Report of the ALMA Science Advisory Committee to the Board

October 2006

ASAC Committee

John Richer (Cambridge, **chair**), Lee Mundy (Maryland, **vice-chair**), Leonardo Testi (Arcetri), Pepe Cernicharo (Madrid), Susanne Aalto (Onsala), Jean Turner (UCLA), Andrew Blain (CalTech), John Bally (Colorado), Christine Wilson (McMaster), Kotaro Kohno (Tokyo), Satoshi Yamamoto (Tokyo), Toru Yamada (Subaru),

Apologies from Peter Schilke (Bonn) and Diego Mardones (Chile)

Invited Attendees and Guests

Ryohei Kawabe (NAOJ), Tom Wilson (ESO), Al Wootten (NRAO), Robert Laing (ESO), Darrel Emerson (NRAO), Balthasar Vilar (Vilaro NAOJ), Paula Andreani (ESO), John Hibbard (ESO), Hans Rykoczewski (ESO), Adrian Russell (NRAO), Robert Lucas (IRAM), Jeff Mangum (NRAO), Ethan Schreier (AUI), Phil Puxley (NSF), Koh-Ichiro Morita (NRO), Gianni Raffi (ESO), Sheng-Yuan Liu (ASIAA).

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. Review the revised Commissioning and Science Verification Plan for ALMA
2. Review the revised Calibration Plan for ALMA
3. Review the existing work on developing complete descriptions of the ALMA observing modes (e.g. software, hardware etc.) and make recommendations as to their relative priority
4. Any other matters that you want to bring to the Board's attention.

Introduction

The fourteenth face-to-face meeting of the ASAC was kindly organised by Leonardo Testi and colleagues in the tranquil grounds of Convitto della Calza in Florence, and sponsored by the INAF-Departimento Progetti. We had visited the Convitto before in February 2001, in the early days of ALMA design and development. Incredible progress towards realising ALMA's ambitious scientific vision has been made since then. We are grateful to the local organisers, and all those who took time out from their busy schedule to give presentations to the ASAC. We were delighted to have interested observers from NRAO, NSF, AUI and ESO; and for the first time, an observer from ASIAA attended, illustrating the growing global participation in ALMA.

1 Charge 1: Commissioning and Science Verification (CSV)

Review the revised Commissioning and Science Verification Plan for ALMA

The ASAC thanks Robert Laing and Balthasar Vilar-Vilaro for their presentations, and was satisfied that the list of complex and interleaved tasks necessary for the commissioning and science verification (CSV) of both ACA and the baseline ALMA to the early science (ES) stage was sound and sensible. We have several suggestions to highlight areas where we thought that this carefully considered plan could encounter difficulties, but stress that these are caveats, and that we judged the basic plan to be sound and to need no fundamental revision.

We considered that a more detailed CSV plan was needed in several areas as CSV approaches: i) for the joint commissioning of the ACA and ALMA, in particular concerning the process of integrating the use of their distinct correlators; ii) for the list of correlator modes to be commissioned during CSV and ES; iii) for the range of polarization and mosaicking modes to be commissioned towards the end of CSV.

We appreciated that single-dish total power modes and large mosaics would have lower priority than single-field interferometric imaging during initial CSV activities.

It is clear that aspects of CSV involve research work, for example the implementation of phase correction, and the evaluation of trade offs between different calibration strategies. In particular, we consider that the resources required to carry out these tasks could be significant, and may be currently underestimated. We suggest that the CSV team gather suitable supporting data as early as possible in the process, at the possible expense of delaying CSV tasks that do not require research work. In the history of commissioning other facilities we note that planned schedules have rarely been met. Furthermore, the ASAC is concerned to ensure that throughout the CSV plan enough flexibility is retained in terms of both time and the allocation of staff and resources to allow the efficient resolution of problems that arise: this is especially important in light of the aggressive timescale and staffing levels foreseen for CSV.

The commissioning of ALMA presents unique challenges. There are large and steadily growing numbers of subcomponents to integrate, and a large number of duplicated and co-dependent subsystems. With the combination of turno, 24-hour operation, and a harsh physical environment, the ASAC was keen to ensure that the best support be provided to the Project Scientist in terms of resources to support communication, administration, documentation and delegation in order to accomplish CSV according to the planned schedule. The ASAC was very supportive of the idea that there be two commissioning scientists to support the project scientist in the day-to-day execution of his/her duties, and to help with the retention of knowledge on progress as staff rotate in and out of the OSF.

While it remains relatively modest, given the size of the project, the number of staff required in the CSV plan represents a significant fraction of those trained to work in the area of submm-wave instrumentation and interferometry worldwide. The ASAC recommends a diligent and continuous effort on behalf of the project to identify and recruit the best staff for the CSV team. Furthermore, the ASAC considered that ALMA and the Executives should think hard about what incentives it can offer to attract and retain the most qualified candidates to the CSV team.

The ASAC noted the extension of the CSV period to 20 months and the consequent delay to the start of early science. The ASAC has previously had concerns about the aggressive CSV schedule, and endorses the revised baseline. It notes that ALMA will now enter the ES phase as a more powerful and capable instrument with 15 antennas and 6 observing bands, ready to provide unmatched scientific capabilities. An announcement of the capabilities of ALMA in the ES phase 12 months after the start of CSV was considered as a reasonable timescale on which the project scientist can make concrete suggestions, and the community can be given suitable time to prepare for ES. The plan for the execution of projects during CSV and ES, including ALMA Public Images (APIs), under the control of the project scientist with the help of suggestions from the community, is sound. Prior to the establishment of a public archive, the ASAC hopes that the dissemination of this non-proprietary data to the community can be achieved without undue burden on CSV staff.

The ASAC supports the idea that a sabbatical visitor program be considered: the aim here would be to assist the project scientist to continue commissioning once ES begins, and the array grows beyond 15 antennnas.

All of these issues can probably be most fruitfully considered after a Project Scientist is appointed and starts to integrate their skills and style of work with the project staff that are currently planning for CSV.

2 Charge 2: Calibration

Review the revised Calibration Plan for ALMA

We commend the ALMA project for providing a comprehensive calibration plan that recognizes the ten or so types of calibration that ALMA needs to provide. Jeff Mangum and Balthasar Vilar-Vilaro presented the plans for ALMA and ACA calibration, and each of the calibration examples documents was reviewed by an ASAC member. It is clear that although much of the theoretical groundwork has been done thoroughly, there remains a lot of research work to be done to develop optimal calibration schemes once ALMA starts to function as an interferometer on the high site. This is particularly true for phase, amplitude and flux calibration. This research activity is a key part of CSV and the project should ensure sufficient resources and expertise are available to carry it out. ACA calibration planning is of course at an earlier stage to that of the main array, and presents unique challenges: further work is needed to finalise the plans for joint calibration of the arrays.

It is vital that the hardware necessary for calibration is well-tested, and ready for use on the first antennas at the OSF. This includes the production water vapour radiometers, and the dual-load device for amplitude and flux calibration. Contracts for the production of these subsystems have not yet been signed, and it is important that this is rectified in a timely manner to avoid delays at the OSF during the CSV phase.

The ASAC highlights the importance of the calibration activities being carried out under the leadership of Mangum and Vilaro. The ASAC was encouraged to see that the calibration leads were aware of relevant calibration activities at other observatories and space missions, and were starting to make links to these projects. This is a time consuming task. Specific projects which also need lists of point sources for which some or all parameters such as flux, position, spectrum, polariza-

tion, and structure are known include ASTRO-F/Akari, Herschel/Planck, JWST, SMA, CARMA, IRAM, ATCA, NMA, and VLA/VLBA/EVLA. It is important that ALMA benefit as much as possible from specific calibration strategies being used at other interferometers, be aware of problems being encountered with these strategies, and the approaches being used to mitigate them. The calibration leads will clearly need to be intimately connected to the teams responsible for commissioning and science verification activities in Chile. We suspect that a significant amount of CSV time will be devoted to the observation of secondary calibrator sources to build up an extensive list of objects that have been observed with the ALMA systems and referenced to primary calibrators.

Several detailed issues were raised by the ASAC during their deliberations of the detailed calibration documents, and these will be passed on to the Project Scientists directly.

3 Charge 3: Observing Modes

Review the existing work on developing complete descriptions of the ALMA observing modes (e.g. software, hardware etc.) and make recommendations as to their relative priority

Robert Lucas presented the work that has been done from the software side developing observing modes for ALMA. These modes include ones that will be used primarily by observatory staff (e.g. optical pointing, holography) and ones that will be used for science observations (e.g. interferometric mosaic observations). Al Wootten noted that the new modes for the baseline correlator including the tunable filter banks are not yet available but are expected in the near future.

The ASAC is pleased to see the progress in developing observing modes that will be used by the observatory for commissioning. There has clearly been significant progress in the last year; two modes (optical pointing and holography) have been developed and either partially tested or are ready for testing with the hardware. The general prioritization given from the software perspective for developing the modes to be used by observers is reasonable, but much more work remains to be done on developing sub-priorities within the modes and fleshing out the details of the modes. For example, the ALMA correlator will be powerful but complicated; developing a priority list of the first few correlator modes to be tested should be a high priority as soon as the revised list of correlator modes is available. There will also need to be a new consideration of the configurations to be available for early science now that it is clear that more than 8 antennas will be available. These tasks will obviously involve the Project Scientist and the ASAC would like to be consulted again when the work is further developed.

At the meeting, Al Wootten presented details of a recent proposed change to the IF frequency range for Band 6, which would have technically precluded the interesting scientific mode of observing the ^{12}CO, ^{13}CO and C^{18}O J=2-1 lines simultaneously. This would have been a major loss to ALMA's capabilities. We understand that subsequent to the meeting, a specification change was adopted that allowed this mode to survive, although the change restricts somewhat ALMA's spectral flexibility in this band. This example highlights the need for the new Project Scientist to maintain with vigilence the scientific specifications of ALMA, and defend them where possible against loss of scientific capabilities as systems are developed.

Rapid antenna tracking (at greater than the standard sidereal rate) will be necessary for certain transient solar system objects, such as near-Earth asteroids. ALMA has specifications on how

much faster than the sidereal rate it must be able to track without a significant drop in the signal-to-noise ratio. However, it is important that even faster tracking rates be allowed by hardware and software, if possible, to be able to follow unusual or unexpected transient events. The ASAC recognizes that these faster tracking rates would involve a decrease in the signal-to-noise ratio if the delays cannot be updated sufficiently quickly.

Overall, the ASAC felt that good progress was being made towards implementing observing modes as concrete tasks, but that a detailed examination of the specification of the modes and their priorities was premature given the state of software development and the Socorro single-baseline testing.

4 Computing

Although computing development was not a formal charge to the meeting, the ASAC were very grateful for Gianni Raffi's attendance at the meeting, and his presentation on the status of the science software was extremely helpful for ASAC members: user software is a critical part of the ALMA system and will play a signficant role in determining the scientific impact of ALMA, and the community's perception of the observatory. The presentation included both the online software system, for data collection, and the offline system, for mapping and analysis. The Committee is impressed with the progress made by the Computing IPT and appreciates the great complexity of its task. The ASAC notes below some areas of critical importance to ALMA science.

The software required to take and do initial reduction of data has made impressive advances in recent months. The team manages their progress using a central database that links requirements, schedule, status, and internal and external user testing. The IPT has moved to Function-Based Team (FBT) development, in which teams are constructed to work on subsystems based on specific functionalities. The FBT schedule focuses first on subsystems that will support testing and first fringes at the first interferometers, at the ATF and in Chile, and they are expecting to have these initial subsystems in place rather soon. Significant development of subsystems needed later, such as the archive and observing tools, is already under way. More advanced subsystems such as WVR, fast-switching, and mosaicing modes are in the planning stages. The Computing IPT appears to be making good progress towards supporting the first fringes and first telescopes in a timely manner, although this has naturally been helped by slippage in the overall project. It is planning for the more complex interferometer modes to follow. The ASAC is pleased with the significant progress in this area.

The Computing presentation also included an update on the progress of the offline system for post-processing of data. This includes archive functions, calibration, imaging, atmospheric modeling, pipeline, and single dish support in addition to interferometric data reduction. Much of the offline functionality is provided by CASA, the "Common Astronomy Software Application." CASA is the successor to AIPS++, but its user interface is scripted in the Python language rather than glish. It promises to be far more robust than AIPS++, and offer a more familar user interface to astronomers. CASA has inherited the AIPS++ libraries (written in C++) and a comprehensive system of internal NRAO and external user testing.

CASA will be a vital part of ALMA. The robustness and ease-of-use of this system is key to the broad participation of the astronomical community in ALMA science. It is important that CASA

be well-documented, well-supported, user-friendly, robust and well-tested before the community is first introduced to ALMA during Early Science.

CASA is moving ahead, with the most recent user tests in April 2006. Results from these tests suggest that single-baseline data reduction procedures appear to be working well, but that additional visualization capabilities are needed before commissioning begins. It is anticipated that CASA will be used to analyze the results of single baseline tests at the ATF; this has not yet occurred but is imminent.

The CASA schedule is critical for commissioning, verification, and early science. CASA needs to be released to the community at some point before Early Science data become available. At the January 2006 ASAC meeting, the public release of CASA was planned for mid-2007; however, this release date now seems to be mid-2008, to allow for additional testing. While caution in releasing a new software package is commendable, to ensure quality and useability, it is important that testing move to testers beyond NRAO. The proposed 2009 date for a general release of CASA is uncomfortably close to the time of Early Science.

The ASAC notes the progress that CASA has made, and that the simple interferometric reduction modes appear to be close to user acceptance. The Committee recommends that these modes previously tested in AIPS++, such as single field interferometry with existing BIMA, OVRO, PdBI data, be re-tested using CASA. The Committee recommends that the CASA release schedule be constantly scrutinised to ensure that the goal of meeting ALMA's early science requirements is met. The Committee also recommends that a significant number of users who are outside NRAO be included in CASA beta testing in addition to NRAO users, with the goal of having the software available to a broad community before the start of early science.

The ASAC further notes that the concept of the CASA support, in particular a CASA "help desk" has not been clearly set forth. To whom do users go for assistance with the CASA package, for questions, installation issues, bug reports? Does the CASA group run a help desk, do the ARCs run a help desk, or does ALMA run a help desk? This issue should be addressed when the CASA user point person is hired later this year.

5 Operations Planning and ARC Activities

The ASAC was pleased to hear the progress and plans for the Science Operations and ALMA Regional Centers (ARCs). The current plans for three full archives, ARC staffing, and "Beyond ARC" functions are essential to maximize the science from ALMA. We realize that the man-power requirements of the ramp-up of science operations over the next few years will be a management and recruitment challenge. In addition, the fact that "Beyond ARC" functions are not funded directly by ALMA, and require new sources of funding, is a significant complication and challenge to the planning. We encourage and endorse the Project's commitment to success.

The development funding in the present plans are a vital component of ALMA's future success. We strongly recommend including funds in operations for upgrading software and incremental improvements of existing hardware. We also strongly believe that JAO must be continually planning, developing, and implementing new science capabilities for ALMA. We are creating a powerful state-of-the-art instrument. Beyond completion in 2013, we must not neglect it. ALMA will be

a working observatory and an invaluable infrastructure for future science developments. This requires significant development funds and these funds must be in our baseline concept for ALMA.

The ASAC endorses the plans to include the community in workshops and committees which will begin the process of identifying and prioritizing new capabilities for ALMA in the operations phase. We believe that this needs to start in 2007. It is vital that this be done in an open and inclusive way so that there is community buy-in, a complete airring of the competing scientific priorities, and a consensus plan supported by the community.

6 Programme Review and Time Allocation

Although not a formal charge to the ASAC, open discussions were held in Florence in the context of the Operations Plan report concerning how best to establish the ALMA proposal review system.

The ASAC has made several reports to the Board on time allocation in the past 5 years. These have considered in detail the merits and limitations associated with different systems of time allocation. The content of these reports stands. In particular, the ASAC reiterates its view from its previous reports that a single TAC process has many strong benefits, but that both a unified proposal review scheme ('single TAC' option) and region-based scheme ('multiple TACs') can be made to work effectively. But no system is perfect. Whatever scheme is established, there will need to be detailed rules concerning, among others, how to handle multi-partner applications and duplicate proposals, how to handle proposals in different subject areas, and the role of the executives.

The latest operations plan presented to the ASAC contains, for financial planning purposes, a single unified TAC process. The merits of this system have been emphasised in previous ASAC reports. In particular, a majority of the ASAC believe that this system will simplify and encourage the preparation of joint proposals across different communities, and simplifies their scientific assessment. The ASAC is in general broadly supportive of this 'single TAC process' as a baseline for planning.

Nonetheless, there are serious concerns among some ASAC members that such a system may compromise significantly the ability of some partners to focus on their scientific priorities, including the development of their communities. There are several strong arguments which favour regional based TACs.

It is vital that if the single TAC process is adopted by the Board, the detailed rules of the scheme are designed to address these concerns. In particular, we must find a way to ensure that the scientific priorities of each executive can be reflected in the time allocation process, and that each executive can ensure their community can grow effectively.

7 Summary of Recommendations

1. The ASAC supports the proposed extended CSV schedule, and consequent later start to Early Science but with a much enhanced array.
2. The ASAC highlights the need to pursue a diligent and continuous effort to identify and recruit the best staff for the CSV team, and identify incentives to attract and retain such

staff.

3. The ASAC recommends that the best support be provided to the Project Scientist in terms of resources to support communication, administration, documentation and delegation in order to accomplish CSV according to the planned schedule.
4. The ASAC was very supportive of the idea that there be two commissioning scientists to support the project scientist in the day-to-day execution of his/her duties, and to help with the retention of knowledge on progress as staff rotate in and out of the OSF.
5. ASAC recommends that ALMA consider the creation of a sabbatical visitor program to assist the project scientist to continue commissioning once ES begins, and the array grows beyond 15 antennnas.
6. The ASAC recommends that the Project Scientist and the Science IPT should develop a more detailed list of observing modes, and that the ASAC should revisit this charge when this work is more advanced.
7. The Committee strongly recommends that the CASA release schedule be constantly scrutinised to ensure it meets the requirements of ALMA for early community testing, and Early Science observations with ALMA.
8. The ASAC recommends that external users be included in CASA beta testing in addition to NRAO users, with the goal of having the software available to a broad community before the start of Early Science.
9. The ASAC endorses the plans to include the community in workshops and committees which will begin the process of identifying and prioritizing new capabilities for ALMA in the operations phase.

Appendix: ASAC Agenda, 16th and 17th September 2006

Held in Convitto della Calza, Florence

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16 September 2006

8:45 am Organization and IPT liaisons (Closed session) (Richer, Mundy)
9:00 am 1. Project status reports
Director's Report: Massimo Tarenghi
    * Project Scientist Advertisement
9:30 am Project Managers Report: Hans Rykaczewski
10:00 am Discussion
10:30 am Break
10:45 am 2. Charge 1. Review the revised Commissioning and Science
Verification Plan for ALMA (Laing)
11:30 am Discussion
12:30 pm Lunch
13:30 pm 3. Charge 2. Review the revised Calibration Plan for ALMA
(Mangum, Lucas, Vila Vilaro)
14:50 pm Discussion
15:30 pm Break
16:00 pm Raffi
17:00 pm 4. Science and Operations Review(Wootten, Wilson, Kawabe;
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Project Scientists)
- Operations (Tarenghi, Hibbard)
- JP ARC (Kawabe)
- NA ARC (Hibbard)
- EU ARC (Andreani)

Discussion
18:00 pm Break for Dinner

17 September 2006

08:45 am Closed Session (if needed)
9:00 am 5. Charge 3 Review the existing work on developing complete descriptions of the ALMA observing modes (e.g. software, hardware etc.) and make recommendations as to their relative priority (Wootten, Raffi, Lucas)
10:30 am Break
10:45 am
- ALMA PRC/TAC
- JSAC Meeting Report (Yamamoto)
- ANASAC (Mundy)
- ESAC Meeting Report (Testi)
- ALMA science meeting

12:30 pm Lunch
13:30 pm 6. Drafting of report (Closed Session)
15:00 pm Presentation of Findings (All)
15:30 pm Adjourn