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ALMA Science Advisory Committee (ASAC) Report to the ALMA Board

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General considerations

The ASAC face-to-face meeting was held at INAF-Osservatorio Astronomico di Cagliari on October 18-19, 2019. 10 committee members were present in person with 2 present via video. In addition, Observatory Scientist John Carpenter and the three regional Project Scientists (Daisuke Iono, Franciska Kemper and Al Wootten) attended both days of the meeting, while the three regional ARC managers (Misato Fukagawa, Tony Remijan and Martin Zwaan), Alvaro Gonzalez (EA operations) and Liz Humphreys (DSO head) attended the first day. Felix Stoehr (ESO) and Eric Villard (JAO) presented material in person, and Jennifer Donovan Meyer (NRAO) presented remotely. Logistics (transport, meals and communications) for the meeting were organized by Osservatorio staff together with Elena Zuffanelli (ESO), and ASAC is extremely grateful to Silvia Casu (INAF) and Elena for all their efforts to provide a smooth meeting, and for dealing with frequent changes in requirements, some due to the fact that Japanese attendees were affected by the recent typhoon. ASAC appreciates the timely delivery of all the documentation and presentations for this meeting prior to the meeting itself, which aids in ASAC's preparations, results in an efficient meeting process, and allowed important feedback from the regional SACs.

The ASAC meeting followed the ALMA science meeting in Cagliari, and the breadth and depth of the spectacular scientific results presented there is a tribute to the successful implementation of ALMA's promise. In particular, a number of the large programs presented results that clearly demonstrated the value of those dedicated efforts. ASAC commends the SOC of the meeting for putting together an exciting program that highlighted the full range of ALMA science.

While there were no new ad hoc charges from the Board at this ASAC meeting, we were asked to address several items by JAO, and several additional major items were raised in the course of the meeting. We emphasize the discussions of concern about the implications of the CUP-1 cancellation, total power continuum sensitivity, and calibration errors, provided in responses to the appropriate charges below.

Permanent Charge #1. Assessment of the performance of ALMA scientific capabilities: ASAC shall indicate what information is required from the Joint ALMA Observatory (JAO) to perform this assessment.

Recommendations:

- ASAC has discussed the recent analysis of total power continuum observations that shows that the initial sensitivity anticipated for this capability cannot be met with the current receivers, and that matching the sensitivity of the interferometer data requires excessive integration times. Bright sources may still be able to take advantage of the total power capabilities, and at the next f2f meeting we request an assessment of the flux levels needed for sources to benefit from TP measurements with reasonable integration times.
- ASAC continues to place a very high importance on offering high frequency observations as standard mode, and encourages the project to complete commissioning so that it can be offered (for targets with suitable calibrators) in Cycle 8.
- We welcome the provision of polarization mosaicking observations, but continue to be disappointed that stand-alone ACA polarization cannot yet be offered.
- We note that currently ALMA participation in mm VLBI observations requires non-ALMA staff to be on site to phase up the array. ASAC supports the intent to identify permanent JAO staff who can become local experts for VLBI observing and phasing the array.

Science cases for total-power continuum observations: ASAC has discussed the recent analysis of total power continuum observations that shows that the initial sensitivity anticipated for this capability cannot be met with the current receivers due to instability intrinsic to the heterodyne receivers, apparently occurring on a timescale faster than 20 Hz. This means that matching the sensitivity of the interferometer data at the level required formally to combine in the uv plane requires excessive integration times. Total power (TP) continuum measurements were specified as part of the ALMA design to provide zero baseline information for continuum maps. Other observatories with detectors better suited to total power measurements may be able to provide suitable data, but they will not match ALMA interferometer data in frequency and bandwidth exactly, as the ALMA TP data do (e.g., bolometers typically measure much wider bandwidths). We note that TP measurements of bright sources (such as the Sun and planets) are still important, and other bright continuum sources (e.g., galactic center, HII regions) may still be able to take advantage of the total power capabilities. This calls for a more careful assessment of the flux level at which it still makes sense to offer this capability: a quick inspection of the report provided indicated that it did not contain the information needed for such an assessment. At the next face-to-face meeting, ASAC would like to review an assessment of the flux levels that are still suitable for TP measurements in order to assess the TP continuum capabilities that could be offered.

Advancement of ALMA capabilities: ASAC appreciates the clear enumeration of EOC priorities and the status of each (Go/No-Go/Tentative). New capabilities such as mosaicked (linear) polarimetry and high-frequency long baseline observations will enable exciting new science cases. Several EOC efforts aimed at increasing observing efficiency, like the improved daytime focus model and the dynamic calibrator integration times, are about to bear fruit. We are particularly happy to see that standard mode high-frequency observing is a “Tentative Go” for Cycle 8, as this has been a priority of ours in recent

ASAC reports, both because it enables more science on the ACA and because it will reduce the manual calibration load on JAO. We urge JAO to ensure that this capability can be released for the Cycle 8 call.

We note that the ACA stand-alone polarimetry remains low on the list of EOC priorities and that it will not be available in Cycle 8. We continue to believe that this capability should be a high priority for EOC and inclusion in Cycle 9, and hope that the efforts to prioritize polarization capability in pipeline development are fruitful.

VLBI capabilities: The crucial role played by ALMA in the M87 event-horizon image demonstrates the importance of ALMA phased-array operations for mm VLBI science. ASAC was informed that at present no ALMA staff are sufficiently trained to reliably set up phased-array operations, and that it requires a physical visit to the site by non-ALMA staff. JAO recognizes that in the long term they need in-house capability for phased array operations, and ASAC strongly supports this. We welcome the fact that the release policy for the ALMA data obtained during Event Horizon Telescope (EHT) operations has been agreed upon, and the provision of pulsar and spectral line capabilities for VLBI observations.

The issue of scheduling VLBI sessions was also discussed. ASAC understands the complexity of this issue, due to the need to coordinate with multiple independent observatories, and with timing restrictions imposed by ALMA's configuration schedule. At present mm VLBI sessions are scheduled well in advance, and somewhat abrupt cancellations can happen if anticipated resources are not available at the scheduled time. Suitable uv coverage relies on observatories being available, which instrument failure and other issues can derail. Further, high-frequency operations (specifically Band 7) are very sensitive to local weather conditions, and finding a time suitable for all sites is challenging. The mm VLBI community would like scheduling to be more flexible and dynamic, which would benefit the science: ASAC suggests that JAO should investigate whether mm VLBI scheduling at ALMA could be more flexible.

Permanent Charge #2. Assessment of the technical aspects of the ALMA system performance: ASAC shall indicate what information is required from the JAO to perform this assessment.

Recommendations:

- ASAC is very unhappy to find that a major problem with T_{sys} calibration affecting strong line features has still not been reported to the community over 6 months since it was identified. ASAC continues to find this approach unacceptable, since it makes ALMA responsible for the needless publication of incorrect results.
- ASAC welcomes the attempt to learn from recent data reduction problems and the implementation of tighter CASA regression testing, both for CASA and for the ALMA pipeline.
- ASAC appreciates JAO's commitment to prompt data delivery, although the original goals are not yet being met.
- ASAC commends the archive group for their work despite their limited manpower. Still, ASAC is concerned by the apparent lack of coordination between the groups working on archival matters in different regions.

T_{sys} calibration errors: ASAC was made aware (by a committee member; the issue was not discussed in any of the slides provided) of a significant calibration error particularly affecting strong line features. The initial T_{sys} determination by TelCal is carried out off-source, but is then normalized by the autocorrelations measured on-source. When the source is bright, e.g., a strong line is present on-source, this normalization results in an incorrect T_{sys}: if the source temperature is the same as the off-source T_{sys}, this can result in an error of a factor of 2 in the flux calibration of the channels affected.

This error in calibration for bright sources had been known for at least 6 months by the time of the ASAC meeting, but no disclosure has been made to the community, even though one of the large projects underway identified the issue and developed its own correction. The error will appear in any quantitative analysis of ALMA data on bright sources, and therefore may have implications for many studies.

ASAC is alarmed that once again a major problem that results in the publication of incorrect results, likely needing future retraction, has not been disclosed to the community in a timely fashion. As with the earlier mosaicking-bug issue, we regard it as irresponsible for the project not to inform the community once the problem is identified: failure to do so results in ALMA itself being responsible for the publication of incorrect data, and we believe that ALMA's reputation is harmed by such a cavalier approach. A "knowledge-base" article is apparently in preparation, but has been for some time: we ask that the project put a priority on completing and releasing this report, together with prescriptions for correction, and we repeat our request for a formal policy on timely announcements of such issues to be implemented in order to minimize the chance of avoidable publication of incorrect results. ASAC does not agree that ALMA should wait until a solution has been found before announcing significant problems such as this: we feel that the community should be informed as soon as the problem has been recognized.

Data delivery for Cycle 6: Data completion has been achieved (by time) at about 86% and 80 % for grades A and B, respectively. Problems with weather and power outages together with being in long-baseline arrays led to a decline in QA0 success towards the end of Cycle 6. The data delivery is now complete and 90% of the pipelined data were delivered within 64 days (118 days for manually processed data). We note that the need to reprocess data affected by the mosaicking bug in CASA and the 1GB memory error has affected data delivery times, and data processing has still not caught up on the reprocessing. Cycle 4 reprocessing of ACA data has not been completed, and Cycles 1-3 have not started: ASAC appreciates the offer by the EU ARC node network to take over the reprocessing of the missing cycles.

CASA regression testing: Several recent CASA issues (mosaicking bug, "1GB" memory error) have harmed data processing efficiency because of the need to reprocess already-delivered data in order to correct for the bugs. These problems emphasize the need for a more rigorous approach to testing the use of CASA to process ALMA data. ASAC received a presentation on the steps taken to formalize the validation and testing procedures, and we welcome this effort. This includes a shift in the approach to CASA releases, in which the development path will be separated and developments will be fully tested before release to "master" versions, and the addition of staff to carry out the testing. The intent is for CASA "stakeholders" to define what is correct for their applications: we look forward to a more detailed

description of how this will be approached in the near future, since the description we were provided is at a fairly high level and it seemed that there were still a lot of details to be worked out. We note that it is believed that the new, more rigorous, approach would have identified the mosaicking bug, but likely not the 1GB problem, which was due to incorrect implementation of the CASA pipeline.

ALMA Science Archive: ASAC was presented a summary of the recent review of the ALMA Science Archive (ASA) together with the review itself, and received a presentation by Felix Stoehr on the archive and current developments. The review intentionally focused more on the archive infrastructure and forward planning than on the actual ALMA user experience. A few ASAC members had tried the new ASA interface and reported a positive experience. However, it is a concern that the developer has recently left the project and that archive management commented that it will be hard to improve the new interface further. For the amount of tasks that it has to fulfill, the archive group seems overstretched and understaffed.

ASAC notes some apparent duplication in capabilities between the ASA's current and planned future developments and, for example, the ALMA data features accessible through the popular Japanese Virtual Observatory. There seems to be a rather striking lack of communication, coordination, and re-use of capabilities between these two efforts, and ASAC is concerned that this may extend to other groups working on archival capabilities (e.g. the ARI-L project, the CADC). While recognizing that ASA has a formal responsibility as the official ALMA archive that is not necessarily shared by other sites, overall ASAC has the impression that work on the ALMA science archive and related capabilities could be better coordinated, resulting in reduced duplication of effort and more quantitative progress.

Permanent Charge #3. Assessment of the science outcomes from ALMA: Statistics on publications, citations, press releases, web sites, etc. collected by the Executives shall be collated by the JAO, and analyzed by the ASAC.

Recommendations/Issues:

- Action item: ASAC needs to provide a baseline set of questions to be addressed by the publication statistics for its next face-to-face meeting.

ALMA publications: ASAC received a detailed presentation by Felix Stoehr on the process by which ALMA publication statistics are collected and processed, in order to inform our assessment of science outcomes. ASAC was asked to provide more detailed information on the kind of questions it would like to see addressed by the publication statistics and it is happy to do so. ASAC understands that the implementation of plots addressing some of the questions might not be straight-forward and provides some prioritisation for a baseline set of questions with the expectation that this will be an iterative process. The baseline set of questions (plots) is provided in the appendix.

Permanent Charge #4. Recommendations of ways to maximize ALMA's scientific impact: This includes review of the scientific effectiveness of the Proposal Review Process after each Proposal cycle.

Recommendations:

- ASAC supports the implementation of dual-anonymous review (anonymous proposals) for Cycle 8, without the need for a statement of experience for regular proposals.
- If this is not put in place, ASAC recommends that the observatory permanently implement the randomized investigator lists and usage of first-name initials in proposal reviews.
- ASAC finds that the move to increase the number of panels and reduce the number of proposals per reviewer for the Cycle 7 review was welcomed by reviewers, although we note that the feedback was that the number of proposals is still too large.
- ASAC supports the new scheme proposed by JAO, in which any proposal asking for more than 150 hrs in the 7m array for ACA stand-alone observations is considered a large program.
- ASAC shares the concern that there has been a drop in submissions of large program (LP) proposals, and that the APRC felt that the quality was not adequate to fill the available LP time. ASAC suggests that Large Programs be permitted to request time to be spread across two observing cycles, with a contingency to complete in a third cycle, and other measures could be considered.
- ASAC would like to see steps taken to improve the success rate of proposals requesting 30-49 hours, i.e., just below the threshold for large proposals, since they currently have a very poor success rate.
- ASAC notes the importance of a thorough review of the DPR test in the Cycle 7 ACA supplemental call for the future of ALMA proposal reviews, and looks forward to seeing a detailed report at the next face-to-face meeting.

The impact of randomizing names on review bias: In the Cycle 7 proposal review process the investigator list was randomized and all first names were given as initials as a first step towards dealing with potential biases (such as regional and gender bias) in the review process. ASAC appreciates the overview of the impact this appears to have had on the review outcomes. The statistics on the proposal ranks show i) no particular significant differences between “most experienced PIs” and “intermediate experienced PIs”, same for “second-time PIs”; ii) significant improvements in the ranks of the Chilean-PI proposals; iii) no impact on the relative rankings of the East Asian proposals; and iv) no discernible gender-bias (for the first time, female PIs did marginally better). The statistics presented have no information on seniority of the PIs and co-Is, and thus this factor cannot be folded into the discussion, and particularly, in the statistics on the expected acceptance rate for female/male PIs. The randomized investigator list still reveals some regional information about the investigator team; ASAC notes that it was useful to see the percentage of co-Is per region for submitted proposals, but to see the full impact this should also be compiled for successful proposals.

ASAC supports the use of a "dual-anonymous proposal review" for Cycle 8: Noting the success of randomized names in reducing bias, ASAC is strongly in favor of implementing “dual-anonymous”

review in the ALMA observing proposal process. In the implementation, ASAC notes that ALMA can learn from the experience of HST, which has used dual-anonymous review for the past 2 cycles. Several other observatories, such as NuSTAR, are also moving to dual-anonymous reviews. ASAC also notes that dual-anonymous review will be especially important if the distributed peer review process is implemented for the primary ALMA call in addition to the ACA supplemental calls. ASAC would like to highlight that there are a number of implementation issues that will need to be dealt with, for example: i) how can new, but still unpublished results be described in a proposal without compromising anonymity? ii) how can teams that rely on the collaborations with named theory or laboratory teams describe this? iii) how to best inform the community about the underlying reasons for doing dual-anonymous reviews? iv) how to best support the community in the changed manner/style of writing? and v) how to verify if all proposals comply with the “dual-anonymous” requirements. Furthermore, ASAC highlights the need to monitor the reception and impact of the dual-anonymous review approach on the community by running a satisfaction survey. Finally, ASAC notes that HST has removed the requirement for provision of a 'team statement' from their proposals, and ASAC does not feel that such a statement is needed for regular ALMA proposals.

Reviewer workload in Cycle 7: ASAC reviewed the APRC panel outcome for Cycle 7. The ALMA proposal review panels, the total number of panels had been increased from 18 to 25, which meant a lower load per panel member with 65-80/panel, and the number of panel members decreased to 6 in most panels. ASAC notes that the feedback from the reviewers commenting that the number of proposals is still too large.

ACA large program definition: ASAC shares the concerns about the current imprecisions and/or inadequacy in the current definition of ACA and TP large programs, and the loopholes that it leaves for programs asking for >150hrs of ACA time without being considered a large program (e.g. 12m proposals). Thus, ASAC supports the new scheme proposed by the Observatory Scientist, in which any proposal asking for more than 150 hrs of 7m time in ACA standalone is considered a large program (LP), independent of the TP time requested. A related issue is that in the past there has been some confusion among panel chairs regarding whether the ACA request that accompanies many 12m array proposal requests should be factored in when considering the total time requested as a factor in proposal review. JAO should provide clear guidance to panel chairs on this issue.

Large program status: There is concern regarding the decrease in both quantity and perceived quality of Large Programs submitted for Cycle 7. ASAC feels this may be driven, at least partly, by the fact that many of the obvious projects have already been proposed, and/or other projects might be waiting for the current/previous LPs to provide results to motivate further science. ASAC suggests that JAO allow Large Programs to request that observations be spread across two observing cycles, with observations potentially completed across three cycles. This would be particularly important for high-frequency and/or long-baseline projects, as well as projects focusing on specific regions of the sky, where limited time is available during each cycle. Other trends in proposal submission were noted, including decreases in requested ACA stand-alone time as well as joint 12m+ACA proposals and 12m C43-1 configuration requests that traditionally have often been combined with ACA data.

Medium-sized proposals: Regular proposals requesting more than 40 hours have a very poor success rate on ALMA panels. ASAC feels that it is worth taking steps to encourage proposals >20 hrs (instead of the current explicit recommendation of >10 hrs); this should be done both in the Call for Proposals as well as in instructions to the APRC panels. Furthermore, ASAC encourages JAO to consider whether it would be worth implementing a medium proposal category in future cycles, for proposals ranging from 30 hours to 50 hours. Medium length proposals should support both deep integration of individual sources, which we think tend to suffer in the current review process, as well as surveys.

Assessment of Distributed Peer Review (DPR) in the ACA supplemental call: ASAC notes that the distribution of ACA supplemental proposals to DPR reviewers seems to have proceeded smoothly with most (but not all) reviewers getting proposals suitable to their expertise. ALMA should study in detail the current application of the DPR model on ACA supplemental call. Although the committee has raised several concerns on the implementation of DPR in the ALMA regular calls, ASAC recognizes the desire by JAO to make the proposal review processes sustainable, given the inflating number of assessors and large number of proposals to be reviewed per panel in the current process. Careful assessments of feedback from both PIs and reviewers of the ACA cycle 7 supplemental call will be mandatory before the go/no-go decision for DPR for the cycle 9 main call. ASAC reminds JAO to maintain a close dialogue with ESO, where DPR is being tested systematically with direct comparison to the traditional review process. The science impact of implementing DPR under the condition that a dual-anonymous review will also be introduced in cycle 8 should be carefully investigated in advance. ASAC looks forward to seeing a rigorous statistical analysis of the ranking, outcomes, and PI and reviewer surveys from the DPR test in the Cycle 7 ACA supplemental call at the next face-to-face meeting.

Permanent Charge #5. Reporting on operational or scientific issues raised by the wider community as communicated by the three regional Science Advisory Committees (ANASAC, ESAC and EASAC).

ASAC welcomes the announcement that ISOpT has set up a new working group to investigate the main issues that ALMA users face, addressing the full end-to-end experience, starting with surveys of users at meetings such as ALMA 2019 and the AAS winter meeting and including in-depth interviews with under-represented focus groups. We look forward to seeing the results of this review.

Apart from a query as to whether there had been any movement on joint observing programs with JWST (answer: no), no other new issues were raised for this topic that are not covered elsewhere in the report.

Permanent Charge #6. Assessment of the scientific impacts of the ALMA Development Program, and particularly of new projects that are proposed.

Recommendations:

- The sudden cancellation of CUP-1 brings to an end the only increase to ALMA capabilities planned before 2030. ASAC views the stagnation of ALMA capabilities as a severe risk to the scientific relevance of ALMA in the coming decade. ASAC urges that the partners collaboratively explore how ALMA can implement a new correlator capability as soon as

possible.

- ASAC re-iterates the need for a coherent, integrated approach towards development across the regions to ensure a timely implementation of the ALMA2030 Roadmap.
- ASAC is happy to see the timely progress on Band 1, the completion of the new alarm system, and the installation of the polarization-calibration beacon, and we are looking forward to the likely increase in science time that should follow from the completion of the HiL system.
- ASAC appreciated the thorough update on progress of Band 2, and looks forward to providing input in the near future on the current development plan.
- ASAC feels that the plan to have the OT implemented on the Cloud should proceed only if the following aspects are fully addressed: (1) including the option of saving a PDF of the complete proposal for off-line review, (2) providing stand-alone off-line sensitivity calculators, and (3) ensuring that use of the Cloud does not exclude countries, such as China, where there may be limits on external Cloud-based services.
- It was suggested that the roll-out of the redesigned OT would be incompatible with the introduction of new capabilities for the Cycle for which it occurs: ASAC is strongly opposed to such a limitation, although it is certainly reasonable to request modest changes in the timeline for decisions on new capabilities for that cycle.

Cancellation of CUP-1 and implications for ALMA 2030: The sudden cancellation of CUP-1 brings to an end the only likely improvement on ALMA's initial planned capabilities (which the community regards as including Bands 1 & 2) that could have been implemented before 2030. While ASAC accepts that the technical problems made this decision necessary, it can only be regarded as a setback for ALMA. It makes the value of wider bandwidths available in any receiver upgrades over the next decade marginal, since there will be no improvement in continuum sensitivity or higher spectral flexibility, e.g. for spectral scans. ASAC views the stagnation of ALMA capabilities as a severe risk to the scientific relevance of ALMA in the coming decade, when exciting new instruments will become available. It further notes that the assumed increase in continuum sensitivity is a pre-requisite for efficient operations of both more extended configurations that are currently being discussed, and of high-frequency observing.

The cancellation of the CUP-1 project apparently came as a surprise to many people deep within the project, and this reveals issues in communication within the project that have been raised before. ASAC regards this as an example demonstrating that the piecemeal regional approach to development will not work for the implementation of the ALMA2030 roadmap, and re-iterates the need for a project-wide integrated approach towards ALMA2030 development.

In this context, ASAC welcomes the correlator workshop planned for February 2020 to explore possible technical alternatives to CUP-1 and discuss potential ways forward, together with the additional workshops on front-end and IF/LO requirements. ASAC urges that the partners collaboratively explore how ALMA can implement a new correlator capability as soon as possible, preferably one that can keep up with planned improvements to receiver IF bandwidths. However, we note that with an implementation time of order 8 years and approval process likely to be at least 2 years, we are faced with no major new improvements in ALMA capabilities before 2030 (again regarding Bands 1 and 2 as planned capabilities that the community has long been anticipating, and will mainly be used for science different from that

done by, e.g., current Band 6 and 7 users). We expect that the community will be very disappointed with this state of affairs, and ALMA's prestige and reputation will likely suffer.

Future of the baseline correlator: Due to the CUP-1 cancellation, components purchased for CUP-1 will be made available to the Hardware-in-the-Loop (HiLS) project, and resources may be reallocated from CUP-1 to provide spare parts for the baseline correlator. The latter issue now becomes critical as the correlator ages and components fail at increasing rates. Since it is now necessary to extend the life of the baseline correlator to at least 2030, maintenance and spare parts must be given high priority to ensure that observing capability is not interrupted due to a future correlator failure.

Development status: The presentations demonstrated that there continues to be impressive work on technical developments in all three regions and the observatory has made progress on several fronts. In particular, the APP team is to be congratulated for their role in the spectacular result from EHT. ASAC was happy to see that Band 1 will undergo MRR later this year, with completion of the upgrade expected by the end of 2023. Similarly, we were happy to see the polarization calibration beacon installed and we look forward to timely resolution of the remaining power problems with this system, and its prompt use to advance the prospects for achieving full and accurate polarization capabilities.

Band 2 receivers: ASAC was also happy to see the detailed planning for Band 2. We note that the schedule is very tight, with many issues remaining undecided. We look forward to providing input in the near future on whether or not to proceed with this ALMA upgrade as planned.

Redesign for the Observing Tool (OT): ASAC believes that the time is right to develop a new OT, and we understand the advantages of using Cloud services. However, we continue to feel that the ability to work on proposals when web access is not available is an important capability, and we feel that several issues have not yet been fully addressed by the OT team:

- At a minimum, any new OT must be capable of saving the draft proposal in a format such as PDF that allows for off-line review;
- stand-alone off-line sensitivity calculators should be provided; and
- the use of the Cloud needs to be implemented such that it does not exclude countries, such as China, where there may be limits on external Cloud-based services.

It was suggested that for a successful roll-out of the redesigned OT it would be necessary to avoid the introduction of new capabilities in the Cycle in which it is introduced. ASAC is strongly opposed to the idea that new observing capabilities should be subservient to the new OT, although we agree that it is reasonable to request modest changes in the timeline for decisions on new capabilities for that cycle.

Appendix: Possible options for publication statistics

Baseline set of questions to be addressed by publication statistics. Lower priority questions are listed using *italics*:

- What is the evolution and distribution of the overall peer refereed publications by ALMA over time?
 - as a function of science category (used by the APR process)
 - as a function of region (EA, EU, NA, CL, others)
 - as a function of low (up to band 7) and high frequency (band 8 to 10)
 - as a function of configuration (compact/intermediate/long)
 - as a function of project type, i.e. PI/archival/archival+PI/SV as well as separate for archival data and normal vs. large PI projects
 - *as a function of capability (polarization, solar, VLBI, ...)*
 - as a function of high impact (Nature/Nature Astronomy/Science) vs. standard journals
- What is the delay between data delivery and publication of a first paper?
 - as a function of low (up to band 7) and high frequency (band 8 to 10)
 - as a function of configuration (compact/intermediate/long)
 - *as a function of capability (polarization, solar, VLBI, ...)*
- How many projects have received at least one publications?
 - *as a function of science category (used by the APR process)*
 - *as a function of region (EA, EU, NA, CL, others)*
 - as a function of low (up to band 7) and high frequency (band 8 to 10)
 - as a function of configuration (compact/intermediate/long)
 - *as a function of capability (polarization, solar, VLBI, ...)*
- What is the distribution of publications per project?
 - as a function of overall integration time
 - as a function of project type, i.e. normal vs. large PI projects
- How many multi-band projects publish data from multi-band observations in a single paper?
- How many publications present multi-configuration data?
- What is the time evolution of the average (mean) citation of a publication?
- What is the distribution of citations per publication (separated by cycle or delivery time)?
 - as a function of project type, i.e. normal vs. large PI projects
 - *as a function of overall integration time*

- What is the correlation between proposal rank and impact (as measured by number of citation) (separated by cycle or data delivery time)?
- How does ALMA's publication output over time compare to that of other facilities (if possible including other mm-interferometers, e.g. IRAM/NOEMA/PdBI)?