration
            2. Blanking
            3. Nutator Offsets
            4. LO1 Frequency Offset
            5. LO2 Frequency Offsets (4)
            6. Weight (for Pipeline)
            7. ...
13. Water Vapour Radiometer
    1. Use {YES NO}
14. Data Processing
    1. Script
        1. Calibration
        2. Imaging

C Glossary and Acronyms

The following is a digest from the official ALMA Software Glossary.

actor Actors are used when writing use cases. Actors are a role of an entity external to the system, and can be humans, machines, or devices. Actors are divided into primary and secondary. A primary actor is one having a goal requiring the assistance of the system, while a secondary actor is one from which the system needs assistance to satisfy its goal. (see The Unified Modeling Language Reference Manual, Rumbaugh, Jacobson, and Booch, p.144)

alarm Alarms are logged errors with sufficient severity to alert the Operator.

array The entire set of all ALMA antennas.

AOS (see the Executor)

boresight The actual orientation of the axis of symmetry of the main reflector with respect to established local coordinates (zenith direction and nominal azimuth zero).

command A statement executed by the ALMA instrument causing some discrete action on the equipment. It comes from the repertoire of the ALMA command language grammar.

data set All data belonging to a particular set of observations including *uv* data, astronomical information (sources, coordinates, frequencies, etc.), raw observing and reduction scripts, system data, logs, warnings, environmental data, etc.

delay tracking The continuous adjustment of the instrumental delay to match the geometric delay as a source is tracked.

delay tracking center The direction on the sky for which the total delay to each antenna is a constant. When the compensating delay is implemented after a down conversion (the usual case in radio interferometers) a fringe results that is a function of the down conversion local oscillator frequency. By changing the phase of this local oscillator (with the fringe rotator), the fringes may be reduced in frequency or stopped, as desired by the correlation system. Any errors in the total delay due to transmission or compensating delay imprecision result in a phase shift to the visibilities that is a function of IF frequency.

dump The acquisition of data from the correlator corresponding to a dump time (see below).

dump time The smallest interval of time for which a set of correlated data can be accumulated and output from the correlator.

engineer A person who uses scientific knowledge to solve practical problems. For ALMA an engineer's principle assignment will be to build and maintain the hardware and software.

error Errors occur as the result of command failure, for example, when a property is set. Usually they are a response to writing an inappropriate value or a hardware problem, but they can be any error condition that can be reported in the return of an operation.

Executor The control and command section of the ALMA instrument. It is responsible for executing observing commands on the hardware.

fringe rotator A mechanism to introduce a time-varying phase shift into the local oscillator signal to reduce the frequency of the oscillations of the correlator output. Fringe rotation allows the correlator output (whose amplitude is proportional to visibility amplitude) to be sampled at a lower rate. The fringe rotation is chosen so the fringe frequency for a point source located at the fringe stopping center would be reduced to zero (or very nearly zero). Usually the fringe-stopping center and the delay-tracking center coincide; both then are called the visibility phase tracking center.

GUI Graphical User Interface.

IF Intermediate Frequency

integration A set of dumps, all identical in configuration (except for the antenna motion and some others), that is accumulated and forms the basic recorded unit.

interactive command An interactive command can be used to specify table parameters for the next observation, start the next observation, cancel the current observation, etc.

LO Local Oscillator

mode A state in which operations are constrained to a particular set of procedures for specific goals - e.g. Interferometry or Total power.

MPPS Million pixels per second

MVPS Million visibilities per second

observation A set of integrations while the antennas complete an elemental pattern across the source, and possibly while frequency switching, nutator switching, etc.

observation descriptor The hierarchical set of parameters that define the current observation.

observer The person who prepared, or is otherwise responsible for an approved observing program. The observer is usually an astronomer.

observing program A set of observing sessions to fulfil a formalized astronomy proposal with a particular scientific goal. A synonym for observing project.

observing script The procedural representation of an observing session. It may contain loops and conditional tests using environmental parameters, pipeline results, and current scheduling status.

observing session A time-contiguous set of schedule blocks in the same observing program. Note that sessions are defined post facto, as the scheduler only schedules schedule blocks.

observing tool A GUI tool used by astronomers to prepare observations, usually from a template. The observing tool will produce an observing script, or may be used to directly control the instrument.

operational mode The mode of a system, subsystem, or component that is installed in its intended environment.

operational requirement A requirement that is applicable to a system or component that is installed in its intended environment.

operational state The state of a system, subsystem, or component that is installed in its intended environment.

operator The person in immediate control of the array. The operator is not usually an astronomer.

package A major subdivision of a software project that

collects a set of associated functions that are designed, developed, and tested together and independently from other packages. Software packages can be recursively defined as containing other software packages.

pattern An antenna movement that is superimposed on (added to) the tracking of the target. Example patterns are a simple offset, a raster, and a spiral. A pattern is composed of one or more 'strokes'.

phase tracking An adjustment of the LO phase needed because delay tracking is done at the IF and not RF frequency.

phase tracking center Usually the fringe stopping and the delay tracking centers coincide. When this is the case, both are referred to as the visibility phase tracking center, sometimes called the phase referencing center.

preamble A set of observations to be executed at the beginning of each observing session in a given programme, in order to setup the system, measure some parameters, and perform some calibrations.

postamble A set of observations to be executed at the end of each observing session in a given programme, in order to measure the final value of some parameters, and perform some final calibrations.

process A program in execution. It consists of a dynamical image executable on a particular computer which changes over time from the original program. It may also access resources external to the program such as files and change their state over time.

scan A set of observations with a common goal, for example, a pointing scan, a focus scan, or atmospheric amplitude calibrations scan.

scheduling block An un-interruptible scheduling unit, which may consist of a set of scans and logic to control their execution. The scans must be scheduled contiguously.

scheduler queue The prioritized list of observation blocks produced by the dynamic scheduler.

status The set of values of all the parameters (state, numeric read-outs, flags...) that define the condition of a system, subsystem, or component.

stroke Patterns are composed of a series of separate strokes. For example, when a raster pattern is being performed a stroke is generally a single line in the raster.

subarray A group of ALMA antennas used to execute coordinated, synchronous observations. This group of antennas is allocated to a single observing session.

subsystem A secondary or subordinate system within a larger system. It usually refers to a physical device or a group of physical devices equipped with the control electronics and low level software.

system A collection of components organized to accomplish a specific function or a set of functions. When no further characterized, it is generally used to refer to the whole of a complex piece of equipment made up by heterogeneous parts.

target The central position being tracked by the antenna's receiver beam. Normally this is a celestial object, but it can be anything able to be specified to the AMS.

TBD To be determined

turn One turn of an antenna axis, or 360 degrees.

use case A specific way of using the system by performing some part of the functionality. Each use case constitutes a complete course of action initiated by an actor, and it specifies the interaction that takes place between an actor and the system. The collected use cases specify all the existing ways of using the system.

VLBI Very Long Base Interferometry

WVR Water Vapour Radiometer