Report from the ALMA Scientific Advisory Committee

Face To Face Meeting ALMA OSF Chile
January 28th & 29th 2009

Membership of the ALMA Science Advisory Committee
S. Aalto, J. Afonso, A. Baker, J. Bally, A. Blain (Chair), J. Cernicharo, F. Gueth (Vice chair), M. Hogerheijde, K. Johnson, D. Johnstone, K. Kohno, N. Kuno, N. Nagar, T. Ohnishi (Vice chair)

JAO
T. de Graauw, R. Hills, R. Kurz, A. Peck

Project Scientists
K. Morita, L. Testi, A. Wootten

EXECUTIVE SUMMARY

The ASAC met at the OSF in Chile on January 28th/29th 2009. Overall, ASAC is very pleased to see the progress with the project in Chile since our last face-to-face meeting in September 2008, and our last visit to OSF in January 2008. We remain confident that the Director, Project Scientists and their growing team are on track to commission ALMA as a transformational global observatory. Interaction between the JAO and the user-support ARCs in the executives appears to be reasonably good: however, as Early Science (ES) operations come closer, the need for final definition of plans for the ingestion, review and execution of proposals is becoming more urgent. We report in detail on the five charges sent to ASAC by the ALMA Board in Section III. Our greatest concern is the readiness of ALMA hardware and software for ES operations. We appreciate that ES operations should start only when the observatory is fully ready, but note that there is substantial excitement and pressure in the community for access to ALMA. We see that the key project targets for the coming six months are the successful operation of a two-element interferometer at the OSF, and the definition by the operations team of procedures for ES, especially concerning the requirements on the archive system and Phase-I observing tool.

I. INTRODUCTION

This report describes the discussions at the ALMA Science Advisory Committee (ASAC)'s face-to-face meeting held at the Observing Support Facility (OSF), for submission to the board at its meeting in Santiago in March 2009. The committee is grateful to Project Scientist Richard Hills and his staff for organizing the ASAC meeting, and for ensuring a smooth and hospitable visit to all the ALMA facilities in Chile. We would also like to thank North American Project Scientist Al Wootten for organizing our bimonthly telecons, and to the workers throughout the Project for their help in preparing and presenting documents and reports for our meeting.

The ALMA Board gave ASAC five specific charges. Our reports on the charges can be found in Section III.

We start our report with a general overview of the discussions at our meeting, and on additional questions raised about the project during our discussions of the charges. We would welcome future formal charges from the board on matters of concern highlighted in Section II.

II. GENERAL DISCUSSION

II.1 ASAC continues to follow the ongoing re-scheduling process keenly. We remain ready to assist the Board in advising on and reacting to the results. In particular, ASAC views a deadline for receipt of Early Science (ES) proposals close to the end of 2010 as an important goal for the project. We address issues of the recently proposed current program milestones in III.2 below.

II.2 ASAC was pleased to see both very substantial construction underway at the AOS, and an array of system components arriving at the OSF. The schedule for the front end integration process is a natural concern, as is the continued uncertainty involving the development of the LO distribution system, which is needed at the AOS in October 2009. These high-risk elements in the project schedule appear to be receiving all due attention, as the planned first operation of a 3-element interferometer approaches in November 2009 (in the proposed expedited schedule).

II.3 The project noted that there was a serious need for additional systems engineers. This seems to be very sensible, given the clear complexity of the integration process that is underway at OSF/AOS.

II.4 ASAC heard and enthusiastically endorses plans for a visiting scientist scheme to support travel and accommodation for long-term (3-to-12-month) visits to Chile to assist with commissioning and operations of ALMA, under the aegis of the JAO Director.

II.5 The committee spent considerable time discussing the issue of time allocation, especially in the context of ES. We view the proposal review committee (PRC)/time allocation committee (TAC) process as critical for the efficiency and success of the project, and so it needs very careful thought, planning, oversight and review. The PRC/TAC process came up at several points during the meeting (for example, as described in discussions of the information that must be captured by the Phase-I observing tool, ingestion into the archive, and of the ARCs' readiness to perform technical reviews below). Although a comprehensive examination of the PRC/TAC process was not charged to our meeting, ASAC remains intensely interested because of the potential impact on ALMA’s scientific output and relations with the scientific community. We note that the details of how the Chilean fraction of time will be integrated into the observatory schedule are also uncertain at present. The ASAC would welcome the opportunity to provide input on how proposal review might be structured to optimize ALMA's scientific return, including how best to attribute observing time to the executives and how to encourage proposals from scientists who are not part of the current (sub)millimeter community. We look forward to the chance to answer charges on this issue again in the future.

II.6 The format for ASAC meetings was discussed, and there is strong support on the committee for the continuation of the constitutionally mandated pair of face-to-face meetings per year, one in Chile and one at one of the Regional Centers. The opportunity to discuss issues frankly between ASAC members, both inside and outside of the meeting sessions was considered to be vital. Meeting in Santiago rather than at the OSF was considered to be attractive, to reduce the duration of travel for the Chilean meeting. The committee was happy that project management report remotely by video to the non-Chilean face-fo-face meeting.

We discussed the rigor of the East Asia-Chile trip, which is substantially longer than the trip to Chile from either Europe or North America, and so suggest that an overrepresentation of ASAC meetings in East Asia might be considered.

II.7 Several ASAC members have information about potential applications within the Project of ‘environmentally friendly power’. We collectively think that improved operating costs and positive publicity for ALMA could both be generated by considering this possibility. We commend Dick Kurz’s consideration of this issue in ongoing ALMA power planning.

We propose our next meeting is held in Garching, and that the next chair Ohnishi-san from the East Asian partners.

III. RESPONSE TO BOARD CHARGES

III.1 ASAC should continue to monitor and assess the readiness of ALMA software, in particular to review the outcome of software CDR number 6 and the ongoing work on detailing the software requirements for Early Science.

The ASAC was given reports on ALMA software and computing readiness (from Brian Glendenning, Alison Peck, Crystal Brogan and Leonardo Testi). These presentations were very informative, and we would like to thank these individuals for their time in preparation for our meeting and their ongoing commitment to the ALMA project. We felt that these reports were candid, highlighting areas of achievement as well as the potential concerns that are discussed below. It is clear that substantial effort has been put into the ALMA software, and we commend the Computing Integrated Product Team (CIPT) group for their progress.

The CIPT recently underwent an additional high-level review, culminating in a set of nine major recommendations, which were addressed point-by-point by Brian Glendenning. Of these nine major recommendations, five have already been substantially complied with. Responses to two of the recommendations are in progress, including the recommendation for a formal review of software priorities. Two of the recommendations have resulted in no action, including the recommendation to discontinue efforts to support CASA on laptops. We found the responses of the CIPT to be well considered and reasonable, and agree with CIPT that a laptop-based CASA is very likely to increase user acceptance and take up of the package.

While significant progress has been made, there remain issues that could potentially cause setbacks. First, and perhaps foremost, the issue of staffing within the CIPT remains a concern. In particular, we commend Brian Glendenning’s continued efforts as acting Head of CASA Development. This situation is only tenable because Brian and his staff are putting in exceptional (perhaps unreasonable) effort, and because there has been some restructuring of responsibilities. However, while Brian reported that this organization has settled into a workable state, ASAC does not believe that this arrangement is stable or desirable in the long term, and we recommend continued efforts to restructure further or fill this position. Secondly, without the security of continuing positions for key CIPT staff ahead of the planned ramp down in CIPT staff numbers from mid 2010, there is a danger that critical personnel may begin to leave the project soon. Early and careful attention needs to be given to the management of staff retention.

CASA subsystem scientist Crystal Brogan described the status of the CASA system. Substantial progress continues to be made, with many new capabilities added. In particular, a filler has been created to load SMA data, and the University of Maryland (UMD) has been contracted to produce a filler for CARMA observations. These new capabilities, along with numerous other improvements, should be extremely valuable for testing purposes. ASAC encourages the CASA team to pursue the addition of sophisticated data analysis tasks (such as spectral line fitting) within CASA as time allows. The ASAC also supports efforts to ensure the broad adoption of CASA in the community by assessing the capabilities and features that have contributed to the popularity of other successful software programs. We are pleased to see that high-performance computing requirements for reducing data from the full array are being worked on by the CASA team, but remain concerned that the effort being applied to these longer-term developments should not distract from making ready the more modest software (including single-dish analysis) that is needed now to support Commissioning and Science Verification (CSV) and needed soon to support ES.

ASAC endorses continuing efforts by the CASA team to enhance documentation including the CASA 'Cookbook' and individual procedural scripts. ASAC notes that the 400-page 'Cookbook' is becoming increasingly similar to a user's manual in nature, and we endorse efforts to create and disseminate well-documented scripts to serve as 'recipes' for specific types of data. The experience of user support for CASA at the ARCs can hopefully be exploited to generate more concise online help material (see SIII.4.vii).

The Observing Tool software for Phase II (observation planning) has also undergone development, and the ASAC has been impressed by the demonstrations that have been given by European Project Scientist Leonardo Testi. ASAC strongly supports the efforts of the Observing Tool project to engage in more rigorous testing, with opportunities for community feedback and input. A particular area of concern is that the requirements for the Phase I tool require urgent clarification: we advocate that this becomes a high-priority effort. Internal tests are planned for 2009, with beta testing scheduled by the first half of 2010. Special attention needs to be paid to meeting the current deadline for scientific use by the community in ES proposals by mid-to-late 2010. The ASAC also encourages the Observing Tool team to ensure that their subsystem successfully operates with the integrated software system, including the storage and retrieval of proposal details from the archive, in support of science operations and the PRC/TAC process. The ASAC would like to receive a status update on the Phase-I Observing Tool, and its interface with the archive, at our next face-to-face meeting.

Software testing for isolated subsystems is proceeding, and Alison Peck presented plans for integrated testing with a simulated system. We endorse the change to incremental acceptance tests and a reduction in the rate of releases to twice per year, which allows for a slightly longer development cycle to address more difficult issues. Procedures for creating new software requirements are in place, and such requests will be prioritized based on 1) the perceived urgency, and 2) the required effort.

The integration of all subsystems will continue to be a potential cause for setbacks. The CIPT is proactively addressing this issue and intends to purchase test equipment in advance for the purpose of simulating the final ALMA systems. ASAC strongly supports this effort. In addition, software testing on the ATF throughout 2008 proved to be extremely valuable, and we endorse the project's efforts to coordinate with CIPT to ensure adequate test time with the hardware at the OSF as it becomes available. Plans for scheduled CIPT testing are in place, and seem to be reasonable. The experience at ATF emphasizes that the establishment of 2-element interferometry at OSF as soon as possible is highly desirable, for the integration and test of software as well as hardware.

III.2 ASAC should continue to review AIV/CSV activities and to recommend necessary and desirable changes.

Here we discuss issues of schedule and progress that affect commissioning, especially where they influence the readiness for ES.

The Project presented a new plan with definitions of four main scientific milestones (Start of Commissioning, Early Science, Inauguration and End of Construction), and a list of potential second-level milestones. The ASAC endorses those definitions and supports the effort of the

Project to define as precisely and as realistically as possible key events in ALMA's deployment. It is critical to have clear milestones, both as main drivers for the Project activities, and as well-defined deliverables to the astronomical community.

ASAC notes that different interested groups will be listening and reacting to reports of these milestones: including (to name only four) the ALMA project staff, the executives' leaders, the astronomical community, and the general public. Some of the second-order milestones are clearly targeted to only a single group. The Project should make sure to use an appropriate communication channel in each case, to achieve the maximum impact of these announcements: for example, the announcement of an exacting technical achievement may be very important and motivating for the ALMA staff, but could send an unclear or confusing signal to the scientific community. ASAC endorses a steady stream of announcements confirming the satisfaction of minor milestones, as a way to maintain the profile and awareness of the progress of the project amongst these different communities.

Among the four main milestones, ES is certainly a very important one, regardless of the relative schedule of the milestones, as it marks the first contact of the scientific community with ALMA. Managing the (high) expectations of the astronomical community is a challenge for the Project, and this will continue into and beyond ES. ASAC recommends:

- **III.2.i Readiness for ES.** The starting point of ES should remain tied to a set of specifications being met, and not to a given date. For ES, ALMA must provide a new tool that allows scientists to obtain exciting, original results.

- **III.2.ii Priority of CSV and ES.** ES operations will compete directly with the CSV process for staff, resources and time on the array. In case of conflict, CSV should be given priority, as the overall goal of the Project should remain the delivery of the full ALMA capabilities as soon as possible.

- **III.2.iii Community Expectations.** As a way to manage the expectations of the community, the Project's communications must make clear that ES will not only involve a limited number of antennas, but also provide a limited functionality, and include a limited amount of observing time (probably up to about 50%). This last point was not clear to many members of ASAC before the meeting, who had assumed a larger duty cycle for ES. We expect that this misperception will be widespread and so the announcement of opportunity for ES must be advertised carefully.

- **III.2.iv ALMA capabilities and details**. There needs to be a unique, clear and central store of public information regarding ES (for example, definition, capabilities and timeline). Many different dates can currently be found in various documents and web sites, which is an obvious source of confusion for the community. It would be highly desirable that the recently created **www.almaobservatory.org** website acts as the central source of information.

- **III.2.v Additional capabilities for ES**. Regarding the definition/requirements of ES, ASAC understands that the number of antennas (16) is a reasonable goal given the current antenna delivery schedule, but that other specifications (including the number of available bands, single-dish modes etc.) may turn out to be more difficult to match depending on CSV results. We suggest that these additional capabilities remain as important goals for ES, but that they are treated flexibly, and are not mandatory requirements for the start of the ES operations.

- **III.2.vi Readiness Review.** We suggest that the exact definition/requirements of ES be reviewed at some appropriate time in the coming year, in view of the first experience of interferometry from CSV.

The ASAC also briefly discussed the readiness of the system for ES. Some concerns were raised concerning the tight schedules projected for the development of the Phase-1 Observing Tool, and the testing and release of the Archive hardware and software. The ASAC suggests that, if necessary, appropriate additional resources should be allocated to these areas. While the necessary ideas and staff appear to be in place, the schedule for delivering the software systems appears to be close to the critical path if ES is to be announced in mid 2010.

ASAC recognizes that the schedule for ES remains uncertain. Along with the community we are keen to get first scientific use of the array. This is especially significant for some communities that have decommissioned pre-ALMA facilities. In general, we favor the availability of a streamlined capability for ES in preference to a later onset of a more complete ES capability.

There has been clear general progress with recruitment, especially in Chile, as compared with our visit in 2008; however, the ongoing availability of numbers of high-quality CSV staff remains a key issue for the schedule and success of the project. We continue to encourage the project and executives to take whatever innovative steps are necessary to attract suitable candidates.

We also wish to commend the degree of commitment and hard work of the CSV staff. While we stress that we see no problems with morale, we are concerned that the project is proactive in taking good care of staff, to avoid potential risks of burnout or problems with retention.

III.3 The ALMA Board has charged the Project to draw up a long-term ALMA Development Plan in consultation with the international astronomy community. The plan should set out the scientific context for transformational science with ALMA in the next two decades, in the era of for example JWST, ELTs and SKA, and recommend developments necessary to achieve this vision. The ALMA Board views this plan as having a high strategic priority, and is coordinating its development across the entire ALMA partnership. The process of generating the ALMA Development Plan should be led by the JAO Project Scientist and the ASAC (with support from the Executives). It is anticipated that a larger-scale activity will follow after the start of ES.

The regional SACs, ASAC and the ad hoc development working group (WG) have all continued to discuss science drivers and ideas for ALMA development. In addition, these issues were presented at topical meetings and the January 2009 AAS meeting. Many ideas for future development were identified. Scientific priorities were discussed by the WG and at the January ASAC face-to-face meeting. Alongside this studies were made to quantify the nature of the gains likely from different developments.

At this stage, the wider astronomical community is inevitably uncertain as to what the scientific impact of the baseline ALMA will be. This simply reflects the great step forward in capacity that is enabled by the baseline array. Awareness and enthusiasm is high, but it is hard for non-experts (and also for experienced mm/submm-wave interferometrists!) to foresee the key developments that will enable another wave of transformational science after the baseline ALMA is completed.

Development ideas break down into three broad categories.

First, specific near-term ideas. These are generally supported most strongly by a single science area, although they can have general application, require other contingent developments of the system, and be expensive (see Appendix A).

Second, major developments that enable new science. These typically have a medium-to-long timescale, involve adding distinct new capabilities, and impose significant requirements on the underlying infrastructure of ALMA.

Third, incremental improvements of the system to speed up observations, to make them more efficient or enhance the ability of users to analyze and interpret them. Examples include more collecting area, enhanced performance of frontend and backend performance, adding enhanced receivers for a wider field of view in the spatial or spectral domain, enhancements to atmospheric phase monitoring and correction, and enhanced software tools, for both science analysis and operations planning. Advanced software tools can ensure that the maximum information is captured by the archive in unit time, and that the maximum information and scientific impact can be wrung from the data cubes in the archive.

Many developments require significant research work before it is possible to make a confident decision on cost, practicality and date of deployment. This work can be expensive if substantial lab staff and resources are involved.

III.3.i PRIORITIES

ASAC and the ad hoc working group discussed key priorities for specific developments which will enable new and different science with ALMA. We present these items in approximate priority order in the following sections, noting that they can have widely differing costs. We strongly endorse efforts to implement all these suggested developments.

III.3.i.i Relatively short-term, straightforward developments:

The phasing up of the array for VLBI to allow imaging of the galactic center down to the scale of the last stable orbit around the black hole, and unprecedented sensitivity to non-thermal emission from high-energy regions, including maser emission.

The commissioning of re-imaging optics to under-illuminate the primary mirrors, which will enable new wide-field solar imaging investigations. The point here is that the full collecting area is not required but a wide field of view is needed to capture the rapidly varying activity, the exact location of which cannot be predicted.

Restoring the full number of 6 subarrays, allowing 4 simultaneous tunings of the 12m array. This will, for example, allow monitoring of comet and planetary signals.

Building in the capability to expand the baseline range of ALMA into an extended configuration (20-50km), which would allow sub-AU angular resolution in bright disks and masers.

Increasing the number of 12m antennas. The benefits of this would be very substantial and would be felt across the whole range of ALMA’s science and, most importantly, for the whole of the lifetime of ALMA. Not only would the sensitivity improve in direct proportion to the collecting area, the imaging quality would be improved by an even greater factor – roughly speaking this scales with the square of the number of elements. In addition, even a few additional antennas would greatly improve the scope for using the array in a flexible manner and would make the operation more robust in the event of equipment failures. This item has been placed at the end of this section because it is in a somewhat separate category: the size of the investment is much larger than for the items above. It is however straight-forward in that no development is required and it is near-term because the options for additional purchases at a fixed price will soon close. ASAC has consistently identified the purchase of additional antennas as being of the highest scientific priority, but had appreciated that an early commitment to this was not possible within the planned ALMA Development line. Recent announcements about the U.S. "stimulus package" appear to make such a commitment more possible, leading us to reaffirm this rating. We are confident that money spent now on additional 12m antennas will still be benefitting the astronomical community in 20 or 30 years time.

III.3.i.ii The implementation of additional receiver bands: 1-2, 5 and 11.

In order of scientific priority, band 5 appears to stand out. There is an existing European Union-funded program to manufacture a handful of band-5 receivers that are scheduled for delivery to the project. The ability to track water and related species in the ISM with this band adds a crucial new capability for ALMA. This band also increases the coverage of atmospheric windows to track red-shifted line emission from galaxies over a wide tranche of cosmic time.

Band-1 and -2 receivers enable new ALMA science, for imaging cold molecular gas at high red-shift, masers, radio recombination lines, and the continuum emission from a variety of very deeply optically-obscured regions on a wide range of distance scales. Furthermore, these bands can also be used efficiently during the less dry periods of the year.

A new THz band-11 would enable more accurate measurements of the total luminosity of protostellar cores and nearby galaxies, and would detect fine-structure emission lines from the brightest galaxies at moderate red-shifts. In particular, this band could provide follow-up capability to line emission detected using *Herschel*-HIFI. The development of new optics and tools for calibration and analysis at the highest frequency might feed back into useful receiver developments in current bands.

III.3.i.iii Projects that require at least modest lab-scale development, and require replacement/augmentation of systems on the telescope:

Atmospheric phase correction and calibration accuracy are developments that will benefit almost all users, but especially those making images of faint targets at high-resolution. Developments that may be required include additional atmospheric monitoring tools, new calibration software, better site-specific weather/phase prediction tools etc. A plausible 10% increase in efficiency of the array by better phase correction, and a significant reduction in the number of tracks that have to be terminated because of deteriorating weather would help all users.

Upgrading the digital backend system to include a deeper level of analog-digital conversion, and thus reduce digitization noise, could lead to a potential 10% sensitivity gain for all observations. This is a significant gain: equivalent to adding five antennas.

Ongoing receiver developments, to increase the bandwidth over which the receiver temperature is lowest in each band, and to further reduce receiver temperature to approach the quantum limit more closely could lead to up to 20% improvement in sensitivity. In principle, mixer replacement could be done as part of routine maintenance, as cartridges with relatively better performance are identified once operations begin.

III.3.i.iv More dramatic long-term investments that require major developments

Multi-beam feeds, and/or simultaneous multi-receiver operation would require additional optics, digital electronics and correlator capacity. An additional dedicated low-resolution correlator for serendipitous detection of galaxies in the field of all ALMA observations, by accepting the remainder of the IF bandwidth not used by the existing correlator could be a possible enhancement.

In the higher-frequency bands, the modest physical sizes of receivers allow tens of detectors to be packed into the existing focal plane. Mapping molecular clouds in the Milky Way and nearby galaxies more rapidly, to catch arcsec-resolution images over many arcmin fields are the key science goals. Using the current ALMA, imaging nearby galaxies is a very time-consuming task. With a 16-element receiver in band-9, observations of the planes of handfuls of nearby galaxies would be much more viable, providing great symbiosis with legacy data from *HST*, *Spitzer* etc.

New optics and calibration tools to enable precise polarization mapping, including associated enhancements to imaging and mosaicking software, are developments that are likely to be desirable once ALMA's polarization performance is determined.

III.3.i.v Software developments

A variety of software tools could be developed to increase the attractiveness of ALMA to non-specialist observers and the science return of observations. Reduction and visualization tools for observers could include automatic software for efficient correlator setup, enabling the automatic capture of unused correlator capacity, and better operator tools to predict observing conditions. In principle, such developments could increase the scientific output of ALMA by several percent.

The development of enhanced data reduction tasks, and of tools for the fitting and visualization of complex large datacubes is likely to increase the science return of existing observations for experts and non-experts alike. The availability of effort by software specialists to incorporate new tools contributed by the scientific community into an ALMA-wide format, and to distribute these tools, from either JAO or ARCs should be interesting to the project and executives.

III.4 The ASAC should review the plans for provision of ALMA Regional Centers and report to the Board's March 2009 meeting.

The ASAC face-to-face meeting at the OSF followed directly after a meeting of the executives' ARC leaders in Santiago. We appreciated hearing from head of science operations Lars-Ake Nyman about the functionality of all three ARCs working together. ASAC appreciates that each regional ARC is required to deliver different services to its community, and that scrutiny of the details of the provision of these regional services should be primarily by the regional SACs: EASAC, ESAC and ANASAC. However, in some cases, these details can certainly impact the overall project.

The presentations about the provision of (and, significantly, coordination among) the ARCs, had a clear and appropriate focus on ES. The intended rapid ramp-up in staffing levels remains a challenge for all of the ARCs, although the ASAC heard at the meeting that additional hires of East Asian ARC staff are imminent. The Science Operations IPT (i.e., the head of DSO, the ARC Managers, and the Director) appears to be an effective clearinghouse for identifying the requirements for ES and developing implementation plans to meet them. There are a few areas of particular concern on which the ASAC has suggestions and would be receptive to requests for further input:

- **III.4.i User-friendliness of ALMA software.** The project software suite defines the 'face' of ALMA to the user community. A coherent, standard 'feel' to this software is desirable (e.g., for both proposal preparation and offline data analysis). The ASAC suggests that the regional ARCs all identify a fair sample of non-(sub)millimeter specialists in their respective communities who could be enlisted to evaluate user friendliness during beta testing.
- **III.4.ii Ease of use of ALMA for non-(sub)millimeter interferometer specialists**. The ASAC suggests that ARC preparations for ES include the preparation of a slimmed-down version of the 400-page CASA 'cookbook' that will be less forbidding to novice ALMA proposers. In addition, past experience of existing (sub)millimeter

PRCs/TACs suggests that many novice proposers stumble on a small number of avoidable errors in scientific strategy (e.g., choosing a transition that is unnecessarily demanding in terms of frequency or column density). Current PRCs/TACs often address such errors by effectively "rewriting" incoming proposals, a practice likely to be unrealistic for the large, complex and oversubscribed ALMA. ASAC therefore encourages the DSO/ARCs to consider developing a 'scientific strategy cheat sheet' as part of the documentation for the call for ES, to highlight some of these common errors.

- **III.4.iii Technical review of ES proposals.** At present, it is not clear whether the proposal submission tool will capture enough technical information *at Phase I* for a uniform and efficient technical review prior to the PRC/TAC meetings. ASAC would like to hear how the Project proposes to implement technical review, and the expected burden on DSO/ARC scientists.

- **III.4.iv Operation of the ALMA helpdesk**. ASAC would like to see a clear plan from the Project concerning access to helpdesk functionality for users from the different regions, and for how the support of the helpdesk will be shared among the ARCs.

- **III.4.v Availability of non-core deliverables produced by the ARCs throughout the project**. While much of the non-core (that is 'enhanced') services that will be provided by the ARCs to their respective user communities is face-to-face or online support that cannot be transferred, it is likely that some non-core work at the ARCs will produce tools that **can** be shared (for example software). At present, there is no well-defined mechanism for the Project to incorporate such products into what is provided to all ALMA users. Establishing such a mechanism, perhaps along the lines of what is already in force for the European ARC nodes, would be a highly desirable goal that the ASAC encourages the Project to prioritize.

- **III.4.vi Construction and dissemination of molecular line databases**. The ASAC views this need as critical for the success of ALMA, with tabulation of uncertainties in line frequencies and transition strengths just as important as the values of these quantities themselves, and requests an update at its next meeting about how this effort is being coordinated within and between regions. Molecular line databases present an obvious and essential test of integrating non-core deliverables (see III.4.v above) into the larger Project.

- **III.4.vii Management of community expectations regarding ES.** Given the high profile and broad enthusiasm for ALMA across the astronomical community, there is a risk of disappointment even in the event that the ambitious set of scientific milestones for ES is fully achieved (see also III.2.iii). The ARCs should make sure to deliver realistic and consistent messages to their user communities about, e.g., what fraction of array time will be devoted to ES once observations begin, and how easy it will be to reduce, analyze and publish ES data.

ASAC notes for the record that guidelines are now in use for deciding how to accommodate requests for the establishment of new European ARC nodes.

III.5) Noting that 2009 is the International year of Astronomy, the ASAC should examine the Project's activities in the area of Outreach, both to the general public and to the astronomical community, and make suggestions as to how they and the ALMA Project could enhance these activities.

ASAC notes that information resources within the project continue to improve, giving a more unified and coherent appearance and greater uniformity of information. As a large and complex project, however, further improvements are certainly possible. ASAC supports all ongoing efforts to improve information resources within the project. ASAC continues to see advantages in having the JAO maintain an efficient and proactive EPO team in Santiago, both to provide a consistent message from the Director of the Observatory, and to provide a common set of information and resources to the EPO teams within the different executives that can then be tailored to match outreach efforts in their own communities.

APPENDIX A: Interdependence of development issues

performance to be improved	development item	degree of improvement	speed/technical difficulti	cost	beneficial for
sensitivity	more antenna	add 5 antenna 10%	quick	expensive	all science
	new digital system/2GC	10%	moderate	expensive	all science
	receiver development (lower noise)	10 – 20%?	moderate?	moderate?	all science
angular resolution	longer baseline	a factor of a few	easy/quick but phase stability issues (including atmospheric and LO reference) should be improved as well	expensive?	limited brightest sources
	VLBI	orders of magnitude	easy/quick?	cheap	Sgr A* and very limited bright and compact sources
field of view	multi-beam receiver	a factor of a few?	long/tough? Enhance correlator power is also required?	expensive?	almost all science (but for compact sources)
	under-illuminated feed	a factor of a few	moderate?	moderate	Solar obs only
spectral coverage	band 1		medium-term	moderate	SZ, redshifted lines, protoplanetary disks, solar
	band 2		medium-term	moderate	SZ, redshifted lines, protoplanetary disks, solar
	band 5		medium-term	moderate	redshifted lines, planetary atmosphere
	band 11		long-term	moderate?	redshifted atomic lines, galaxies?
simultaneous frequency coverage	multi-frequency feed	a factor of a few	moderate? Enhance correlator power is also required (for narrow band observations BLC can accommodate?)	moderate?	almost all science?
	receiver development (wider frquency coverage)	a factor of a few?	moderate? Enhance correlator power is also required to cover whole wide freq. range?	moderate?	ISM, galaxies?
	new digital system/2GC	an order of magnitude? (at high spectral resolution mode)	moderate	expensive	ISM, galaxies?
imaging quality	more antenna	add 5 antennas ==> ~13% gain?	quick	expensive	targets with extended structures
	more 7m antenna	?	moderate?	expensive?	targets with extended structures
	software development	??	all	moderate?	all science
accuracy of amplitude	improved calibration device	???	difficult?	??	ISM?
accuracy of phase	improved atmospheric correction	???	difficult?	??	almost all science which requires high angular resolution
accuracy of polarization	improved calibration device	???	difficult?	??	star formation, ISM