Science IPT & ASAC Response to BCP Options

Joint ALMA Office

September 8, 2005

This document presents a response by the Science IPT to the items identified as descopes or deferrals in the Baseline Change Proposal spreadsheet which may have impact on the science goals of ALMA. Also included is the recent letter from the ASAC to the ALMA Board (September 15th 2005).

BCP 2. Construct only 4-km ALMA

An angular resolution of 10-100 milliarcsec is a key to the scientific success of ALMA. In the March 2005 report, the ASAC notes that the implementation of the longest baselines (i.e. more than a few km) is one of the most challenging aspects of the project, both technically and scientifically, and could be delayed into the operational era of ALMA. Nevertheless, it is important to avoid taking decisions that may prevent or seriously delay their future implementation, such as adopting an inadequate Local Oscillator distribution scheme or abandoning phase correction systems.

The protostellar/protoplanetary disk level one science goal is severely compromised by this BCP.

BCP 5. WVR Production

Atmospheric phase correction using radiometers and fast-switching is a critical part of the plan to obtain scientifically valuable data from under average conditions on Chajnantor, even at the lower frequencies and on short baselines (see ASAC October 2002 report and several ALMA Memos for a quantitative assessment). We stress that both the WVRs and fast switching will have a vital role on baselines as short as 100m: it is a fundamental misconception to view them as part of the long baseline operation of ALMA. The WVRs estimate the atmospheric phase every second, and allow the removal of the rapid fluctuations associated with small scale structure in the atmosphere, with the fast switching every few tens of seconds removing the large errors on long baselines. The WVRs will significantly enhance the efficiency of ALMA, by allowing operation in a wide range of atmospheric conditions, and increasing the coherence and hence sensitivity of the array.

BCP 6a. Defer Solar Filters

Without the solar filters, ALMA can do no observations of the sun. Uniquely among suggested descopes, this disenfranchises a whole community. ALMA will have a major impact on observations of the Sun. Observations of the Sun, in turn, will influence the interpretation and understanding of observations of distant stars and stellar systems, for it is against detailed observations of the Sun that a great deal of stellar astrophysics is referenced. ALMA will make unique contributions in three key areas. First, ALMA will operate at wavelengths that will probe the low solar atmosphere, a region where non-radiative heating first makes itself manifest. Sensitive, multi-band imaging observations will make it possible to observe the thermal structure and dynamics of the solar chromosphere. In particular, observations of chromospheric oscillations will reveal in detail the nature of chromospheric heating. Second, ALMA will have the sensitivity, wavelength coverage, and spectroscopic bandwidth and resolution to perform imaging spectroscopy of radio recombination lines of hydrogen and certain ions such as O VI that become detectable because of dielectronic recombination. Detection of these RRLs would open an entirely new chapter of solar physics and offer wholly unique diagnostics of the solar atmosphere. Third, ALMA will detect the synchrotron emission from the most energetic electrons accelerated in solar flares (10s to 100s of MeV), yielding new insights into the outstanding problem of magnetic energy release and particle acceleration.

BCP 6b. Remove 1/4–wave plate for Band 7

See comments for FE polarization below. Deleting the ¼ wave plate would eliminate the use of linear polarization at 345 GHz, which is to be used for molecular line and dust polarization studies to be used in modeling molecular clouds.

BCP 7a. Defer one IF–DTS

To achieve the full continuum sensitivity and spectral line observation flexibility, ALMA requires the planned dual IF system. The loss of one IF chain would be equivalent, in terms of rough continuum sensitivity, to a loss of 40% of the antennas for a modest savings in cost. Full polarization capabilities are also an essential asset of ALMA which would be removed by the loss of one IF, with the consequent loss of all the related scientific programmes. The cost savings is only one antenna.

BCP 7b. Remove two (of four) subarrays

(excluded if 7c is selected)

There are strong scientific arguments for the four planned subarrays envisioned, which have been planned since Feb 2000. Two subarrays is insufficient for a scientifically productive ALMA, though of course sufficient for early operations. Additional hardware to support subarrays can be purchased later.

BCP 7c. Use AM LO scheme

(excluded if 7b is selected)

Use of an amplitude-modulation scheme for the Local Oscillator system would provide savings to the project, but lead to poorer phase stability over long baselines.

BCP 7d. Remove EDFA from DTS

Current analysis of the digital transmission system indicates that Erbium-Doped Fiber Amplifiers may not be needed. Removal of these amplifiers should be based on technical specifications and performance.

BCP 8. Front End Bands

The scientific priorities of the receiver bands were discussed in the ASAC reports of March and October 2000 and reviewed again on several occasions, the most recent being the October 2004 ASAC report. The Science IPT fully endorses the ASAC recommendations. To ensure the scientific success of the project, the ALMA array should start full operations with the receiver bands number 3, 6, 7 and 9, with the ultimate goal to cover the entire millimeter and submillimeter atmospheric windows. Second scientific priority frequency bands were identified as 1, 4, 8, and 10; third priority bands were 2 and 5. We note that the level one science goals cannot be met with this BCP in place, with only one polarization for Band 3 and with 50 antennas. With both Band 3 polarizations and 50 antennas, the first of them may be met. Few of the DRSP proposals can be done with only one polarization of Band 3. Only 17 of the more than ten dozen proposals can be done with only Band 3 available. Little or no redshifted [C II] work may be possible with Band 3 alone, for example, among important ALMA goals.

BCP 9. Front End Polarization

Similarly, the loss of one polarization for a given receiver band will produce a similar decrease in sensitivity and loss of polarization capabilities for that particular receiver. Both this item and BCP 7a were discussed in detail in the March 2005 ASAC report.

BCP 10. Software Descope

The delay of a large fraction of the computing deliverables will also have a substantial impact on the science capabilities of ALMA, most notably on the usability of the instrument by non-experts. To assess the impact on ALMA scientific capabilities of the reduction of computing deliverables, a detailed description of the proposed reduction would be required. Discussions with the Computing IPT have identified the following items as possible capabilities lost if a 20% descope is implemented (these have not been planned in detail or widely reviewed):

- No dynamic scheduling;
- No science pipeline;
- No observatory support software (e.g., TAC support);
- Little VO support, only simple science archive queries;
- No easy-to-use mode in observing tool;
- Very limited simulation;
- Little commissioning against the real hardware system

ALMA BOARD

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ASAC Letter to the ALMA Board

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Purpose of Document: To provide the Board with an ASAC letter regarding the rebaselining process.

Action expected of the Board: For information and discussion at the Board's September 15, 2005 telecon

O = Ordinary List Access on ALMA EDM
C = Closed List Access on ALMA EDM

Dear ALMA Board members,

The ASAC's next face-to-face meeting in October is after discussions and meetings of the Board and ESO Council. These bodies may have some important decisions to make. The ASAC thus wishes to provide scientific advice on the ongoing rebaselining effort in advance of our meeting in October.

The ASAC, addressing specific charges by the ALMA Board, has carefully reviewed during the last year the scientific impact of possible cost saving tradeoffs in the ALMA project.

We reaffirm our earlier assessment (October 2004 and March 2005 ASAC reports) that an array with 50 simultaneously operating antennas, four receiver bands (3, 6, 7 and 9) plus WVRs on each antenna, two IF chains and full polarization would be a superb instrument, which would achieve many of ALMA's scientific goals. It would also have a very high scientific impact and a strong community support.

All these ALMA components (antennas, IFs, polarizations, receivers and WVRs) are key items for sensitivity, image quality and frequency coverage of the array and will determine its scientific capabilities.

The impact of decreasing the number of antennas has been carefully reviewed in our March 2005 and October 2004 reports, where we quantified the effect of reducing antennas on the array sensitivity and ability to obtain high fidelity images. We suggested that a minimum of 50 simultaneously operating antennas is required to achieve the ALMA science goals. The ASAC notes with enthusiasm the recently-signed North American contract for the procurement of between 25 and 32 antennas, and hopes that ESO will be in a position to place a contract in the very near future.

The scientific priorities of the receiver bands were discussed in the ASAC reports of March and October 2000 and reviewed again on several occasions, the most recent being the October 2004 ASAC report. To ensure the scientific success of the project, the ALMA array should start full operations with the receiver bands number 3, 6, 7 and 9, with the ultimate goal to cover the entire millimeter and submillimeter atmospheric windows. Second scientific priority frequency bands were identified as 1, 4, 8, and 10; third priority bands were 2 and 5. The ASAC reaffirms these scientific priorities and the need to begin full operations with the four top priority receivers; these will be the necessary bands to achieve the top level science goals of ALMA. Band 3, 6 and 7 will allow observations of CO in the universe from the local interstellar medium through redshift z=8, while band 9 will allow complementary observations of the [CII] line at an important stage of the universe evolution (z=1.6-2.1) when strong evolution of the star formation rate is predicted. All four receivers will be needed to study the range of chemical and physical conditions during the formation of stellar and planetary systems.

To achieve the full continuum sensitivity and spectral line observation flexibility, ALMA requires the planned dual IF system. The loss of one IF chain would be equivalent, in terms of rough continuum sensitivity, to a loss of 40% of the antennas for a modest savings in cost. Full

polarization capabilities are also an essential asset of ALMA which would be removed by the loss of one IF, with the consequent loss of all the related scientific programmes. Similarly, the loss of one polarization for a given receiver band will produce a similar decrease in sensitivity and loss of polarization capabilities for that particular receiver. Both these items were discussed in detail in the March 2005 ASAC report.

The ability to reach an angular resolution of 10-100 milliarcsec is also a key to the scientific success of ALMA. In our March 2005 report, we note that the implementation of the longest baselines (i.e. more than a few km) is one of the most challenging aspects of the project, both technically and scientifically, and could be delayed into the operational era of ALMA. Nevertheless, it is important to avoid taking decisions that may prevent or seriously delay their future implementation, such as adopting an inadequate Local Oscillator distribution scheme.

We note that atmospheric phase correction using radiometers and fast-switching is a critical part of the plan to obtain scientifically valuable data from ALMA under average conditions on Chajnantor, even at the lower frequencies and on short baselines (see ASAC October 2002 report for a quantitative assessment). We stress that both the WVRs and fast switching will have a vital role on baselines as short as 100m: it is a fundamental misconception to view them as part of the long baseline operation of ALMA. The WVRs estimate the atmospheric phase every second, and allow the removal of the rapid fluctuations associated with small scale structure in the atmosphere, with the fast switching every few tens of seconds removing the large errors on long baselines. The WVRs will significantly enhance the efficiency of ALMA, by allowing operation in a wide range of atmospheric conditions, and increasing the coherence and hence sensitivity of the array.

The delay of a large fraction of the computing deliverables may also have a substantial impact on the science capabilities of ALMA, most probably on the useability of the instrument by non-experts. To assess the impact on ALMA scientific capabilities of the reduction of computing deliverables, a detailed description of the proposed reduction would be required. If such a reduction is being considered as a possible cost savings option, we recommend that a detailed description of the items considered for delay should be included in the BCPs package to be evaluated at the Oct 2005 ASAC meeting.

Yours,

The ALMA Science Advisory Committee

All ASAC reports are posted at:

http://www.alma.nrao.edu/committees/ASAC/

(note that these are usually labelled as September rather than October, depending on whether the date of the meeting or date of the report is used)