Potential ALMA Enhancements over the Next 5 Years

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Scope

The ASAC should identify the highest priority science goals over the next 5 years that cannot be done now or can only be done inefficiently, and identify the enhancements needed to enable that science.

The science goals should be tied to the activities listed in this document that could be done in the next five years by JAO and Regional Center (ASC) staff. The listed items include capabilities needed to complete nominal baseline activities or could be done in replacement of baseline activities to enhance steady-state operations, or other small items that would not require substantial investment.

The following enhancements should be taken as "given" because they are already placed at high priority from previous ASAC meetings: 1) 90-deg switching on the baseline correlator, 2) improved efficiency for spectral scan observations, and 3) the artificial beacon for polarization studies.

Potential Enhancements

Observing efficiency

For the purposes of this document, we use observing efficiency generically to describe scheduling block efficiency (fraction of time in an SB spent on the science target), lack of technical downtime (system stability), and calibration efficiency (the fraction of the time the bulk of the array is doing calibration observations instead of PI science). The goals for each of these are:

- Scheduling block efficiency driven by dynamic determinations of calibrator signal to noise and multiple, consecutive executions recycling calibration from the previous observation (strongly depends on science requirements).
- Technical downtime of less than 10% (short term), less than 5% long time.
- Calibration fraction of less than 15%.

Efforts are already underway to address each of these areas, namely session observing, overall stability efforts, and subarrays. Further efforts on dynamic calibration times could drive another 5-15% savings in scheduling block efficiency for short executions. If the trend is towards longer integration times, the return on the work is much less. Specific items to prioritize are:

- **Dynamic calibrator integration times** to allow calibration integration to arrive at a sufficiently high signal to noise before proceeding based on antenna numbers, weather, specific tuning in the band, source brightness at observation (not previously measured values) etc. Note that for very high signal to noise science observations the calibration signal to noise ratio must be even higher. Time saving varies.
- **Dynamic science target integration times** to allow for weather and antenna count based modifications to the total integration time. Time saving varies.
- **Multiple intents** to allow some calibrations in specific instances to be used for multiple purposes (e.g., for TDM observations, many phase calibrators are sufficiently bright to serve as bandpass calibrators as well). Time saving varies.
- **Constant Tsys** by allowing total power detectors on target to scale the average Tsys, reducing the frequency of Tsys observations (only need to update spectral component periodically).
- **Simulation improvements** to the software setup allow for lower impact upgrades to the system and general performance enhancements. Time savings is likely 8 hours a week simply in testing and variable time savings from reduced debugging of new versions and improved stability.
- Full use of a dynamical scheduling system to optimize the short term scheduling
- Full implementation of subarrays for science operations
- Optimize polarization observations calibration and its efficiency

Data Rates and Volume

The datarate policy is currently limiting the scientific output of the array by reducing the useable correlator modes/resources in FDM mode. Besides allowing for more flexible observations, it will increase the informational content of the archive.

- Increase operations datarate to the maximum allowed by the current hardware/software
- Implement online application of the WVR corrections and data averaging

Correlator Modes

There is a series of original correlator modes that are already available in hardware, but due to other priorities, they have not been scheduled to be delivered and commissioned.

- **3-bit, 4-bit quantization modes and double Nyquist sampling** to improve sensitivity. A 2-bit correlator provides 88% efficiency, a 3-bit correlator has 96% efficiency, and a 4-bit correlator 99% efficiency.
- **Multi-resolution modes** to allow for a zoom-in like feature per base-band. Better bandwidth utilization by allowing on a per base-band basis to observe at two different spectral resolutions.
- **Fast accumulation mode**, 1 ms correlator dumps, autocorrelation only.

- **Side-band separation** based on TFB sub-bands sharing for independent upper/lower frequency offsetting.
- **Tsys in FDM mode** to allow for more accurate weighting of atmospheric features.
- **Highest spectral resolution modes** halving the currently finest resolution.

ACA modes

- **Phased array** for mmVLBI and pulsar searches. This observing model can be useful for projects that do not need to the full phasing of the 12m array.
- **Rapid response DDT** for projects not requiring the full ALMA resolution and sensitivity, especially when ALMA is an extended configuration that may not be suitable.
- **90-deg switching** to double bandwidth at bands 9 and 10.
- **Dynamic subarrays** to aid calibration of 7-m data (use 12-m total power antennas for 7-m data calibration and then separate to do total power and 7-m observations separately).
- **Total Power continuum.** Continuum observing mode for the TP antennas has not yet been implemented.

Rapid Data Reduction

- Allow pipeline execution on individual Execution Blocks to provide more rapid verification of data and delivery to PIs. This also provides more timely feedback to engineers on data quality.

Duplication Checking Tool

- Tool that will allow the user to perform meaningful duplication checking between an OT proposal and data already present in the archive or a project in the queue (A class, B also?).

Archive

- Define and implement a proper set of parameters that will be used for Duplication Checking and implement an interface to the Duplication Checking tool
- Provide the possibility of searching on raw data and search and delivery of calibration data.
- Provide the ability to download quick-look data and quality check logs, without the need of downloading entire raw datasets
- Provide means to ingest and offer search capabilities for non-QA2 data products, including data delivered by PIs from large programs or regular proposals.
- Download calibrated uv data directly without having to run a pipeline script

Observing modes

Other observatories have proposal capabilities not currently offered by ALMA., including:

- Multi-cycle programs for time-monitoring programs
- Multi-cycle programs for large programs
- Medium proposals to encourage proposals between "small" and "large" categories
- "Calibration" proposals, proposal category for projects focused on delivering science datasets that improves the calibration accuracy for the larger community benefit.
- "Generic targets", which allow a PI to propose for observations that are contingent upon the results of another proposal (not necessarily ALMA). The sample can be anticipated, but the exact targets may not be known yet.

Observing capabilities

- Polarization of wide-fields (7-m and mosaicking)
- Circular polarization for Zeeman observations
- Band cycling observations (3 bands observing in somewhat rapid cycling)
- Science subarrays
- Single dish frequency switching
- Single dish nutator
- Single dish fast scanning
- Single dish bands 9-10
- On-the-fly interferometry for bigger mosaics
- Combined Array Mode: Cross correlate all of the antennas of ALMA (12m array and ACA). This mode will yield 15-20% improvement to the overall sensitivity, providing scientific benefits to targets that require deep integration (e.g. deep high-z surveys). It will also shorten (by factor 4 – 9) the time required for calibration of the ACA, and this is particularly beneficial for high frequency observations.