ALMA Science Advisory Committee

Report from Meeting of October 1–2, 2005

Santiago, Chile

ALMA Scientific Advisory Committee

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1 Executive Summary and Recommendations

The ASAC considered four charges from the ALMA Board at its October 2005 meeting in Santiago.

Scientific Impact of ALMA Rebaselining. Following an evaluation of their impact on the ALMA scientific capabilities, the ASAC concludes that, with the possible exception of BCPs 1, 7c, and 7d (see Appendix A for the list of BCPs with numbering), all the BCPs marked as "MA" will compromise the ability to achieve Level 1 science goals; all efforts should be made not to implement these changes to the ALMA project. In addition, the removal of Water Vapour Radiometers and proposed 20% descope of the Software should not be implemented. We also recommend that the project carefully evaluate whether the cost savings of BCPs 6a, 6b, and 7b are really worth the impact that these have on the scientific capabilities of the array.

Careful scientific analysis of the impact of purchasing fewer than 64 antennas has been carried out in our last report. The ASAC concluded that an array with 50 operating antennas would achieve many of ALMA's science goals. We stress here that any reduction below this goal damages ALMA science, and that the effect of reducing the number of antennas is non-linear: each antenna cut is affecting science capabilities more than the previous one. We realize that the reduction in the number of antennas to 50 purchased antennas is dictated by severe budgetary constraints. We urge to keep the goal of building a 64 antenna baseline ALMA, if possible.

Noting the low impact on scientific capabilities, we recommend to adopt BCPs 3, 4a–g, 11, and 12.

Science Requirements. We recommend that the Board adopt the Science Requirements document after some clarification, especially in the area of calibration and solar observations. We note that,

[1]Not present in Santiago but participated part-time via telecon

[2]participated in Santiago part-time

following the ALMA rebaselining process and depending on the final decisions on which of the proposed BCPs should be implemented, this document may require some revisions.

Time Allocation Policies. The ASAC still believes that a single international Programme Review Committee would best serve the ALMA project, minimizing several of the concerns on joint programmes and scientific duplication of programmes. Nevertheless, the ASAC has sketched a possible programme review model, based on Regional Programme Review Committees and an International Programme Review Committee, that may minimize the adverse scientific effects of adopting a region-based review model. Regional PRCs, each with identical science sub-panel, structure and policies, will review and rank the proposals from the respective regions. They will then pass the ranked lists to an international PRC, of which all the Chairs of the regional science sub-panels are members, for merging lists and solving conflicts. Proposers should be free to indicate which fraction of the requested time should be allocated by which partner (in this case all involved RPRCs would see and rank the proposal). We believe that, at this stage, there is no need to set up special procedures for Large or Legacy-type projects. Policies, procedures and structure of ALMA time allocation should be periodically reviewed to ensure the best scientific output of the project.

Demonstration Science. The ASAC-proposed concept of "demonstration science" has been discussed within the framework of current plans for Commissioning, Science Verification and Early Science. We suggest to split demonstration science into two different concepts: Science Verification and ALMA Public Images.

Science Verification (SV) will be an end-to-end test of an ALMA mode using science projects proposed by external users. SV activities could start as soon as a new ALMA mode is fully commissioned and prior to any standard call for proposals that includes that particular mode. Scientific proposals for SV should be reviewed by an international proto-TAC under strict control from the observatory staff. It is expected that SV activities will start before Early Science and will continue, at a reducing pace, throughout the ALMA construction period.

ALMA Public Images (API) will be large-scale projects selected by the ALMA project, whose primary goal will be to convince the community and the public of the value of ALMA. It should be possible to select a very limited number of southern sources (e.g. Eta Carinae and Centaurus A) for which data could be accumulated during Commissioning and Science Verification without imposing an additional burden on construction, technical and first scientific activities. The images of these sources could be used to show the improvement in ALMA capabilities as it grows to completion.

Additional recommendations. The ASAC recommends that the Project adopt the new version of the ALMA inner configurations design document (ALMA-90.02.00.00-006-A-SPE) prepared by the Science IPT. We encourage continued work on the longest baselines configuration and reconfiguration plans.

The ASAC also noted the slow pace at which the ALMA Regional Centers (ARCs) are developing and starting their activities. We believe that there is now an urgent need to hire key personnel both in the ARCs and in the JAO to plan for early operations and to ensure a smooth transition from construction to operations personnel.

2 Introduction

The ALMA Science Advisory Committee (ASAC) met on October 1 and 2, at the Holiday Inn El Golf Hotel in Santiago. All ASAC members were able to attend the meeting, with the exception of Tom Wilson who participated via teleconference. The ASAC was joined by members of the Joint ALMA office (JAO) from Santiago and by members of the individual executives, from North America, Europe, and Japan, for discussions and presentations. The ASAC is grateful to the JAO, especially Alejandra Araya and Massimo Tarenghi, for arranging and sponsoring the logistics of this meeting.

From the presentations of the Director Tarenghi and Project Manager Beasley, the ASAC learned of the progress in ALMA construction in Chile, in the staffing of the Santiago office, and the overall progress in the project, including the rebaselining effort and the antenna procurement status. The ASAC was also informed about the difficulties in finding a suitable candidate for the JAO Project Scientist position and of the fact that the regional Project Scientists have agreed to act in this role as an interim solution. The ASAC welcomed Al Wootten as the first of the regional Project Scientists to serve as interim Project Scientist and thanked all of them for taking on this additional task and for their commitment to the project. The ASAC also welcomed with enthusiasm the news that the ESO Council had declared the project affordable, which will allow the ESO management to go ahead with the antenna procurement process and, more generally, with developments in all areas of the project. The ASAC heard of the plans for the ALMA Cost Review to be held in Garmisch-Partenkirchen in mid-October. The ASAC congratulates the JAO and especially the Project Manager for the enormous effort that was devoted to the rebaselining process and the associated documentation and presentations for the Board and Cost Review Panel.

The ASAC heard two presentations on the progress of the ALMA-J project from ALMA-J Project Scientist R. Kawabe and Instrument Scientist B. Vila-Villaro. The progress in the design and construction of the ALMA-J and the integration with the baseline ALMA project is encouraging.

E. van Dishoeck, C. Carilli and S. Yamamoto reported on issues discussed by the regional ALMA Science Advisory Committees. In addition to regional specific issues, all these committees discussed and provided community input to the ASAC discussion, especially concerning charge 1 on rebaselining and charge 3 on time allocation.

3 Charge 1: Scientific Impact of ALMA Re-baselining

The Board's most urgent need is for ASAC to review critically the materials on rebaselining being prepared by the JAO and comment upon the impact of the proposed options on the scientific capabilities of ALMA.

The ASAC, addressing specific charges by the ALMA Board, has carefully monitored during the last year the progress in the rebaselining effort and has evaluated 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 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 final list of Baseline Change Proposals (BCPs) that was presented to the Board by the JAO as the result of the rebaselining process was delivered to the ASAC on September 11, 2005. Extensive explanations and clarifications were provided by the Project Manager, Tony Beasley, in several occasions during ASAC telecons, upon e-mail requests and finally at our meeting in Santiago. We thank Tony for all the support he has provided to the ASAC during the evaluation of the BCPs.

A clarification of the meaning of the verb "defer" used in many of the BCP descriptions was requested by the ASAC Chair to the ALMA Board at the September 15, 2005 telecon. The answers received by both executives imply that if any of the "deferred" BCPs is accepted, the corresponding ALMA capabilities will not be permanently removed, but the funding for their future implementation could not come from either the construction or the operations budget. This means that such items would effectively be removed from the baseline project, although they could still be implemented later on as an ALMA upgrade should additional funding for this purpose become available.

In appendix A we provide, for each proposed BCP, our evaluation of its impact on the ALMA scientific capabilities. Most of the proposed BCPs were already evaluated in our previous reports dated October 2004 and March 2005. Our assessment of the impact of these has not changed. Nevertheless, for convenience, we also provide in appendix A a short evaluation for these as well.

Two main criteria have always guided the ASAC in the evaluation of the scientific impact of possible descopes of the baseline ALMA project: the ability of the rebaselined ALMA to achieve outstanding science goals as presented in the Level 1 science requirements and the nature of ALMA as a wide community instrument, usable and supported also by non millimeter interferometry experts.

With the exception of BCPs No. 1, 7c, and 7d (which we discuss below), **each one of the BCPs marked as "MA" and BCPs No. 5 (WVRs) and 10 (Software), if accepted, will prevent ALMA from achieving the Level 1 science goals and being a truly community wide instrument. For this reason, the ASAC believes that none of them are acceptable for descope.**

In our March 2005 report we suggested that long baselines could be considered for delay. However, given the clarification on the meaning of the verb "defer" mentioned above, the adoption of BCP No. 2 would seriously put at risk the implementation of long baselines within a few years after the nominal end of construction in 2012. This would limit the nature of ALMA as a high angular resolution instrument for millimeter wavelengths and would not allow the achievement of Level 1 science goals (see appendix A); we thus consider this unacceptable.

We realize that, due to budgetary constraints, it is only possible to place contracts for a reduced number of antennas at this time. Nevertheless, we urge to keep 64 antennas as a possible goal for the future.

BCPs No. 7c and 7d may have a major impact on the scientific capabilities of ALMA. However, at this time, we lack quantitative estimates of their impact on the array capabilities. We note that, due to the likely much higher phase noise of the Amplitude Modulated Local Oscillator with respect to the currently planned Photonic Local Oscillator, if accepted, BCP 7c may seriously compromise high frequency and long baselines observations. If this particular BCP is to be considered for implementation, we suggest performing a thorough evaluation of the AM LO possible design and the expected performance degradation compared to the baseline Photonic LO. The decision to include or remove the Erbrium-Doped Fiber Amplifiers within the Digital Transmission System should only be based on technical specifications.

BCPs No. 6a, 6b, and 7b will not compromise the Level 1 science goals. Nevertheless, although these items have certainly lower priority than those mentioned above, we caution that the savings-to-impact ratio for these BCPs is extremely low. We thus suggest to consider them for implementation only if such a modest cost saving is really considered absolutely necessary at this time.

We suggest adopting BCPs No. 3, 4a-g, 11, and 12, noting their low scientific impact. Nevertheless, while a saving in the construction cost of the OSF residence should be attempted, a good working environment and some, albeit limited, recreational facilities should be supported to attract and maintain a top level scientific and technical staff at the observatory.

4 Charge 2: ALMA Science Requirements Document

Please review the revised Science Requirements Document and make recommendations concerning its adoption by the Board.

In reviewing the Science Requirements document, the ASAC continues to be concerned that the requirements relating to ALMA calibration are not laid out with sufficient clarity. In particular, we have emphasized in the past that the repeatability of ALMA calibration needs to be significantly better than the accuracy of ALMA's absolute calibration, which is currently set at 3% below 300 GHz and 5% above (see September 2003 ASAC Report for a detailed discussion). The difference in requirements between absolute and relative calibration as well as repeatability is not sufficiently clear in the current document. Additional clarification is also needed for the calibration requirements relating to polarization and for the requirements on the primary beam calibration accuracy.

Another area of concern relates to imaging the Sun. While the ASAC believes that ALMA will provide outstanding results in the field of solar observations, these observations will be both technically challenging and very different from other ALMA observations with the potential risk of damage to ALMA antennas and equipment during the observations. For ALMA, most secondary beams and far side lobes will look at the Sun, which will make interpretation of the data very difficult without specialized software. Advanced simulations accounting for far side lobes from each telescope will be needed to correctly establish the requirements on beam characterization and software developments when compared with those required by most DRSP projects.

The ASAC considers that, once the calibration issues are addressed, the Science Requirements document will be ready for acceptance by the Board. The Board may wish to consider whether the document should be revised further to be brought into agreement with the parameters of the rebaselined ALMA (e.g. 50 instead of 64 antennas)

5 Charge 3: Large Programs, Legacy Programs, and Joint Programs with ALMA

Following thorough assessment of the pros and cons of policies in use at existing ground- and space-based facilities, including those currently operated by the ALMA executives, ASAC is invited to consider policy recommendations on:

1. *how to facilitate joint projects between scientists of different partners*
2. *how to handle large proposals with significant scientific duplication, and*
3. *whether provision needs to be made at this time for legacy projects and, if so, what mechanisms should be used for such projects.*

These complex, often-contentious issues should be addressed in the spirit of demonstrating how ASAC believes their recommendations, if adopted, would maximise ALMA's scientific impact.

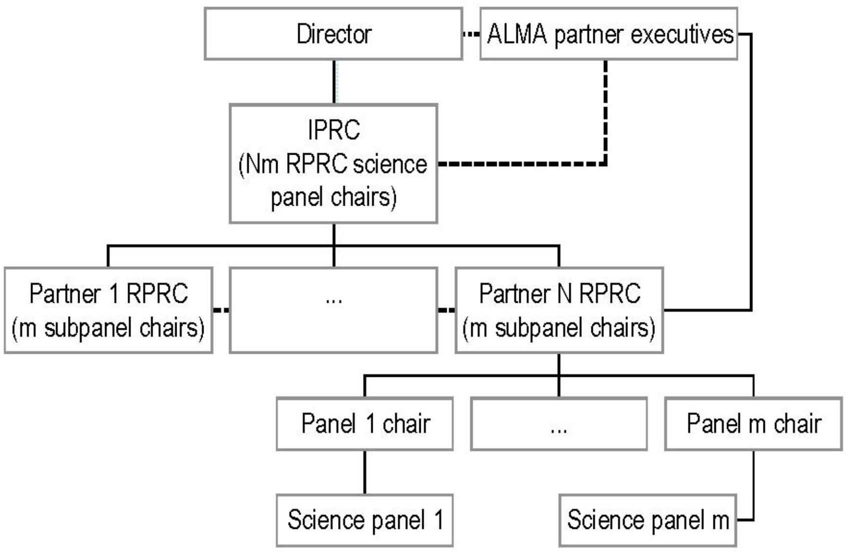

Figure 1: Proposed time allocation structure for ALMA. Each of N partners m science panels receive and rank proposals. The N Regional Program Committees (RPRCs) merge them and submit a single ranked list of their regions proposals to the International Program Committee (IPRC), which resolves duplications and conflicts and submits a final recommended programme to the director.

The ASAC considered the full range of time allocation policies at work in existing international facilities and discussed this important issue extensively in Santiago. The ASAC still believes a project-wide programme review committee is a good model for time allocation, based on sound scientific judgement and input from all partners. Nevertheless, we recognize the desire from the Board to maintain the sovereignty of partners' individual time allocation policies. To maximize the efficiency of the time allocation process and the quality of approved ALMA proposals across the project, while minimizing the administrative burden on both project staff and the user community, we make the following recommendations.

We propose that partners work with a common proposal system, and each partner's executive appoints a regional programme review committee (RPRC), made up of a certain project-wide set of chaired subject-specific subpanels under an overall RPRC chair. Different partners may have different distributions of numbers of subpanel members, reflecting their communities' size and scientific interests. RPRCs would have flexible relationships with and support from their partners' ARCs. Each RPRC will assess the proposals it has received, and submit, through their Executives, a ranked list, merged across all science areas, to a central international programme review committee (IPRC). The IPRC will be composed of the chairs and sub-panel chairs of the RPRCs. The IPRC will meet to recommend a final merged ordered list of projects for scheduling. This process allows regional autonomy in programme definition, while leaving major issues of duplication and conflict to be resolved by the IPRC, a scientific body which carries the memory of the allocation priorities, concerns and discussions of all the RPRCs. The possibility of allowing RPRCs to rank projects so highly that they will be scheduled automatically from that partner's share of ALMA time should be left open, but we hope that such programmes could be shepherded through the IPRC by that partner's representatives. ASAC expects that on average the IPRC will recommend for time allocation a merged list of programmes that will reflect the partners' shares in the project, and supports leaving the process and procedures to be followed by the IPRC to resolve conflicts as flexible as possible. Owing to the wide community of users expected for ALMA, ASAC recommends that the project should maximize the quality of feedback returned, especially to unsuccessful proposers and in the early phases of the project.

ASAC believes that to the greatest degree possible, proposers from multiple partners should be free to ask for time in chosen fractions from different partners, and set their own project size. We believe that ALMA will be sufficiently revolutionary that no special provision is required for large or legacy projects in the early years of operations. Should investigators wish to offer some of the features often found in legacy projects, for example to waive proprietary rights, supply additional data products, or work more closely than usual with project/ARC staff, then we would encourage them to submit these offers in the proposal to the scientific judgement of their RPRCs and IPRC in their proposals.

To make best use of ALMA's status as a world facility, ASAC recommends that a small fraction of non-partner applications should be supported, subject to review by the IPRC, especially as the ALMA project matures. Individual partners should be free to open their time to non-partner investigators at the discretion of their executives and RPRCs. We also recommend that a very easy to use, powerful and open archive be implemented to ensure wide access to ALMA's output and reduce accidental proposal duplications.

The international, two-phase nature of the process, and the reconfiguration timescale of the array favors an annual proposal cycle. ASAC supports annual reapplication (with progress reports in case of long-term projects) for all projects.

The effectiveness of the implemented time allocation procedures must be kept under review at all levels of the project to ensure the maximum scientific promise of ALMA is realized.

6 Charge 4: Demonstration Science

Following from your Sept. 2004 discussions, the ASAC is invited to continue developing proposed "demonstration science" guidelines or policies. The ultimate goals include:

1. *providing a proposed framework (rationale, principles) that establish the value to the astronomical community of accomplishing demonstration science as you envision it during the early operations era; and*

2. *facilitating evaluation of the concept, its proposed timeline and the planning for its implementation during a period when demand for ALMA construction and operational resources will likely be high*

The concept of "demonstration science" first appears in the May 2004 ASAC report, where the ASAC recommended that the ALMA project focus on exploiting its high resolution and high frequency capability to maximize its early science impact. The ASAC also identified two categories of science demonstration projects: public demonstration images for publicity for the general public, funding agencies, etc. and science demonstration projects to demonstrate ALMA's capabilities to the astronomical community. The September 2004 ASAC report elaborated on demonstration science by recommending that it be carried out from end-to-end by a team of community astronomers and ALMA experts. The ASAC suggested that demonstration science should take place before the first open call for proposals and that demonstration science should be delayed until ALMA has about 16 antennas. The draft ALMA Commissioning and Science Verification (CSV) Plan (2004-09-03) covers the period up to but not including Early Science. It describes demonstration science as being part of the science verification process, which tests the system end-to-end (from proposal submission to final science) and involves outside observers.

In comparing the CSV Plan to the two ASAC reports, it becomes apparent that there is some confusion on what is meant by demonstration science and what is meant by science verification and how the two are related. Including two categories of projects under the term "demonstration science" is also confusing. In this discussion, we assume that demonstration science takes place after successful and complete commissioning of the instruments/modes. (It is worth noting that validated CSV data will be made public as soon as possible.) We then suggest replacing the original term "demonstration science" as used in the ASAC reports with the following two definitions:

1. Science verification (SV) = end-to-end test of an ALMA mode done using a science project proposed by an external user; this usage is consistent with the draft CSV plan

2. ALMA Public Image (API) = large-scale project whose primary intention is to convince wider community/public of the value of ALMA

These two types of observations have different requirements and pose different constraints on ALMA and so they are discussed separately below.

6.1 Science Verification

Each mode of ALMA that will be used for early science must be tested by one or more projects in an end-to-end fashion. These tests should be done by SV observations of scientifically interesting targets. Ideally, science verification projects should provide novel and unique information with professional appeal and are also important to show astronomers who are not familiar with radio interferometry what ALMA can do. The APEX commissioning experience suggests that it will be possible to have a big impact with observations at high frequency because the site is so much better than Mauna Kea. This implies that high frequency bands (Bands 7 and 9) should be available from the beginning. Science Verification observations, as described here, play a critical role in the successful construction of ALMA. They also serve an important role in involving the broader community in early use of ALMA. We recommend that a comprehensive programme of Science Verification should be viewed as the start of "Early Science" and thus allow the formal call for proposals for Early Science observations to take place a little later than is currently planned.

Science Verification observations are closely tied to commissioning observations. The CSV plan proposes that the science verification team be responsible for the selection of a small number of proposals of scientific interest. It would be good to supplement them with a single international proto-TAC or an advisory group with a broad range of scientific interests. ALMA staff would need to be involved to assess feasibility and the process would need to be light and nimble. Again based on the APEX experience, we should expect a strong response to any call for science verification projects.

The first SV observations could be made as soon as soon as a single mode of ALMA has been commissioned. Additional work is required on the logistics of SV observations e.g. how to get the word out to the community, the role of the TAC, the degree of focus of the call for proposals, etc. For example, one issue that needs to be considered is whether science verification projects will be limited to a single configuration or allowed two configurations (i.e. compact and extended). The call for proposals for SV should be very specific about which modes are available (e.g. OTF mosaics, observations of moving targets, new baseline range) and solicit projects that exploit all of ALMA's capabilities, especially the new ones. Another possibility is to chose some projects which can be built upon in the future as ALMA grows more powerful, e.g., a low-resolution mosaic of a star-forming region to which higher resolution data could be added later.

The CSV document suggests that very limited reconfiguration will occur during early commissioning (that is, the commissioning before early science) and notes that scheduling the multiple array configurations required to produce good images for demonstration science is a concern. It is important that the configurations commissioned during this period be chosen carefully to allow the best possible imaging.

Both commissioning and science verification are activities that will not be finished until all the modes of the completed ALMA have been tested. However, although science verification observations would continue to be carried out for new modes of ALMA as construction continues, they are expected to have less impact on the community in the later construction years, when many modes and a large fraction of the total time will be available for normal observing with ALMA

6.2 ALMA Public Images

ALMA Public Image (API) observations will be important for ALMA to show progress in construction to the general public and the funding agencies. Although they do not play an important role in the actual construction of ALMA, their overall importance to ALMA should not be underestimated. Ideally, the first ALMA Public Images would be made as early as possible; however, it is difficult to make pretty images with good publicity value with only 6-8 antennas in the array.

It should be possible to generate impressive images of one or two sources by careful choice of science verification projects. For example, if the ALMA project was careful to always observe some unique southern source (such as Eta Carina or Centaurus A) in small mosaic mode with the appropriate correlator setup in each of the six early science configurations at one of the higher frequencies (Band 7 or 9), those data should produce a spectacular image. This type of API observation would not impose much additional stress on scarce ALMA resources and should be considered seriously. As for Science Verification discussed above, this approach implies that individual pads should be commissioned in a sensible order so that good imaging configurations are available.

If early API observations are made with relatively small numbers of antennas, it would be worth considering a second round of API observations when ALMA has 25 antennas or so. These images could illustrate the improvement in the capabilities of ALMA as it grows, and would probably not impose a significant burden on ALMA construction or operations.

7 Additional recommendations

7.1 ALMA configurations design

Al Wootten, interim JAO Project Scientist, gave a report on the recent progress made by the science IPT, including the completion of a new inner (baselines up to 4 km) configuration design document. The committee commends Conway and others for their efforts. In particular, the on-site survey efforts of Roberto Rivera were key to these efforts. **The ASAC endorses the new configuration plan as being adequate to meet the ALMA science goals, while saving the project money**. We encourage continued work (surveys and simulations) on defining the longest baseline configuration. We also encourage continued work on the reconfiguration plan based on the programmes in the Design Reference Science Plan, although this should evolve based on real proposal pressure during ALMA operations.

7.2 ALMA Regional Centers

While not part of the main charge, the ASAC also heard detailed reports on the ARC planning in each region from R. Kawabe, R. Laing, D. Mardones and A. Wootten. The European ARC will have a central node for core functions at ESO, and (as of now) 6 sub-regional centers for user support, software development, training, and other services, depending on local funding. There will be a central coordinating committee made up of representatives of each sub-center, plus the central node ARC manager. ESO is currently seeking an ARC manager. In North American, NRAO/CV will perform the ARC core functions, plus serve as the North American ALMA Science Center. The NAASC currently has only 2 full-time employees, but will be hiring over the coming years. Also, it was noted that Paul van den Bout will be stepping down from the NAASC directorship as of Jan 2006. Chile has started discussions about a Regional Center within their ALMA working group; a post-doc is starting in early 2006 with duties specifically related to the center. Japan is seeking funding for a regional center in Tokyo, which will also host the regional ALMA VO archive.

The ASAC noted that the start-up at all the ARCs appears to be slow. Concern was also expressed about the lack of coordination between regions, with the danger of duplication of efforts. In order to be fully incorporated and knowledgeable of the project, there must be close coordination between the regional centers and the JAO, including scientific staff exchanges, as written in the current operations plan. Appointment of regional directors in all regions, and a science operations head at the JAO, should greatly facilitate, and accelerate, the development of the regional centers, and the definition of the ALMA operations plan. **The ASAC encourages the executives to fill these positions as quickly as possible**.

8 Summary of recommendations

1. With the possible exception of BCP No. 1, we strongly suggest not to implement any of the BCPs marked as "MA" and BCPs 5 and 10 (WVRs and Software).
2. Although these have lower priority with respect to the other items considered above, we suggest to carefully consider the cost-to-impact ratio before accepting any of BCPs 6a, 6b and 7b (Solar Filters, 1/4 Wave Plate for Band 7, and Subarrays).
3. We endorse the 50-antenna array proposed by the project, and recommend no further reduction in antenna number is made. We also strongly endorse the goal of building 64 antennas if further funds become available.
4. We suggest adopting BCPs 3, 4a-g, 11, and 12 (OSF Residence, Miscellaneous Site, Travel and Site Characterization.
5. We suggest to adopt the Science Requirements Document following minor revisions, but note that this document will have to be updated when the rebaselining process will be completed.
6. We propose a Programme Review Committee structure with an International Programme Review Committee empowered to merge ranked lists from Regional PRCs and solve possible duplications.
7. We believe that, at this time, no provision needs to be made for special projects like Large or Legacy Proposals.
8. The structure and policies of the ALMA PRC should be periodically reviewed to monitor and ensure the maximum scientific output of ALMA.
9. We suggest to split the demonstration science concept into Science Verification activities and ALMA Public Images.
10. We propose to adopt the inner (within 4km) ALMA configuration design document.
11. We note the difficulties within each region and the JAO in the ramping up of the ARC and operations planning activities. We recommend to hire key personnell in these areas as soon as possible.

A Evaluation of BCPs scientific impact

The evaluation of the scientific impact on ALMA for each of the proposed BCPs is presented below. For each BCP we report the number, short description and category as in the list prepared by the JAO in early September.

1. **Reduction to 50 antennas [MA]**. 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. It was concluded that a minimum of 50 simultaneously operating antennas is required to achieve the ALMA science goals. We also urge to maintain the goal of building a 64 antenna baseline ALMA array, if possible.

2. **Construct only up to 4km ALMA [MA]**. The ability to reach an angular resolution of 10-100 milliarcsec is also a key to the scientific success of ALMA. The highest angular resolution attainable at high frequency with the 14-km baselines will allow to study the gaps in protoplanetary disks produced by young planets. In addition, the use of long baselines at low frequencies is an essential asset to allow the study of high redshift galaxies and their morphology. In our March 2005 report, we noted 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, if the adoption of this BCP would put them at risk of not being constructed in the first years after the nominal end of construction, then we would strongly advise not to accept this BCP.

3. **OSF Residence [PR]**. Indirect and possibly modest scientific impact. Providing a good working environment is essential if ALMA aims to recruit top level science and technical staff. We suggest to explore options for cost savings in this area with the caveat of providing an attractive working environment for the staff.

4. **Miscellaneous site**.

   (a) **Reduction of antenna stations from 216 to 175 [RE]**. This BCP has two separate components. A reduction from 216 to 186 has been obtained through a careful redesign of the antenna configurations with the goal of minimizing the number of pads without seriously affecting the imaging performances of the array. We fully endorse this first part of the BCP. The second reduction, from 186 to 175 is a consequence of reducing the number of antennas from 64 to 50.

   (b) **High site hangar [RE]**. Very low science impact

   (c) **Remove video surveillance [RE]**. No science impact

   (d) **Overhead lines [RE]**. No science impact

   (e) **Remove 20% furniture cost [RE]**. No science impact

   (f) **Remove sports facility/pool [RE]**. Moderate impact, some recreational facility should be provided to attract and maintain top level staff.

   (g) **Purchase road maintenance equipment [RE]**. No science impact

5. **WVR Production [PR]**. 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 removal of the WVR devices will also significantly affect the calibration accuracy of the ACA and, consequently, the possibility to combine the short spacings data with the baseline ALMA data to reconstruct accurate images of the sky (as required by the Level 1 science goals).

6. **FE support hardware**.

   (a) **Defer solar filters [PR]**. If accepted, this will not compromise the ability of ALMA to achieve Level 1 science goals. Nevertheless, it will prevent to perform observations of the Sun, which is listed as a Science Requirement in the Project Plan. We urge to consider that, for a modest cost savings, the implementation of this BCP would cut an entire science theme from ALMA's capabilities and disenfranchise a fraction of the expected users community.

   (b) **Defer the 1/4 wave plate for Band 7 [PR]**. The 1/4 wave plate is a necessary device if ALMA is going to attempt to reconstruct high accuracy (0.1%) polarization images of astronomical sources. It should be noted that removing this device will not prevent ALMA to perform full polarization observations. This device was especially designed to achieve the highest possible calibration accuracy in Band 7, i.e. in a spectral region where the most interesting polarization measurements of molecular line and dust emission could be attempted.

7. **Back End descopes**.

   (a) **Defer one IF [MA]**. 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.

   (b) **Defer two (of four) subarrays [PR]**. The ASAC felt that ALMA operations can function well, in the short term, with just two subarrays, one for the science observations and one for technical work (measuring baselines for recently moved antennas, etc.) However, this would preclude simultaneous science observations of more than two frequencies, which may affect observations of objects with rapid variability, including perhaps Solar flares. Additionally, there are a number of cases in which a number of subarrays larger than two would be desirable. For example, for moving antennas out of the compact configuration, antennas along the transporter access path shall be pointed away from the path. If one subarray is already being used for technical activities on other antennas, then the second subarray will have to be used to move antennas out of the path and observations will have to be stopped with *all* antennas for the time required for the move. As a second example, if the array will be equipped with a receiver band only in a subset of the total numer of antennas, then a dedicated subarray would be needed to observe at that frequency band with those antennas. If the second subarray were in use for technical work, then all the antennas without that particular receiver band would have to stay idle.

(c) **Use AM LO scheme [MA]**. The ASAC notes that this option will probably cause higher phase noise, which will have a negative impact on high frequency and long baseline observations. Under the current specifications, the electronics are already the limiting factor in the best 5% of the weather. For the time being we lack a detailed study of possible AM LO schemes that could allow to estimate this effect. Given the adverse impact on the array performance, we do not recommend to implement this BCP. If it will be considered for implementation, we suggest to first perform an analysis of the expected performance degradation and their quantitative impact on science observations.

(d) **Remove EDFA from DTS [MA]**. The ASAC felt that a decision on this BCP should be taken only after a detailed technical assessment of the need for this device has been performed.

8. **Front End Bands: defer production runs of band 6 and/or 7 and/or 9 [MA]**. 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 receiver bands 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.

9. **Front End Polarization: defer one polarization in FE receiver units [MA]**. The removal of one polarization would have a major scientific impact in that the sensitivity of each affected band would be reduced by a factor of $\sqrt{2}$, which is equivalent to a reduction of $\sim$40% in the number of operating antennas. In addition, polarization observations would not be possible for each affected band.

10. **Software descope: defer 20% in computing deliverables [PR/MA]**. Accepting this descope would imply the termination of software development early in the construction phase of ALMA, keeping only the basic activities of maintenance. The effect of this is not quantified in detail, but, most likely, will affect all the high level software functionalities. Not all the items listed in the BCP description have the same priority level, but the adoption of this BCP as presented here will drastically affect not only the ability to take advantage of the best weather conditions and the ability to maximize the observatory efficiency, but also the nature of ALMA as a wide community instrument. Such a descope would seriously jeopardize the community support of

the ALMA project. If a descope in this area is going to be considered, the ASAC believes that a more detailed proposal of descope options should be presented for discussion of the scientific impact.

11. **Travel**. If such a reduction is feasible for a distributed project like ALMA, we will certainly support it.

12. **Site characterization**. Some site testing campaigns should be maintained.

B Charge to ASAC Meeting of February 2005

General Charge

The ALMA Scientific Advisory Committee (ASAC) will provide advice on those major issues presented to the ASAC by the Project Scientist or the ALMA Board that affect the science capabilities of ALMA and require decisions to be made or priorities to be set regarding project tasks and resources. The ASAC will be kept informed of progress and developments in ALMA through periodic reports and briefings by the Joint ALMA Office and shall meet at least twice a year. Reports of the ASAC's deliberations will be made in writing to the Board by the Chairperson of the ASAC following each Committee meeting, on a schedule specified in advance by the Board. The Project Scientist serves on the Committee ex officio.

Revised Charge for the Meeting of October 1-2, 2005

The ASAC is requested to consider the following topics, and to make recommendations to the Board that include your priority or time scale where your recommendations require expenditure of ALMA's fixed resources:

1. The Board's most urgent need is for ASAC to review critically the materials on rebaselining being prepared by the JAO and comment upon the impact of the proposed options on the scientific capabilities of ALMA.

2. Please review the revised Science Requirements Document and make recommendations concerning its adoption by the Board.

3. ASAC is invited to continue its considerations of this September, 2004 charge, which may be combined with the continued development of ideas for implementing demonstration science elaborated at the same meeting:

   Following thorough assessment of the pros and cons of policies in use at existing ground- and space-based facilities, including those currently operated by the ALMA Executives, ASAC is invited to consider policy recommendations on:

   (a) how to facilitate joint projects between scientists of different partners,

   (b) how to handle large proposals with significant scientific duplication, and

   (c) whether provision needs to be made at this time for legacy projects and, if so, what mechanisms should be used for such projects.

   These complex, often-contentious issues should be addressed in the spirit of demonstrating how ASAC believes their recommendations, if adopted, would maximize ALMA's scientific impact.

4. Following from your Sept. 2004 discussions, the ASAC is invited to continue developing proposed "demonstration science" guidelines or policies. The ultimate goals include:

   (a) providing a proposed framework (rationale, principles) that establish the value to the astronomical community of accomplishing demonstration science as you envision it during the early operations era; and

(b) facilitating evaluation of the concept, its proposed timeline and the planning for its implementation during a period when demand for ALMA construction and operational resources will likely be high.

Please deliver your written report to the ALMA Board four weeks following the meeting.

C ASAC members and attendees

ASAC Members in attendance

Andrew Blain (Caltech)
Chris Carilli (NRAO Socorro)
Yasuo Fukui (Nagoya University)
Diego Mardones (U. Chile)
Munetake Momose (Ibaraki University)
Lee Mundy (Maryland)
Jean Turner (UCLA)
Christine Wilson (McMaster University) – Vice-Chair
Jose Cernicharo (DAMIR–CSIC, Madrid)
John Richer (Cambridge)
Peter Schilke (MPIfR, Bonn)
Leonardo Testi (Arcetri) – Chair
Ewine Van Dishoeck (Leiden)
Satoshi Yamamoto (Tokyo)

ASAC Ex-officio Members

Ryohei Kawabe (NAOJ)
Tom Wilson (ESO), via telecon from Granada
Al Wootten (NRAO)

Project and Partner Representatives

Massimo Tarenghi (JAO)
Anthony Beasley (JAO)
Richard Murowinski (JAO)
Hans Rykaczewski (ESO)
Ryusuke Ogasawara (NAOJ)
Darrel Emerson (NRAO), via telecon from Tucson
Robert Laing (ESO)
B. Vila-Villaro (NAOJ)

Appendix D: ASAC Rules of Procedure

1. The ASAC is an advisory body, and its decisions are to be reached by consensus, so complicated voting rules are not required.
2. No quorum is necessary for the meeting to be deemed 'official' but it must be approved of and chaired by either Chair or Vice-Chair. If neither of these can chair the meeting, the members present shall nominate an acting chair.
3. Decisions shall be by consensus, on motion put by Chair
4. Dissenting opinions shall be recorded.
5. Any item can be added to agenda at any time by consensus of committee.