2016 (Cycle 4) North American Proposals for Development Upgrade Studies for ALMA

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1. Executive Summary

The NA ALMA Development Study Call for Cycle 4 received 13 valid proposals. These were reviewed by a panel of 15 reviewers. The rankings of the proposals from the review resulted in six highly ranked proposals fitting within ($16K over) the $1M budget allocated. The highest ranked proposals fit within the strategic goals of NA Development and the ALMA2030 goals very well. They include hardware studies of (1) a study of modest improvements to the Band 6 receivers and substantial improvements to Band 10 receivers (2) study of advanced configurations for 3mm wavelength SIS mixers in the workhorse ALMA B3 receivers, (3) a study to enhance the mmVLBI capability of ALMA by extending its abilities to weaker sources and to implementation of spectral line observing, (4) a study of upgrading the ALMA antenna article to accommodate larger bandwidths. The recommended program also includes two software studies: (1) developing an improved software capability to make the best use of the combined 12-m, compact and total power arrays and (2) to support the CLEAN process using CARTA: interactive selection of regions of interest, interoperability with CASA cleaning operations. Two of these programs are centered at NRAO, two at Canadian institutions (NRC-HIA and U. Alberta) and two involve US universities (MIT and SUNY-Stony Brook) although many involve multiple investigators.

2. Process

North America issued a call for proposals for ALMA development studies on 2016 March 1. This was preceded by announcements at the AAS meeting, in the NRAO eNews, in the AAS Newsletter and in direct email correspondence with all those involved in the previous Calls (Nov 2011, May2013 and March 2015). Materials included on the Call website included the ALMA 2030 materials developed by ASAC and the ALMA

International Science Team, and copies of reports made on previous Studies.

On 2015 March 9, an ALMA Development Informational Webinar was held. Invitations to the Webinar and Call had been sent to 200 people on the Development email list and 8000 people on the NRAO eNews list. Four external parties attended along with ten local people. There were a few questions, and several followup emails. Contents of these were added to the FAQ. Webinar materials, which included discussion of the ALMA 2030 documents and a review of past ALMA Development Studies and Projects from all Executives, are posted on the website.

The call generated 17 responses in the form of Notices of Intent (NoI) to submit a proposal. Of these seven were from US universities, one from Canada and 9 were from NRAO. Four involved hardware, nine involved techniques and four involved software.

The study proposals were due May 2, 2016. Thirteen valid proposals were received. Along with 13 Principal Investigators, there were 34 Co-Investigators from nine institutions. Funding requests totaled $2.3M. The available funding for this Call was $1M and no individual Study will be funded in excess of two hundred thousand U.S. dollars ($200K).

A review panel was assembled, consisting of highly qualified members of the astronomical community who were proposed by the ALMA North American Science Advisory Committee (ANASAC) membership. None of the review panel members are affiliated with the NRAO to avoid conflict of interest. They have interests in science, software, and various hardware components including mm-wave instrumentation. A goal in the identification and recruitment of panel members was to capture the diversity of the community including reviewers from Canada. A list of 45 proposed reviewers was submitted to the NRAO Management for approval. The resulting list of 45 potential reviewers was then sent to NSF for its consent. NSF's consent was received on June 14. Negotiations with reviewers ensued; fifteen agreed to review four or five proposals. The reviewers are listed in the first table. Summaries of the titles, investigators and affiliations of the proposers were circulated among the fifteen reviewers to determine conflicts of interest which were not immediately apparent. Proposals were assigned to reviewers for whom no conflict of interest was determined. Most reviewers were assigned a list of 4-5 proposals in mid-June, at which time all proposal documents were distributed to them via a secure webpage. Reviewers were provided with a form, prompting for remarks on (1) Alignment with NA ALMA Partnership strategic goals; (2) Strength of the scientific case for the proposed ALMA upgrade concept; (3) Quality of the upgrade conceptual design; (4) Readiness for production in the context of the ALMA Development Plan; (5) Strength of the consortium organization (if applicable); (6) Qualifications of the key personnel of the Study; (7) Technical expertise, past experience (also in series production, if relevant) and technical facilities in the Institutes taking part in the Study; (8) Risk assessment; (9) Strength of the Scientific Team supporting the Study; (10) Level of support guaranteed by the Institutes; and (11) Budget. Responses were due 15 July; many were in hand by by then, the remainder trickling in until the morning before the final telecon. Reviews were graded on a 1 to 10 scale, with 1 being the highest grade.

All initial reviews were received by 25 July. The review scores were combined into a uniform ranking. A spreadsheet was produced illustrating the ranking, giving individual review scores anonymously, along with mean scores and standard deviations for both reviewers and for the studies. This, and the anonymized content of the reviews was made securely available to reviewers. A dividing line was suggested for the top ranked proposals, with the division at the point at which the requests met the budget of $1.000,000.

Reviewers attended a telecon on 25 July during which the results of the ranking were discussed. Attention centered on the division line between the top ranked and lower ranked proposals. Reviewers were given a final chance to submit revisions to their reviews; several reviewers adjusted their scores on the basis of discussion, at which point the ranking was

			10	4	9	1	3	5	6	7	8	11	12	13	14	2	15	Avg	Std
408	Gen2SIS	6		2	3	2	1	1								2		1.83	0.75
403	AppDiver	5	1						2	2			3	3				2.20	0.84
411	Prototype	5	3	3.5			1.5				3						1.5	2.50	0.94
409	TPM2Vis	6			2			3		4		2	2.5		2.5			2.67	0.75
412	DigBEAA	4				4.5					1				3	3		2.88	1.44
413	Clean	6	6		3					3		2			3.25		2	3.21	0.60
404	NeuroSco	4								6		3	3.5				3	3.88	1.44
405	FEFirm	5	5	3				5							3.5	4.5		4.20	0.91
410	CLOA	5			8	4			3		4			3.5				4.50	2.00
401	PAFWide	6	5	1	8		4	2.5						8				4.75	2.86
406	DataXpor	3							5					7			5	5.67	1.15
402	RemRec	5									5	9			5	8	8	7.00	1.87
407	CasaPipe	6				8		8	8	8.5		7	4.5					7.33	1.47
		Sur	20	9.5	24	18.5	6.5	19.5	18	23.5	13	23	13.5	21.5	17.3	17.5	19.5		
		Avg	4.00	2.38	4.80	4.63	2.17	3.90	4.50	4.70	3.25	4.60	3.38	5.38	3.45	4.38	4.88	4.02	0.9397
		STD	2.00	1.11	2.95	2.50	1.61	2.70	2.65	2.59	1.71	3.21	0.85	2.50	0.94	2.63	2.66	2.17	0.7679

Fig. 1.— Proposal/Referee Scoring Matrix. Top row gives anonymized referee name, Left column provides short mnemonic for proposal followed by proposal number.

revised, rediscussed and closed.

Proposals were then reranked (there was little change as few scores had been revised). The final ranked list is given in the table. Some titles have been shortened for ease of presentation. All investigators and their institutions are listed, along with the amount of funding requested. A horizontal line marks the division where accumulated funding requests does not exceed funding available. Six studies fall above the line, requesting a cumulative total of $1,016,073..

3. Summary of Second-Tier Ranked Projects and Committee Recommendations

3.1. 404 Neural Machine Intelligence Tools for Complex ALMA Data

Merenyi (PI), Isella (Rice University) A neural network code, previously used to analyze hyperspectral data cubes from NASA, will be employed to analyze ALMA data

			10	4	9	1	3	5	6	7	8	11	12	13	14	2	15	Avg	Std
408	Gen2SIS	6		5	3	2	3	1								2		2.67	1.37
403	AppDiver	5	1						2	2			3	3				2.20	0.84
411	Prototype	5	3	6			4				4						1.5	3.70	1.64
409	TPM2Vis	6			2			3		4		2	2.5		2			2.58	0.80
412	DigBEAA	4				4.5					1				4	3		3.13	1.55
413	Clean	6	8		3					3		2			4		2	3.67	0.84
404	NeuroSco	4								6		3	3.5				3	3.88	1.44
405	FEFirm	5	7	6				5							5	4.5		5.50	1.00
410	CLOA	5	7		8	4			3		6			3.5				4.90	2.07
401	PAFWide	6	4	1	8		8	2.5						8				5.25	3.16
406	DataXpor	3							5					7			5	5.67	1.15
402	RemRec	5									8	9			8	8	8	8.20	0.45
407	CasaPipe	6				8		8	8	8.5		7	4.5					7.33	1.47
		Sur	30	18	24	18.5	15	19.5	18	23.5	19	23	13.5	21.5	23	17.5	19.5		
		Avg	5.00	4.50	4.80	4.63	5.00	3.90	4.50	4.70	4.75	4.60	3.38	5.38	4.60	4.38	4.88	4.60	0.4835
		STD	2.88	2.38	2.95	2.50	2.65	2.70	2.65	2.59	2.99	3.21	0.85	2.50	2.19	2.63	2.66	2.55	0.6195

Fig. 2.— Proposal/Referee Scoring Matrix. Top row gives anonymized referee name, Left column provides short mnemonic for proposal followed by proposal number. For each reviewer, a normalization was performed to spread grades over the available range. Although this process resulted in some migration of project ranking, the overall recommendations did not change.

cubes. The group proposing this study have already applied this technique to an ALMA protostellar disk dataset, obtaining some interesting results. Disks, however, tend to be small and kinematically dominated by Keplerian motion. More complex applications may be more scientifically important: turbulent giant molecular clouds, PDRs around expanding HII regions, spiral arms in nearby galaxies, blind discovery of isolated line-emitting regions, etc.Undoubtedly, research into new approaches in cube analysis are needed to exploit ALMA to its fullest.The neural network tools championed here are quite fascinating but how they will result in new and/or improved insights into actual astrophysical problems seemed unclear. For example, much emphasis is placed on showing that regions of similarity could be located through these techniques but not why such identifications are necessary and what insights are gained. In reality, the proposed analyses of multiple lines through their techniques will be challenged significantly by excitational and chemical differences between the sources of the observed lines. The team must themselves demonstrate further what physical insights their techniques can reveal using existing ALMA data.

The team is capable of undertaking this project and have been strongly involved in the development of the technique. The timeline and resources are reasonable, and there is a significant amount of in kind contribution from Rice University. The risks identified by the team themselves are indeed quite low, and no risk would confront ALMA itself. severe reservations that the methods proposed will result in useful insights.

Note that this code may not be easily deployed by the ALMA archive and that it seems to rely on commercial software (MATLAB), which can be very expensive and not necessarily available to the community in general. **Summary Recommendation** While very promising, the application of the neural network code to ALMA datasets to achieve scientific insight needs elaboration before the general ALMA user can make fullest use of it.

3.2. 405 Front End Remote Firmware Update & Configuration Database

McLeod (NRAO) This proposal serves the goal of improving telescope efficiency by shortening the time needed to make firmware upgrades to the front ends across the array. The argument is that the present means by which software fixes and parameter changes are made is slow and in the case of a change necessary to maintain array operations, it could serve as a bottleneck to science operations. In an ideal world, this work should be paid for by the observatory operations budget. The work is well motivated and well worth doing, but not to the point of diminishing funding from future development of new science capabilities.

The proposal addresses items within the NA ALMA Development Strategic Goals, by proposing to develop firmware and software to improve ALMA observing efficiency by allowing for as much as 8 hours/month of additional science observations. Personnel are excellent, backed by NRAO with low risk.

Summary Recommendation Consider funding for this proposal from alternate sources, such as the observatory operations budget.

3.3. 410 ALMA Central LO (CLOA) Improvements and Upgrades

Jacques (PI), Shillue (NRAO) The goal is to find a pathway for the ALMA Photonic LO to evolve so that it: (1)improves high frequency array coherence; (2) improves antenna-to-antenna phase stability; (3) enables longer baselines; and (4) increases length of time that ALMA can maintain exceptional phase stability between calibrations. These improvements clearly are relevant to the NA ALMA partnership strategic goals to Improve and extend technical capability.

This study would be of clear scientific benefit to ALMA. Improvements the the ALMA LO distribution would directly address specific scientific needs, including improved stability so that the telescope will be less instrument-limited at its shortest wavelengths; improved coherence and addition of optical amplifiers to support longer baselines; and increased range of line length correction so as to increase the length of coherent observing sessions beyond 1 hour. All of this is very worthwhile and essential to ALMA's future, directly addressing the longer baselines path in ALMA2030.

The two investigators were the core of the original development team for the CLOA, so they are uniquely qualified to carry out this study. They have the NRAO Technology Center Photonics Lab at their disposal, with its CLOA test set.

A clear statement of deliverables or outputs would have strengthened the proposal.

More background and more block diagrams of both the existing and potential designs would have been helpful. It would also have been helpful to give quantitative measures of the existing performance and the goals for improvements.

Summary Recommendation This study would be of clear scientific benefit to ALMA. Immediate benefits include better submillimeter array coherence and phase stability, very important during the best weather. It is also important for the establishment of longer baselines, somewhat farther in the future.

3.4. 401 Wide-Fielding ALMA Using Phased Array Feed Receiver

Roshi(PI), Shillue, Hunter, and Brogan (NRAO) The proposal is to report on the performance that might be achieved with a 19 element phased array feed for Band 3. It is proposed to study the implementation of a phased array feed (PAF) for ALMA band 3 using the existing cryostat and window, but modifying the room-temperature optics, so as to produce 7 continuous beams on the sky. It is claimed in the abstract that the results can be scaled to other bands, but the practicality of that is not shown. If such a PAF were actually deployed, the benefit to ALMA might be reduced observing time for imaging large fields. The proposal thus directly addresses Goal #4: Increasing wide-field mapping speed: Multi-beam receivers, from the ALMA Science Advisory Committee (ASAC) Recommendations for ALMA 2030. Starting to implement phased arrays is an important next step for ALMA. The team has extensive experience in RF and microwave system and radio astronomy instrumentation.

Improving ALMA's mapping speed for large fields would be scientifically valuable. Thus, investigating the possible performance of phased array feed on an ALMA 12-m telescope is a reasonable development project. Although PAFs almost certainly will have higher noise temperatures than the best single receivers, installing PAFs on just the 4 total power antennas is a good goal. These telescopes normally are used to map large fields, hence the multibeam capability of the PAF might improve the mapping speed despite the somewhat degraded noise temperatures. Note that the proposed receiver with LNAs would likely perform less well in terms of noise and bandwidth than the existing ALMA band 3 receiver. If that performance degrades sufficiently, it will quickly eliminate the advantage of 7 spatial pixels on the sky.

The proposal does not make a convincing case for pursuing a PAF rather than a much simpler focal plane array (FPA) for achieving multiple beams. For continuum observations, the reduced bandwidth of this prototype would make the PAF system slower than the single-pixel system for wide-field imaging, so it becomes only a technology demonstration. A much clearer statement of the study's expected outputs is needed.

This proposed study fails to provide any short-term benefit to ALMA and there is considerable uncertainty of any long-term benefit. The cost and power consumption of the extensive signal processing needed for the beamforming is not included in the proposed study. The study is therefore fairly high risk.

Summary Recommendation The proposed study addresses an important first step in the direction of implementation of phased array receivers. However, the proposed study falls short of providing a compelling solution. It may be more suited to the longer term study category offered next year, for 'Strategic Studies'.

4. Summary of Lower Ranked Projects and Committee Recommendations

4.1. 406 Multi-Channel Data Transport and Pre-processing System

Morgan (PI), Wundke, Boyd (NRAO) It is proposed to develop data links using unformatted samples from an analog-to-digital converter, requiring logic that is considerably simplified compared with conventional formatted links. It is based on a concept developed at the NRAO and previously published and patented. The study proposal covers only a proof-of-concept demonstration at a link rate of 10 Gb/s, which is considerably faster than the 2.488 Gb/s previously demonstrated (ref [1] of the proposal). The supposed benefit to ALMA is that it would provide for expansion of the present 16 GHz of RF signal bandwidth transmitted from each antenna in order to enable multi-beam receivers.

Risk is low and the team is well-suited to the study.

The proposal is not timely, it is short and lacks detail. It is not as impactful as other studies that have been proposed.

Summary Recommendation This study is premature and does not provide any near-term benefit to ALMA.

4.2. 402 NA ALMA Antenna Remote Recovery from Power Outages

Symmes (PI), Lopez (JAO, NRAO) This proposal serves the goal of improving telescope efficiency by shortening the time needed for the array to recover from power outages at OSF: without the NA antennas the array cannot achieve the number of antennas needed for science operations. Unfortunately the frequency of occurrence of power outages at the OSF was not provided and correspondingly how much observing time is lost due to the problem remains unidentified. The program will indirectly address the ALMA 2030 development goal of increasing sensitivity. However, it is very difficult to assess how much it will increase sensitivity, given the lack of information on time lost. The study is low in risk, executed by a capable team. **Summary Recommendation** Too little information is provided to assess the benefits the remote recovery will bring.

4.3. 407 CASA Parallel I/O improvements for the ALMA Pipeline

Latham (PI), Pokorny (Argonne Natl Lab, NRAO) The speed of I/O computations within the parallel computing environment are a major – perhaps even the principal – limitation for the scientific output of ALMA. Fields of view, velocity ranges, and correlator usage are restricted in order to keep datasets to a size manageable for reduction with CASA. This limits scientific discovery, both with intended and serendipitous goals. Figs 1-3 demonstrate convincingly that I/O speed is a critical problem. There is no scientific case presented in the proposal beyond specifying a need for 'improvements.' The proposal does not have a well developed technical case. The proposal is vague and seems half-baked, and while it clearly demonstrates the (well-known and painful) problems with CASA I/O, it does not provide concrete solutions in terms of performance enhancement. The proposal does not directly address any of the ALMA 2030 recommendations. Considerable risk is given that the project will not succeed (50

Summary Recommendation the authors prepare a stronger, more detailed and convincing proposal for the next ADP round.

We propose to fund the six most highly ranked proposals according to the process outlined in 'Management Plan for ALMA Development Studies in North America'. Seven proposals would receive no funding under the review committee recommendations. Possibly, some of those could be funded from future Studies funding.

5. Summary of Highly Ranked Projects and Committee Recommendations

5.1. 408 Development of 2nd Generation SIS Receivers for ALMA

by Kerr, PI, Mangum, Lichtenberger, Effland, Dindo and Srikanth

This proposal has a well-developed science case. The technical case for this proposal centers on making modest improvements to the Band 6 receivers and substantial improvements to Band 10 receivers.

Band 6 is one of the workhorse bands at ALMA. Although the Band 6 receivers have outstanding performance, the noise temperatures increase below 5 GHz in the IF passband. This is a problem if one wants to make simultaneous observations of the 2-1 12CO and 13CO lines, which is a very common need. the recent ALMA paper by Zhang et al. (2015) seems to have suffered from the problems illustrated in this proposal. Replacing the existing IF amplifiers with balanced amplifiers should improve the gain and noise flatness across the IF band, and is projected to improve the mapping speed for these observations by almost a factor of two. The second proposed improvement, switching to balanced mixers, would reduce noise contributions from the LO.

The Band 10 science case is much more developed, discussing the importance of studying many of the tracers in the window. Given the proposed improvements in receiver noise temperature for Band 10 (vs. the only factor of 2 improvement for Band 6). It is surprising that the fine structure lines of [NII] and [CII] can be considered as Band 10 Spectral Lines. Why stop with those? You could include [OI] 63 microns at an appropriate redshift, and this would be equally correct. It is the case that red-shifted fine structure and other lines having higher rest frequencies will be observed in ALMA bands, but there are many candidates. There are far better references with lots of real data available for use of the [NII] fine structure line ratio as a densitometer as mentioned in Section 4.1.2.1.2.

Going to balanced mixers and having these use balanced IF amplifiers is a very plausible approach to minimizing LO noise over broad frequency ranges. The scheme for integrating all of this together in a reasonable package is first rate and very promising. This could really improve the situation! By the time one has dual polarization sideband-separating mixers using balanced IF amplifiers one has a LOT of components. But this is a reasonable price to pay, and estimates of volume and power dissipation are very promising.

The band 10 work requires new Nb/Al-AlN/NbTiN junctions. It's questionable whether these devices will be produced in the one year time frame of this study.

While there are some reservations about the expressed science justification, there are no worries about the technical expertise necessary to carry out this work. It is clear to me that the NRAO-UVa collaboration can provide the designs, the fabrication, and carry out the necessary tests of the complete second generation receivers described in the proposal. This has been proven in the past.

There is relatively low risk in this proposal. It is apparent that it builds on a lot of work on sub-pieces of the problem and what is proposed is to bring things together in complete receiver(s).

Summary Recommendation The value to ALMA of improved band 6 and band 10 receivers is large. The science case for this work is strong, and it is consistent with ALMA planning. The work will be carried out by a well-qualified team and carries low risk.

5.2. 403 Diversifying the ScientificApplications of the ALMA Phasing System

by Matthews (PI), Crew, Fish, Hecht, Doeleman (MIT)

The proposed study will further enhance the mmVLBI capability of ALMA in three ways: i) enhancing its sensitivity through fixing the ”delay problem” encountered during previous commissioning, ii) extending its reach to weaker sources via new observing techniques, and iii) studying the implementation of spectral line observing. The science case provided for mmVLBI in this proposal is slim, but it is easy to see how the proposed enhancements will allow a greater scope for mmVLBI for ALMA (and the peer observatories). Indeed, the science case is quite similar to the mmVLBI science cases listed in the 'Pathways to Developing ALMA' document by Bolatto et al., so the case is quite relevant to future ALMA development priorities.

Summary Recommendation Strengths of this study include strong science case, immediate usefulness to ALMA, detailed description of the proposed work, and clear and and measureable deliverables. Weaknesses are that item i) implements a solution devised in a previous study, a matter of creating and releasing appropriate software updates. This is a stretch definition of an ALMA Development Study; it might better be accommodated as a separate project but doing so would postpone implementation owing to the infrequent opportunities for Project funding.

5.3. Prototype Dual-Linear 2SB Block & Single-Polarization Balanced 2SB Block

by Henke, (PI), Niranjanan and Knee (NRC-HIA) Two advanced configurations for 3mm wavelength SIS mixers in the sorkhorse ALMA B3 receivers will be investigated. In the first, a dual polarization 2SB design including a turnstile junction for polarization separation and hole-couplers for LO injection will be used, a design using four single-ended junctions. In the second, a more sophisticated design is studied, using input hybrids to reduce the reflected LO and signal power and requiring 4 mixers for a single polarization 2SB system, half of a complete system. Advantages of the new approaches include lower receiver noise temperature and broader bandwidth compared to existing Band 3 units. Improved LO couplers could deploy the unused LO power to other mixers, useful for future multi-pixel arrays. The proposed work addresses 2 of the main recommendations of the ASAC recommendations to ALMA 2030. This proposal will get significant support from the institute proposing the study, which is certainly important for realizing a considerable amount of work in 1 year.

Summary Recommendation Band 3 is the most-used ALMA Band; receiver development will be studied which can lower system noise and broaden the bandwidth of the critical 3mm band. The study is low in risk (schedule poses a worry) and the investigators are very capable of delivery.

5.4. 409 Total Power Map to Visibilities (TP2VIS)

by Koda (PI), Teuben, Sawada, Plunkett and Brogan (Stony Brook U., U. Md., JAO, ESO and NRAO) Improved software capability to make the best use of the combined 12-m, compact and total power arrays is proposed. This is a clear case of a scientifically important analysis tool which should be available and easily useable to observers. Best practices for combining total power and interferometric data evolve and this proposal follows the most current evolutionary path. Although CASA currently provides a method for data combination, investigating alternative approaches, and quantitatively testing both methods with simulated data, is a good idea. This development study will lead to an actual product - a software tool usable by astronomers, not just a final report. There is no clear mathematical path to total power and interferometric data combintion into the final image as there is using either component alone. This group has a perfect combination of expertise. 'Deconvolution, combination software' was identified under 'Imaging quality and calibration' in the 'Pathways to Developing ALMA' document by Bolatto et al., so this work fits well within that framework. Funding is committed from the University of Maryland though not listed in the 'in-kine' tabulation. **Summary Recommendation** This software tool for the community is important for extended objects with large scale structures. Low in risk, with a well-qualified team, and with a useful deliverable, this study is worthy of support.

5.5. 413 Cleaning Up Interactive Cleaning

by Rosolowsky (PI) and Kern (U. Alberta and NRAO) The proposers seek to extend CARTA, developed under an earlier ADP grant, to support the CLEAN process: interactive selection of regions of interest, interoperability with CASA cleaning operations. The motivation to replace the CASA 3D image visualization and analysis system is very strong. CASA's has a powerful need for a new 3D system. Some level of risk is associated with the fact that CARTA is not yet delivered. Some of the more interesting goals of this study are only 'stretch goals'. The team is very well qualified and the proposed work is very well aligned with the the recommendations from ALMA2030. This work may benefit the largest pool of ALMA users for the lowest cost. but these capabilities should have been planned as part of CARTA development.

Summary Recommendation The impact of the development will be widespread among ALMA users and the activity should be funded.

5.6. 412 Digital Back End Antenna Article

Ford (PI), Ashton, Gerrard, Langley, Revnell, Luce, Erickson, Lacasse, Saez, Carilli, Ricci (NRAO, JAO, CfA) The scientific case for increased bandwidth for continuum and spectral line science is well developed. Improving the instantaneous bandwidth of ALMA is an important goal of ALMA 2030. This will enable science observations to take better advantage of the width of each receiver band, enhance continuum sensitivity, and enable simultaneous observation of spectral lines across a wider bandwidth. A very detailed design is presented, based on the detailed experience of the team. Discussion of the tradeoffs or compromises of this particular implementation versus other approaches would have broadened the study. One focus is whether the current 24 GHz ADCs can really work at the necessary rate; there is some risk assocated with this. The team is excellent.

Summary Recommendation A strong team proposes to study designs for broadband performance and retire the risks associated with high sampling and processing rates. There is a strong likelihood of success and this is an important step toward providing a higher bandwidth system for ALMA science.

Table 1: 2016 ALMA Development Study Review Panel

Reviewer	Institution	Speciality
Yancy Shirley	U. Az.	instrumentation, science
Stephen White	Kirkland AFB	solar science
Paul Goldsmith	(JPL)	instrumentation and science
Lorene Samoska	(JPL)	instrumentation and science
Joaquin Vieira	U Ill.	instrumentation, science
Jeremy Darling	U. Co.	science
James DiFrancesco	HIA/NRC	instrumentation, science
Gordon Stacey	Cornell U.	instrumentation, science
Dick Plambeck	U. California, Berkeley	instrumentation, science
Chris Groppi	ASU	science, radio technology expert
Eric Feigelson	Penn State U.	astroinformatics, science
Paul Rosen	U. S. Florida	software, science
Larry D'Addario	JPL	instrumentation, science
James Aquirre	U. Penn.	instrumentation, science
Henrique Schmitt	NRL	instrumentation, science

Table 2. Summary of Projects and Investigators

ID	Short Title	PI and co-I	Institutions	Budget
408	Development of 2nd Generation SIS Receivers for ALMA	Kerr, Mangum, Lichtenberger, Effland, Dindo, Srikanth	NRAO, Uva	199795
403	Diversifying the ScientificApplications of the ALMA Phasing System	Matthews, Crew, Fish, Hecht, Doeleman	MIT	199286
411	Prototype Dual-Linear 2SB Block & Single-Polarization Balanced 2SB Block	Henke, Niranjanan, Knee	NRC-HIA	145601
409	Total Power Map to Visibilities (TP2VIS)	Koda, Teuben, Sawada, Plunkett, Brogan	Stony Brook U., UMd, JAO, ESO, NRAO	173672
413	Cleaning Up Interactive Cleaning	Rosolowsky, Kern	U. Alberta, NRAO	98991
412	Digital Back End Antenna Article	Ford, Ashton, Gerrard, Langley, Revnell, Luce, Erickson, Lacasse, Saez, Carilli, Ricci	NRAO, JAO, CfA	198728
	The following Proposals were lower ranked & may not be accommodated within the FY17 funding limits			
404	Neural Machine Intelligence Tools for Complex ALMA Data	Merenyi, Isella	Rice University	177277
405	Front End Remote Firmware Update & Configuration Database	McLeod	NRAO	131907
410	ALMA Central LO (CLOA) Improvements and Upgrades	Jacques, Shillue	NRAO	199791
401	Wide-Fielding ALMA Using Phased Array Feed Receiver	Roshi, Shillue, Hunter, Brogan	NRAO	199587
406	Multi-Channel Data Transport and Pre-processing System	Morgan, Wundke, Boyd	NRAO	199263
402	NA ALMA Antenna Remote Recovery from Power Outages	Symmes, Lopez	JAO, NRAO	178463
407	CASA Parallel I/O improvements for the ALMA Pipeline	Latham, Pokorny	Argonne Natl Lab, NRAO	200000

Table 3. Summary of Projects and Investigators

Short Title	PI and co-I	Institutions
Development of 2nd Generation SIS Receivers for ALMA	Kerr, Mangum, Lichtenberger, Effland, Dindo, Srikanths	NRAO, Uva
Diversifying the ScientificApplications of the ALMA Phasing System	Matthews, Crew, Fish, Hecht, Doeleman	MIT
Prototype Dual-Linear 2SB Block & Single-Polarization Balanced 2SB Block	Henke, Niranjanan, Knee	NRC-HIA
Total Power Map to Visibilities (TP2VIS)	Koda, Teuben, Sawada, Plunkett, Brogan	Stony Brook U., UMd
Cleaning Up Interactive Cleaning	Rosolowsky, Kern	U. Alberta, NRAO
Digital Back End Antenna Article	Ford, Ashton, Gerrard, Langley, Revnell, Luce, Erickson, Lacasse, Saez, Carilli, Ricci	NRAO, JAO, CfA