ALMA Science Advisory Committee

Report from Meeting of January 28-29, 2006

University of Maryland, U.S.A.

ALMA Scientific Advisory Committee

C. Wilson (Canada, chair), J. Richer (UK), S. Aalto (Sweden), A. Blain (USA), C. Carilli (USA), J. Cernicharo (Spain), Y. Fukui (Japan), D. Mardones (Chile), L. Mundy (USA), L. Testi (Italy), J. Turner (USA), T. Yamada (Japan), S. Yamamoto (Japan)

Ex-officio

R. Kawabe (Japan), T. Wilson (Germany), A. Wootten (USA)

Other participants

A. Beasley(JAO), D. Emerson (NRAO), B. Glendenning (NRAO), J. Hesser (HIA), D. Iono (Japan) R. Laing (ESO), D. Shepherd (NRAO), M. Tarenghi (JAO), K. Tatematsu (Japan), S. Takakuwa (Japan), B. Vila-Villaro (Japan)

1 Executive Summary and Recommendations

The ASAC considered three charges from the ALMA Board at its January 2006 meeting at the University of Maryland.

Science Software Development: The ASAC is pleased with the accomplishments of the science software development team. We believe that the biggest continuing risk is failure in user adoption and recommend that a plan be formulated to retire this risk in 2009 and 2009. The science software subsystems that are most at risk in this area are the off-line and the pipeline software; we suggest exploring using existing interferometers as testing grounds for the pipeline. We also recommend that the Software IPT develop a plan with milestones for software development for 2008 to 2010 and review the FTEs required to support science software testing and commissioning over this period. It is essential that the ALMA project be 100% committed to sole use of the ALMA science software during the commissioning period

Scientific Integration of the ACA: There has been substantial progress in the integration of the ACA into the baseline ALMA project. The work on calibration has revealed the need for a new calibration requirement, namely the cross-calibration accuracy between the ACA and the 12m array. In our report, we propose precise definitions for this requirement and three other calibration requirements that are already in use for ALMA but are not always clearly defined. A “combined array” mode, wherein cross-correlations between antennas in the ACA and the 12m array are calculated, has clear benefits for ALMA, particularly in the area of calibration, and we recommend that development in the baseline ALMA project include the possibility of operating in a combined array mode. The addition of the ACA increases the complexity both in the observing modes and in scheduling and we recommend that the project carry out a detailed study of these areas. The proposal to use the total power antennas of the ACA for on-the-fly scanning while also chopping has the potential to adversely affect the quality of the total power measurements and we recommend that this technique be studied carefully. Finally, we note that the Design Reference Science Plan does not include projects using receiver bands 4, 8, or 10, or detailed information for the use of the ACA, and we recommend that the DRSP be updated to include this missing information.

Performance of the Hybrid ALMA Array: In concordance with our previous reports, the ASAC believes that having two designs for the 12m antennas should not preculde any of the Level 1 science goals for ALMA, including imaging fidelity and wide-field polarization, as long as tight control of key antenna specifications is maintained. We recommend that the project urgently conclude the final optimization of the antenna design to realize any possible gains in efficiency. It is important to continue simulation efforts to understand the effects of the two designs on imaging performance. The ASAC recommends that the Antenna or System Engineering IPT use EM modeling to estimate the beam and its sidelobes and that these results be fed into further work by the Science IPT on mosaic image fidelity and wide-field polarization imaging. These simulations are necessary not only for the 12m array but also for images combining data from the 12m array and the ACA.

2 Introduction

The ALMA Science Advisory Committee (ASAC) met on January 28 and 29, 2006 on the campus of the University of Maryland. Two ASAC members (A. Blain and S. Aalto) were not able to attend the meeting due to conflicts. 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 Lee Mundy and NRAO for arranging and sponsoring the logistics of this meeting on very short notice.

From the presentations of the Director Tarenghi and Project Manager Beasley, the ASAC learned about the progress that has been made in placing key construction contracts and in approving plans to hire local staff in Chile. The Operations Working Team is expected to meet soon to make progress on the Operations Plan, with a goal of completing a revised document later this year. Now that the delivery dates for the 12m antennas are known, work will get underway to complete plans for assembly, integration, verification, and commissioning (AIVC) that include the antennas for the Atacama Compact Array (ACA). Construction is continuing in Chile, with closing in of the AOS facility planned for March and plans for a temporary AIVC building at the OSF to allow work to start on the first Vertex antenna early in 2007.

The ASAC also heard a presentation on the progress of the ALMA-J project from ALMA-J Project Scientist R. Kawabe, including the collaboration with ASIAA/Taiwan, the schedule for the ACA 12m antennas to arrive in Chile, and the plans for various internal reviews of the ALMA-J project in the coming year. A. Wootten and T. Wilson reported on activities in the Science IPT, including installation of the two prototype water vapor radiometers at the Submillimeter Array in Hawaii. L. Testi, C. Carilli and S. Yamamoto reported on issues discussed by the regional ALMA Science Advisory Committees, while A. Wootten, T. Wilson, and R. Kawabe reported on progress with the ALMA Regional Centers (ARCs). Finally, J. Cernicharo gave an update on plans for the pan-ALMA science meeting in Madrid in November 2006.

3 Charge 1: Science Software Development

Review progress in the science software development for ALMA (e.g., plans for the observing tools, pipeline system and archive) and how they will meet the top level user requirements.

The ASAC received an excellent presentation from Brian Glendenning and Debra Shepherd covering the status of the science software development and testing. This software divides into four major areas: Archive, Observing Tool, Off-line software, and Pipeline. Overall, we are pleased with the accomplishments.

The archive is in the early stages of development. We strongly agree with the decision to follow in the footsteps of the ESO experience. This strategy will enable ALMA to take advantage of ESO's experience with database software, infrastructure, and bulk data handling.

The Phase II Observing Tool is proceeding nicely and looking useful as an expert tool. There is considerable additional work needed to establish the science view for mapping science goals into the system setup. This will be the default mode for expert and novices alike, with experts fine tuning the setup later in expert mode. The Observing Tool will greatly enhance ALMA's usability for the wide astronomical community. We support the development team's plan to have frequent cycles of development and user testing. We also support their recent conversations with NRAO VLA about the proposal submission software (Phase I) and hope for synergies in this area.

There is continuing progress on the off-line software. We like the testing methodology with strong user feedback. The development plans through mid-2007, which culminate with a general release of the re-formed AIPS++, set a good path for the project. We encourage the software group to engage in more testing with a broader group of users (including skeptical users) to reap first-reaction opinions and novice troubles.

The pipeline is making progress, but it is naturally dependent on the off-line software development. The presentation did not cover the details of the software infrastructure or hardware implementation so we could not evaluate those aspects.

The biggest continuing risk to the science software is failure in user adoption. The ASAC recommends that a plan be formulated to retire this risk in 2008 and 2009. We like the proposal to use the ATF to do early testing but do not consider this sufficient. The project should look into using existing interferometers (VLA, IRAM Millimeter Array, CARMA, Nobeyama Millimeter Array, and Submillimeter Array) as testing grounds for the pipeline software. This can be done through agreements with the observatories to do parallel processing of archival or real-time data side-by-side with the observatory's normal processing. The project should also look to adoption of ALMA software in interferometry schools no later than 2008. While we are aware that these steps will not completely eliminate problems that are specific to ALMA, they should lead to a more mature, robust, and accepted software by the time that significant ALMA data arrive in 2010.

The ASAC recommends that the project be 100% committed to sole use of the ALMA science software during commissioning. This means that the commissioning people are committed to using the software and that the software writers are committed to giving the commissioning effort total support. This mutual commitment is essential to long-term success.

The ASAC strongly recommends that the Software IPT review the FTE requirements to support science software testing and exercising in 2008-2009 and commissioning support in 2007-2010, and plan milestones for 2008 to 2010.

4 Charge 2: The Atacama Compact Array

Review the plans and progress towards the scientific integration of the ACA into the baseline ALMA project, e.g. software and calibration issues.

The ASAC heard presentations from members of ALMA-J on the integration of the ACA into the baseline ALMA project to form the enhanced ALMA. There has been substantial progress by the ALMA-J project in this area, which includes detailed planning of calibration, usage, and operations concepts.

The ACA, consisting of the 7-m array and the four total power 12-m antennas, will be an extremely valuable enhancement to the ALMA project. The ASAC is interested in the scientific potential of the “Combined Array” and recommends that the development in the baseline ALMA project include the possibility of operation as a Combined Array, especially for calibration purposes as noted below. The Combined Array may be used for a very small fraction of ALMA projects, but it may provide important capabilities, possibly including an improved sensitivity for those projects. Nevertheless, the priority of ACA must be to provide short spacing information to be combined with the 12m array, and we anticipate that the ACA will spend most of its time operating independently to obtain the short spacing data that are required for roughly one-quarter of ALMA projects.

Calibration has received significant attention by the ALMA-J group. Their work has uncovered a need for definition and clarity in the calibration specifications, as well as the need for a new calibration requirement.

The current ACA expectation for “absolute flux calibration” is 5%. This figure, while meeting ALMA specifications for images made with the ACA only, is not sufficient to meet the imaging requirements for images made with data combined from ACA and 12-m array observations. With a 5% calibration uncertainty between the two datasets, such images would be effectively limited to an image fidelity of 20:1. Higher accuracy is possible with cross-calibration between the two arrays. Cross-calibration will require a complex and carefully coordinated sequence of observations to be executed by the two arrays. Cross-calibration thus stands out as a new calibration requirement and the ASAC proposes the following definitions for calibration accuracy requirements:

- *repeatability*: agreement of fluxes for a non-variable point source observed at a specific frequency within a given band at different times
- *relative accuracy*: accuracy of flux ratios from measurements in different frequency bands
- *cross-calibration accuracy*: agreement of fluxes at a given frequency measured on similar baselines for the 12m array and the ACA
- *absolute calibration accuracy*: calibration with respect to a specific calibration standard source

There are a number of possible ways to achieve cross-calibration of the 12-m and ACA arrays, e.g.,

1. via amplitude self-calibration on overlapping baselines using a strong target source,
2. via observations of a non-variable calibrator source to tie together observations with the ACA and the 12-m array made at different times,
3. via simultaneous observations with the 12-m and ACA not involving cross-correlations between 7m and 12m antennas,
4. as part of the observing process for 12-m + ACA projects using the "Combined Array" mode.

For the last two options, since the ACA requires four times the observing time to achieve the same sensitivity as the 12-m array, cross-calibration will occur only part of the time or in dedicated calibration sessions where the two arrays will simultaneously observe the same calibrator.

Since the addition of the ACA to ALMA adds a number of possible observing modes, the ASAC recommends that the project carry out an analysis of what calibration techniques will be most appropriate in the various modes that include the ACA 7-m array. For example, high accuracy bandpass calibration will be difficult for the ACA 7-m array, since sensitivity is an issue for the smaller antennas. A strategy needs to be developed to help bandpass calibration be accomplished efficiently, potentially using the Combined Array mode. In addition, simulations may be needed to study the cross-calibration issue and determine the requirements on cross-calibration accuracy that are needed to meet the Level 1 science requirements. Also, polarization calibration will be difficult for the ACA by itself, for the ACA plus 12-m array, or for the Combined Array. Since there will be a number of different kinds of antennas in ALMA, a general study of the problem of polarization calibration with ALMA is warranted (see Charge 3 discussion).

Another calibration difficulty may arise with the plan for chopping during on-the-fly (OTF) scanning of the total power antennas in the ACA. It is possible that this method could adversely affect the quality of the total power measurements. The ASAC recommends that this observing technique and its effect on the data quality be studied carefully.

Scheduling the enhanced ALMA will be more complicated than with the 12m array alone. Both calibration constraints and the operation of the Combined Array will certainly complicate scheduling. It is possible that the effects of these complications have not yet been fully worked out. The ASAC recommends that the project carry out a detailed study of the scheduling impact of all modes offered by the enhanced ALMA.

The ASAC feels that, aside from the calibration and scheduling issues that still need to be fully worked out for the enhanced ALMA, the software integration of the ACA into the baseline ALMA effort seems to be well-advanced.

The ASAC notes that the Design Reference Science Plan (DRSP) does not include the ACA, beyond a simple indication of which projects will need short spacings. For example, Bands 4, 8, and 10 are not included, nor are various ACA modes included in any detail. Since the DRSP is being used by the software and operations groups, it is important that the DRSP adequately reflect the new modes and projects that are possible with the enhanced ALMA for design and development purposes.

The ASAC recommends that the DRSP be updated to include new projects for Bands 4, 8, and 10 as well as more detailed information related to the ACA.

5 Charge 3: The Hybrid ALMA Array

Review the existing analysis of the polarization and mosaicing performance of the hybrid ALMA array and consider the priority and timescale for further analysis by the Science IPT.

The ASAC has reviewed the scientific impact of having two antenna designs as part of the "12m array" for ALMA. We heard presentations from T. Beasley on the cost analysis and A. Wootten on the work by the science IPT. Overall, as in previous reports, the ASAC concludes that two 12m antenna designs should not preclude any Level 1 science goals, including imaging fidelity and wide field polarization (see also April 2003 ASAC report). However, we emphasize that this statement requires tight control of the antenna specifications such as pointing, baselines, non-common-mode phase effects (eg. sag, fiber runs and thermal effects...), alignments, panels, fast switching response, and general antenna performance optimization. We also emphasize that having two 12m antenna designs will require added science effort in:

- Algorithm development and testing (software)
- Data processing (i.e. 10% of programs will need three times longer to process; operations)
- Antenna optimization (commissioning)
- Long term monitor and trends analysis, eg. characterization of fast switching response, antenna aging, etc. (operations)

The ASAC recommends that the project urgently consider the final optimization of the antenna design, such as setting the shape of the inner parts of the feed legs to avoid ground spillover, tilt of the subreflector, etc. These issues, which could result in real efficiency gains, need to be settled before the contractors finalize the design, since further changes then become very expensive.

In terms of wide-field polarization, the dominant term is due to the four "polarization lobes" in the main beam, which are inherent to any parabolic antenna, independent of design. The position of the quadrupod legs is a perturbation on this main beam effect. There is also a contribution from beam squint (different pointing centers for L and R). In terms of wide-field mosaicing, if both antennas meet the stringent specifications, then having two antenna designs should not preclude meeting the requirements for wide-field mosaicing with ALMA. However, it clearly adds to the complexity of data reduction and software requirements. The ASAC recommends that the Science IPT continue its effort on wide-field polarization and mosaic simulations. The ACA team is performing such simulations, and we recommend close coordination, although simulations using two different platforms (miriad vs. aips++) would be useful.

We also point out that, at the higher frequencies, it is unclear that two different antenna designs will dominate over general "Ruze" differences or antenna surface/feed illumination 'noise'. The ASAC recommends that the Antenna or System Engineering IPT try EM modeling (eg. Grasp8) to get an estimate of the primary beam, in particular a good measure of the first sidelobe, which may dominate mosaic image fidelity. The Science IPT should then use the results of that modeling to determine the effect of the different beams on mosaic image fidelity. The imaging simulation effort could also be coordinated with a similar effort being done for the ACA. The ASAC also sees this simulation effort as raising the general issue of new software development for ALMA, in this case the need for new software to deconvolve with two different primary beams.

6 Summary of recommendations

1. The ASAC recommends that the project urgently consider the final optimization of the antenna design, such as setting the shape of the inner parts of the feed legs to avoid ground spillover, tilt of the subreflector, etc. These issues, which could result in real efficiency gains, need to be settled before the contractors finalize the design, since further changes then become very expensive.

2. The ASAC recommends that the Antenna or System Engineering IPT try EM modeling (eg. Grasp8) to get an estimate of the primary beam, in particular a good measure of the first sidelobe, which may dominate mosaic image fidelity. The Science IPT should then use the results of that modeling to determine the effect of the different beams on mosaic image fidelity.

3. The ASAC recommends that the Science IPT continue its effort on wide-field polarization and mosaic simulations.

4. The biggest continuing risk to the science software is failure in user adoption. The ASAC recommends that a plan be formulated to retire this risk in 2008 and 2009.

5. The ASAC recommends that the project be 100% committed to sole use of the ALMA science software during commissioning.

6. The ASAC strongly recommends that the Software IPT review the FTE requirements to support science software testing and exercising in 2008-2009 and commissioning support in 2007-2010, and plan milestones for 2008 to 2010.

7. The ASAC recommends that the development in the baseline ALMA project include the possibility of operation as a Combined Array, especially for calibration purposes as noted above.

8. Since the addition of the ACA to ALMA adds a number of possible observing modes, the ASAC recommends that the project carry out an analysis of what calibration techniques will be most appropriate in the various modes that include the ACA 7-m array.

9. The ASAC recommends that the observing technique of chopping during on-the-fly (OTF) scanning of the total power antennas and its effect on the data quality be studied carefully.

10. The ASAC recommends that the project carry out a detailed study of the scheduling impact of all modes offered by the enhanced ALMA.

11. The ASAC recommends that the DRSP be updated to include new projects for Bands 4, 8, and 10 as well as more detailed information related to the ACA.

A Charge for the ASAC Meeting of January, 2006

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.

Charge for the Meeting of January 28-29, 2006

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 ALMAs fixed resources:

1. Review progress in the science software development for ALMA (e.g., plans for the observing tools, pipeline system and archive) and how they will meet the top level user requirements.
2. Review the plans and progress towards the scientific integration of the ACA into the baseline ALMA project, e.g. software and calibration issues.
3. Review the existing analysis of the polarization and mosaicing performance of the hybrid ALMA array and consider the priority and timescale for further analysis by the Science IPT.

Please deliver your written report to the ALMA Board at least two weeks before the 22-24 March 2006 meeting in Kyoto.

B ASAC members and attendees

ASAC Members in attendance

Chris Carilli (NRAO Socorro)
Yasuo Fukui (Nagoya University)
Diego Mardones (U. Chile)
Lee Mundy (Maryland)
Jean Turner (UCLA)
Christine Wilson (McMaster University) – Chair
Jose Cernicharo (DAMIR–CSIC, Madrid)
John Richer (Cambridge) – Vice-chari
Peter Schilke (MPIfR, Bonn)
Leonardo Testi (Arcetri)
Satoshi Yamamoto (Tokyo)
Toru Yamada (NAOJ)

Apologies

Andrew Blain (Caltech)
Susanne Aalto (Onsala)

ASAC Ex-officio Members

Ryohei Kawabe (NAOJ)
Tom Wilson (ESO)
Al Wootten (NRAO)

Project and Partner Representatives

Massimo Tarenghi (JAO)
Anthony Beasley (JAO)
Darrel Emerson (NRAO)
Robert Laing (ESO)
B. Vila-Villaro (NAOJ)

Other Participants

Brian Glendenning (NRAO)
Jim Hesser (HIA)
Daisuke Iono (NAOJ)
Debra Shepherd (NRAO)
Ken Tatematsu (NAOJ)
Shige Takakuwa (NAOJ)

C 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.