CASA Users Committee
Annual Report 2022

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2 Acronyms, Applicable and Reference Documents

2.1 Acronyms

AAS	American Astronomical Society
ACDC	ASIAA CASA Development Center
ALMA	Atacama Large Millimeter/submillimeter Array
ARC	ALMA Regional Center
ARDG	Algorithm Research & Development Group
CARTA	Cube Analysis and Rendering Tool for Astronomy
CASA	Common Astronomy Software Applications
CL	Chile
CNGI	CASA Next Generation Infrastructure
CUC	CASA Users Committee
EA	Eastern Asia
EAS	European Astronomical Society
EU	European Union
EVN	European VLBI Network
EVLA	Extended Very Large Array
HPC	High Performance Computing
IF	Interferometer
IN	India
JIVE	Joint Institute for VLBI ERIC
NA	North America
NRAO	National Radio Astronomy Observatory
RFI	Radio Frequency Interference
TW	Taiwan
SD	Single Dish
SKA	Square Kilometre Array
SRDP	Science Ready Data Products
VLA	Karl G Janksy Very Large Array
VLASS	VLA Sky Survey
VLBA	Very Long Baseline Array
VLBI	Very Long Baseline Interferometry

2.2 Applicable Documents

[AD1] CUC Charge (2014-09-16)
[AD2] Revised CUC Charge (2016-08-01)

2.3 Reference Documents

[RD1] CASA Users Committee - Terms of Reference
[RD2] CASA Users Committee 2014 Report
[RD3] CASA Response to the 2014 CASA Users Committee Report
[RD4] CASA Users Committee 2015 Report
[RD5] CASA Response to the 2015 CUC Report
[RD6] CASA Users Committee 2016 Report
[RD7] CASA Response to the 2016 CUC Report
[RD8] CASA Users Committee 2017 Report
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[RD14] CASA Users Committee 2020 Report
[RD15] CASA Response to the 2020 Report
[RD16] CASA Users Committee 2021 Report
[RD17] CASA Response to the 2021 Report

3 Introduction

The CASA Users Committee (CUC) was formed in 2014 on the initiative of the National Radio Astronomy Observatory (NRAO) Data Management and Software Department. The committee's charge is to provide feedback from the CASA users community on capabilities, usability, reliability and performance of the CASA software package, advising the CASA development team from the user perspective of these matters and informing development priorities [RD1]. In 2016 this charge was revised to include year-to-year tracking of CUC recommendations [AD2, see 3.1].

The 2022 CUC meeting was held virtually on November 11th-14th, following a mid-year online "catch-up" meeting on July 30th. The goal of this meeting was to update the CUC on CASA developments, review actions taken in response to the 2021 CUC recommendations and provide updated recommendations for the 2022-2023 cycle.

The attending CUC members were:

Olga Bayandina (EU)
Abhijeet Borkar* (EU)
Jane Huang* (NA)
Ruta Kale (IN, at large member)
Jihyun Kang (EA)
Adam Leroy (NA, Chair)
Kristina Nyland* (NA)
Imke de Pater* (NA)
Yu-Nung Su (NA)
Yoshimasa Watanabe (EA)

During the meeting, the CUC nominated and elected **TBD** as its Deputy Chair. They will assist the Chair in the upcoming months and become the next CUC Chair in 2022 after the mid-year telecon in June/July 2022.

3.1 Revised Charge [see also AD2]

1. Please comment on the capabilities, usability, reliability, and performance of CASA for current users of ALMA and the VLA. Should any of these areas be getting a significantly different allocation of effort than is currently the case? What areas would you de-emphasize as a consequence?

2. The committee should comment on the CASA project's follow-up to their previous report – whether it is sufficient, whether any activities should be emphasized or de-emphasized.

3. Committee organization: The CUC should appoint a deputy chair who will become the next chair. The CUC appointed **TBD** as the deputy chair.

3.2 Specific Charge 2022

In addition to the CUC charge and revised charge, the committee were this year asked to comment on the following:

1. Progress and planned evolution of CASA Infrastructure (including CNGI).

2. The evolution of the committee in the era of WSU and ngVLA.

4 Meeting Agenda

Monday, November 14, 2022

07:00 MT / 14:00 UTC	CUC Executive Session	
07:30 MT / 14:30 UTC	Welcome pdf	Jeff Kern
07:45 MT / 14:45 UTC	CASA Overview (staff, stakeholders, priorities) pdf	Urvashi Rau
08:15 MT / 15:15 UTC	CASA Users pdf	Bjorn Emonts
08:45 MT / 15:45 UTC	*Break*	
09:00 MT / 16:00 UTC	Infrastructure development (incl. CNGI) pdf	Jan-Willem Steeb
09:30 MT / 16:30 UTC	CASA Visualization pdf	Darrell Schiebel
10:00 MT / 17:00 UTC	*End of day 1*	

Tuesday, November 15, 2022

07:00 MT / 14:00 UTC	Scientific Development pdf	Urvashi Rau
07:30 MT / 14:30 UTC	Verification / Testing pdf	Akeem Wells / Andrew McNichols
08:00 MT / 15:00 UTC	Validation pdf	Joshua Marvil
08:15 MT / 15:15 UTC	Documentation (moved to Wed) pdf	Bjorn Emonts
08:45 MT / 15:45 UTC	*Break*	

09:00 MT / 16:00 UTC	VLBI pdf	Ilse van Bemmel / George Moellenbrock
09:30 MT / 16:30 UTC	CARTA pdf	Juergen Ott
10:00 MT / 17:00 UTC	*End of day 2*	

Wednesday, November 16, 2022

07:00 MT / 14:00 UTC	Organization changes and role of CUC pdf	Jeff Kern
07:30 MT / 14:30 UTC	Single Dish pdf	Takeshi Nakazato
08:00 MT / 15:00 UTC	Pipeline & Archive pdf	Joe Masters + John Tobin
08:30 MT / 15:30 UTC	*Break*	
08:45 MT / 15:45 UTC	ARDG pdf	Sanjay Bhatnagar
09:15 MT / 16:15 UTC	Documentation pdf	Bjorn Emonts
09:30 MT / 16:30 UTC	General Discussion / CUC Executive Session	
10:00 MT / 17:00 UTC	*End of day 3*	

Thursday, November 17, 2022

07:00 MT / 14:00 UTC	CUC Executive Session
010:30 MT / 17:30 UTC	Preliminary report-out
11:00 MT / 18:00 UTC	*End of CUC meeting*

5 Summary

Over a well-run, informative, and positive four-day virtual meeting, the CUC were pleased to see the continued progress CASA has made. The meeting showcased responses to the 2021 CUC report, progress in many important focus areas, and development of a staged long term plan. The CUC commend the new CASA lead, Urvashi Rao, the DMS lead, Jeff Kern, all members of the CASA development team, and the members of the associated teams who presented for their exemplary work on the continued improvements to CASA.

The CASA User Committee is charged to comment on the capabilities, usability, reliability, and performance of CASA for users of ALMA and the Jansky VLA. With this year’s charge, the committee has also been asked to provide user feedback on the CASA project’s plans to evolve to meet the needs of a next generation VLA (ngVLA) and ALMA in the era of the wideband sensitivity upgrade (WSU).

As the CUC charge makes clear, NRAO, DMS, and the CASA team have finite resources to allocate to the CASA effort. This tradeoff was a particular focus this year, with presentations by CASA and DMS focused on plans to revamp the CASA infrastructure and build for the future while working within the limits of the available CASA personnel and resources. The CUC endorses the measured approach towards building a next generation infrastructure and a next generation CASA, and acknowledges that this will come at the cost of development other than bug fixes while the infrastructure is rebuilt. The committee emphasizes that the specifics of this plan, which are not yet determined, will likely matter a lot to the users. The CUC suggests that the major focus of next year's meeting (which might drive the timing) should be on the likely landscape moving forward (i.e., what will and will not develop in CASA 6, likely timescales, etc.).

The user perspective also continues to evolve. Mature pipelines for ALMA and the VLA are now a central part of the user experience and many users, especially ALMA users, now obtain calibrated data directly from the observatory. The observatory delivers imaging products for ALMA and the VLA Sky Survey. Local processing, especially imaging and visualization using CASA, continues to be important, especially for VLBI and planetary observations. But the landscape is changing so that the user interaction with CASA is often interlinked with other systems and groups at a deep level.

This evolving user perspective and the developing long-term plan relates closely to this year's specific charge to evaluate the role of the CUC moving forward. Given that the scope of CASA-related user interests now heavily overlap other "non-CASA" efforts like pipelines, science ready data products, compute resources from the observatory, sky survey execution, etc., our view is that the simplest and most general path forward is to expand the scope of the CUC to encompass topics like SRDP, pipelines, etc. and then to re-integrate the CUC in some way with the NRAO user's committee, perhaps as a subcommittee that reports to the user committee with some overlapping memberships. Alternatively, the CUC could be reconstructed to focus on "power users" and technical issues. Even as the management of CASA and DMS has changed, the CUC membership has also completely rotated over the last two years, so reconfiguring the committee and its charge is timely from our perspective as well.

The virtual meeting ran well and the CASA liaison Bjorn Emonts has done a great job, but with little time for executive sessions or discussion, the committee had limited time to interact and form collective opinions. There was interest in a hybrid meeting possibility from some CUC members for next year, though other members appreciated the ability to participate during the semester when other commitments prohibit travel. Either way, forming a meeting Slack or similar communication medium for the committee would be helpful moving forward.

6. Recommended Overall Priorities for the Coming Year

2021 Endorsements/Recommendations:

1. *Continued work on a tool for interactive tclean to replace the viewer.*
2. *Initial work on the refactoring and modernisation of the remaining CASA GUIs, starting with plotms.*
3. *Continued effort on single-dish/interferometer joint deconvolution work.*
4. *Investigation of some level of support for Ubuntu via virtual machines, and continued MacOS support.*
5. *Continued effort in accommodating the wider radio-interferometry user base e.g. VLBI, GMRT, MeerKat, by allowing greater tunability of existing functions (e.g. widebandpbcor) and advertising widely when new functionality accommodates data reduction/analysis from observatories other than the VLA and ALMA.*

2022 Endorsements/Recommendations:

1. Fixing a firm plan for the CASA to ngCASA transition in a measured, careful way is incredibly important.
2. Once this is done, communicating the likely timescales and user-facing changes and what can be expected to the community will be very important (including what outstanding issues/bugs will be resolved and which not).
3. Continued work on the delivery of calibrated MSes to users.

7 Specific Focus Areas

Based upon the charge of the CUC, in the following section we summarize last year's recommendations, what the CUC learned during this year's meeting, and make new recommendations for the coming year. In light of developments over the past 12 months, some sub-section headings have been updated from the 2021 report [RD16], the CUC notes which sections in the previous report the new sections follow on from where appropriate.

7.1 CASA Management

2021 Endorsements/Recommendations:

1. *The CUC strongly endorses that CASA continues their support of the pipeline teams in their efforts to advance and improve the pipelines for both ALMA, and increasingly the VLA. Pipeline processing is becoming a common application of the CASA software within the community and the balance between supporting 'at-home' CASA users and pipeline developers as stakeholders currently seems appropriate.*

2. *The CUC acknowledges that VLASS is an important project which has presented unique challenges and benefitted the CASA development. However, the CUC cautions against VLASS related activities overshadowing other priorities for the CASA user base.*

3. *Overall, the CUC continues to commend the well balanced approach the CASA team is taking to meet all its stakeholder needs.*

2022 Endorsements/Recommendations:

1. The CUC commends the project overall for handling a large amount of turnover well and using the turnover to develop a coherent vision for the next decade.

2. The focus on simultaneously planning for short-term stability and correctness-focused CASA updates while pursuing a long term strategy to meet the ngVLA + ALMA WSU seems reasonable and forward thinking.

3. Management acknowledged the difficult problem of doing two major projects (CASA 6 maintenance and ngCASA) at once. While balancing these priorities, the CUC recommends that DMS and the CASA team keep in mind that users seem likely to still be focused on CASA 6 for some years to come. Similarly, the CUC and the community have a strong vested interest in the development and correctness of the ALMA and VLA pipelines and recommend that their input (and corresponding SRDP input) be weighed heavily if issues arise.

4. The addition of a validation lead and the continued evolution of the build system and overall release schedules seem to be very positive developments that address stability and performance.

5. The CUC acknowledges the issues with recruitment, retention, specific expertise, and training faced by CASA. If the long term infrastructure changes make tracking from astronomical research viable, then the committee endorses CASA and DMS thinking creatively about pursuing Reber Fellowships, internships, or even potentially arguing for Jansky fellowships focused on building a career path into DMS/CASA. Advertisements of opportunities to the CASA/NRAO mailing list, user committee.

6. The flexibility in location and remote work shown by DMS is a good step to address

these issues.

7. Publication of the CASA paper is commended and represents an important milestone. Integrating CASA into the astronomical literature has been a positive step (same for VLBI, automask, ASP).

CASA and DMS both underwent significant changes in leadership in 2021 and the landscape has continued to evolve with the ngVLA becoming more likely and the ALMA WSU on the horizon. The CUC appreciated the broad, forward looking presented by both CASA and DMS and appreciates that the teams used the turnover to take a "step back." The plan to build momentum and buy in from stakeholders over time, and especially the reviews planned for next spring seemed well thought out.

As users, the CUC notes that our interface with CASA tends to be much shorter term (we want our projects to succeed now), and that if ngCASA and CNGI take time then users will still be engaging with the current versions of CASA 6 and the ALMA and VLA pipelines for years. The CUC acknowledges that this represents a very challenging task to balance resources between the crucial long term development and the short-term stakeholder needs.

The CUC also acknowledges the difficulty in building expertise and recruiting, training., and retaining such a highly expert team in 2022. The CUC appreciates points made during the presentations about leveraging many of the same avenues used to train and recruit other observatory and scientific staff. There is a great appetite among many students these days for data science and programming expertise, and thinking creatively about how to use this to CASA's advantage seems like a good move. It would also serve the community well if there are more developer-scientist positions and a clear track at NRAO.

7.2 Role of CUC Moving Forward

2022 Endorsements/Recommendations:

1. In the long term, the scope of the CUC seems mismatched to the current user experience, and the CUC does advise DMS/CASA to reconsider its basic charge. The user experience is now inextricably linked to a number of items not "directly CASA" - pipelines, compute, SRDP, etc., and this seems sure to become even more true over the next decade heading into ALMA WSU and ngVLA. These are already part of the presentations, but outside the formal charge. The most constructive use of our input and time seems to be to represent the real user experience.

2. An expanded charge would likely overlap other committees representing users, especially the NRAO User's Committee and there seems to be little point in duplicating review and input efforts. Connecting (or reconnecting) the CUC to the

NRAO User's Committee, e.g., as a subcommittee, would seem sensible *if* this would make it easier for DMS and CASA to get the feedback they need from a single, consistent source *and* there is a way to retain good international representation on the committee.

3. In the short term, the CUC was split on the question of virtual or in-person meetings. On the one hand, in person meetings allow more one-on-one and detailed, informal discussion and full day, local meetings would allow one to "dig in" more to key topics. On the other hand, constituting and scheduling the CUC is a considerable challenge. Hybrid meetings have notorious pitfalls, but still might be a reasonable option to explore with next year's committee.

4. Regardless of format, the CUC recommends additional executive sessions and including asynchronous communication like Slack or Teams in next year's meeting. The recent CUC meeting (which was otherwise very well organized) left little room for interaction or discussion among the committee. This limits the utility of having a committee instead of individual reviews (and asking international participants to join live).

The focus on simultaneously planning for short-term stability and correctness-focused CASA updates while pursuing a long term strategy to meet the ngVLA + ALMA WSU seems reasonable and forward thinking.

7.3 CNGI and ngCASA

2021 Endorsements/Recommendations:

1. *The CUC endorses the planning going into CNGI but recommends proceeding conservatively with respect to implementation.*

2. *Given that the CNGI demonstration is in good shape and is ready to be implemented in tasks, the CUC recommends that this is a good time for a formal, external stakeholder review of the plans for CNGI and ngCASA. This echoes recommendations 2 and 3 of last year's report.*

2022 Endorsements/Recommendations

1. The CUC endorses the priorities outlined in the presentations for CNGI and ngCASA, but was nervous about a situation where users are caught in limbo between a frozen CASA 6 and a not-ready CNGI/ngCASA.

2. To avoid this, the CUC recommends that staffing and training procedures be mindful of preserving institutional memory related to CASA 6 during the transition.

3. The CUC recommends that the CASA team interface with the scientists who manage the ALMA and the VLA archive to discuss a data management plan for the transition from CASA 6 to ngCASA that does not leave a significant amount of very expensive data abandoned and inaccessible.

4. As in previous years, the CUC recommends a formal, external stakeholder review of plans for CNGI and ngCASA.

5. Since development on ngCASA seems to have at least partially diverged from the strategy used by other major observatories and there are multiple expertise centers around the world, the CUC recommends exploring opportunities for cross-validation and expertise sharing.

6. The CUC encourages the CASA team to provide clear guidance to other observatories about how to make their data readable in ngCASA and how ngCASA datasets can be made readable by other software reduction packages from other telescopes (e.g., NOEMA, SMA).

The CASA team has clearly articulated the need to develop data reduction software that can handle the large data volumes of ngVLA and ALMA-WSU. Users absolutely want to get the most science per hour out of these instruments and the CUC agrees with the CASA team that processing is often the bottleneck for science and therefore warrants dedicated optimization efforts. To this end, the performance report for the CNGI prototype looks promising, and the VIPER framework will help CASA take advantage of state-of-the-art computing infrastructure.

The CUC has some concerns about the transition from CASA 6 to ngCASA. At the highest level, the worry is that an extended transition that puts user-facing development on hold will make data reduction more confusing and less efficient.

Since a large fraction of publications partially or wholly rely on archival data, ensuring that old datasets from the measurement set era can be processed in ngCASA is essential. Loss of institutional memory may also present a challenge to CNGI and ngCASA development, given that only two members of the CASA team are conversant with ngCASA technology and multiple members of the CASA team are expected to retire this coming decade. Careful internal documentation and further development of training procedures will be essential for facilitating knowledge transfer.

As in past years, the CUC recommends a formal external expert and stakeholder review to offer feedback on design and priorities for CNGI and ngCASA. This seemed to be planned for spring 2023 and the CUC strongly supports this.

7.4 CARTA, Sunsetting the Viewer, and GUI refresh

2021 Endorsements/Recommendations:

1. *The CUC was once again very impressed by the developments made in the CARTA viewer over the last year, both in terms of features and software/resource infrastructure. CARTA seems on track to providing a long term stable image viewer for CASA as well as the general radio astronomy user community.*
2. *The initial work on a standalone interactive tclean widget looked very impressive and a good use of CNGI innovation to support CASA users. The can 'we make this better than it was before' mindset in terms of user features was also nice to see.*
3. *The CUC strongly encourages these efforts to finally allow users to move away from reliance on the CASA viewer.*
4. *The CUC was interested to hear of plans to refactor many of CASA GUI interfaces, which are becoming tired and struggling with modern data volumes.*
5. *Once work on a tclean widget is complete, the CUC suggests plotms is the next obvious candidate: plotms is also a very fundamental tool, and the current implementation can be very slow. The CUC would like to see a refactor of plotms which had a mode, useful for large datasets, where the plotting is speeded up by plotting only a fraction of the points (like XINC in AIPS:UVPLT). Data editing would probably be disabled in this mode. The ability to use some plotms functionality within Jupyter Notebooks would also be a worthy new feature for a refactored version.*
6. *The CUC found the discussion of deprecating the inp/go functionality interesting and timely. However, opinion was divided. For such a fundamental change (from the user perspective), and something common to other data reduction software (if not "vanilla" Python), the CUC encourages soliciting feedback from the larger user community via a survey.*

2022 Endorsements/Recommendations:

1. The CUC strongly agrees that the CARTA is successfully replacing the CASA viewer and that in many ways its functionalities offer a significant upgrade over the traditional viewer. We are looking forward to seeing the new features of the future CARTA versions.
2. The CUC appreciates the many improvements that happened in the latest CARTA version 3, including reliable multi-panel display, position-velocity diagram, 2D Gaussian fitting of sources in the image, vector field rendering, etc..

3. The new developments listed for CARTA version 4, which includes “save & restore state,” channel maps, and an RGB image blender, would be tremendously useful for ALMA users to analyze their data and produce publication-worthy plots. The development of scripting interface features would be very helpful for the users as well.

4. The manual with video tutorials on the CARTA web pages are excellent and the CUC hopes that the new features and descriptions of how to use them will receive similar documentation and video tutorials.

5. The CUC appreciates the efforts of the CASA visualization team. We are happy to see the standalone GUI for interactive control of the CASA *tclean* task. With a new tool emerging, the CUC emphasizes the need to make it accessible and the demo video presented would be useful for users (similar to what CARTA offers) in addition to any written documentation of the tool.

6. If possible, maintaining a consistency in UI between the different visualization tools (CARTA, interactive tclean, ms plotters) would help users.

7. The CUC is also happy to see the features of the *plotms* pathfinder, and support the visualization team to continue their efforts for the standalone GUI tool until it successfully replaces the current one.

8. As much as possible, it would be good to articulate an overarching vision for visualization in ngCASA early, and to try to have the current visualization efforts support and build towards that. The fewer huge resets and more extended user input on these user-facing tools, the better.

Many of the individual CUC members had requests for what they would like to see in an ngCASA visualization suite. These include support graphical user flagging a la TVFLAG and server-side tools for visualization of u-v data, and better exposure of the visibility data for algorithmic operations (user manipulation of the visibilities) and user-driven visualizations. The key point from the CASA perspective would seem to be setting a path forward, discussing with the community, and making sure there is a good path and the right plan to expose the data in the next CASA.

7.5 ARDG and Development work

2021 Endorsements/Recommendations:

1. *The CUC was very excited by the latest developments by the ARDG and Scientific Development teams and is eager to have the opportunity to test and use these new algorithms, including Adaptive Scale Pixels (ASP) deconvolution, msuvbinflag, and*

GPU imaging, and commends the CASA and ARDG teams on their great work here.

2. ***Regarding the specific CUC charge 1 for 2021 (Section 3.2):*** *As GPUs are becoming more commonly used, there is definite value in expending effort on GPU imaging. While VLASS may be the main driver for this, it will benefit other large projects as well, and we would encourage outreach to those teams to help with testing. That said, this should not supersede work on more mission critical aspects of CASA (e.g. viewer replacement).*

3. *The CUC was happy to see, and continues to encourage, the plan to have quantifiable metrics for testing new (and existing) algorithms. It would be extremely beneficial for these to be used throughout CASA work (including single-dish development), and to be advertised to users.*

4. *There have been some lingering issues about how to properly jointly image the ALMA and ACA data, which are not closely dependent on the specific algorithm. The ALMA and ACA have different primary beams FWHM (PB-FWHM). Therefore, in the area that is beyond the ALMA PB-FWHM and within the ACA PB-FWHM, one may obtain a strong signal yet both the synthesized beam size and intensity (in terms of Jy/beam) are not well defined. There are some tentative ways out (e.g., some users have been trying a very complicated muti-scale imaging strategy or trying to taper the primary beam of ACA). It would be useful if the CASA developers or ARDG can provide one suggested strategy and describe it with a CASAguide.*

2022 Endorsements/Recommendations:

1. The CUC was grateful to the ARDG and scientific development teams for the latest developments to improve the performance, reliability, and stability of CASA, and continues to encourage their development to meet the increasing data processing and scientific demands for ngVLA and ALMA WSU. The CUC also endorses their efforts to balance many works including the CASA6 support, ngCASA design work, prototyping, and staff training.

2. The CUC was impressed to see the 100x-200x speed-up of imaging performance by HPG with GPU and the simple system structure of HPG, and feels that this would be valuable for the next generation telescopes. To take advantage of this, it would benefit the users if useful instructions for GPU use (and what systems to purchase) in CASA are provided before a public-release, since the use of GPU is not yet common for the average CASA users.

3. Various scientific fields require accurate polarization imaging and the development of both instruments and softwares are necessary to achieve this. The CUC encourages the development of full-polarization imaging with AIP by Zernike modeling.

4. The CASA core base is a reliable and capable code base, and its use has the advantage of minimizing development overhead. The CUC is wondering how the use of CASA core base in development by the ARDG will affect ngCASA development.

5. Though a small group, the ARDG holds essential expertise and moving in to the ngCASA and CNGI phase, the CUC endorses thinking strategically about where this expertise can make the most difference to the long term performance and correctness of ngCASA.

7.6 Archival Data Processing, Pipelines, and SRDP

2021 Endorsements/Recommendations:

1. *The CUC commends the success of the pipeline efforts supported by CASA at ALMA and the VLA, and recommends that improvement and maintenance of elements that are needed by these pipelines remain a very high priority for CASA. This could include performance improvements.*

2. *The CUC endorses the SRDP plans for a single, unified calibration and flag restoration interface. The ability to easily acquire calibrated, ready to image data from the archive is a great step forward.*

3. *The CUC recommends communication between the CASA, pipeline and archive development teams, for the VLA and ALMA, to find a best approach for explaining which version of CASA to use for which era of data taken from the respective archives. To the user the distinction between these three teams is not always obvious, therefore, providing an easy navigable guide for CASA versions vs. data 'epoch' in the CASAdocs (alongside existing information on the archives) will be of benefit to users.*

4. *The CUC recommends that either the CASA team or the observatory pipeline groups invest effort into increased introductory documentation for 'at-home' users. This could be in the form of a CASAguide or an introductory Jupyter Notebook, (For example, we note it is planned that the EVN data reduction pipeline will use the Jupyter notebook format, a similar approach could be taken for other instruments).*

2022 Endorsements/Recommendations:

Archive and SRDP:

1. The CUC feels that improving the archive is important and needs to be prioritized. The availability of calibrated MSs for the NRAO archive is a good step forward, and expanding this to include the largest possible set of NRAO archival datasets is a good goal that would help user science.

2. Providing a possibility to explore images with quicklook cutouts and (at least) aggregate continuum image fits to download/explore with CARTA for all datasets would be a significant step forward in science readiness. The VLA User-Defined Imaging, which will be coming online next year, is also a significant advance.

3. In the future, the possibility of hosting advanced data products (similar to the MAST HLSP) should be discussed with the observatory partners. This could improve the use of older, unpublished archival data. HLSPs are crucial for focused science explorations and allows for community experts to contribute their own products.

4. More generally, exploring the ability to host user-contributed products (without warranty) for all scales of projects is strongly endorsed by the CUC. This kind of observatory support of a path towards public data management for users could both help the overall science output of the observatory and help US users navigate the NSF and NASA grant-writing landscape. There is not an obvious path to do this in many current subfields, and this affects the scientific output of the observatories.

5. The CUC appreciates the work to implement a modern archive and notes that a large amount of science arises from archival data. However, there have been some implementation issues and the CUC strongly endorses focusing on fixing bugs and building out the archive functionality over the next year. In particular, the CUC notes that some important features available in the old NRAO archive are still not present in the modern archive, and should be implemented.

6. The NRAO Community Webinar Series on the new archive was helpful in making users aware of limitations as well as enhancements (e.g., CARTA interface).

7. Inasmuch as this can be done with relative ease, the CUC also notes that the links to publications using the data in archive are very helpful. This is done in the ALMA archive, for instance.

Pipeline and SRDP:

1. With the majority of the processing of the ALMA and VLA data being performed via pipeline, the improvement and maintenance of pipeline is essential. Given this, the CUC appreciates the progress on VLA and ALMA pipeline improvements, including progress on processing the VLASS. The CUC feels that “stakeholder” input from the pipeline teams directly helps the users and should be weighted heavily.

2. Reflecting the importance of these pipelines, the CUC agrees that the changes and turnover in the pipeline development team(s) represents an important concern, and the CUC worries about the effect on knowledge retention and knowledge transfer in this critical area.

3. The prototype work on automated self calibration was impressive and the timeline for the next year satisfactory. User and community confidence will be important to ensure acceptance of this feature, and to this end the CUC recommends a more systematic testing for automated self calibration could be helpful to assessing the fidelity and reproducibility.

4. Heading into the ngCASA era, the CUC welcomes the convergence of manual and pipeline processing. In the shorter term, the CUC suggests that the ability to manually edit and run the VLA and ALMA pipelines could be better communicated to the users, and suggests that introductory material and tutorials could make the process more accessible to new users and students. The CUC recognize the limited resources of the various relevant teams and the intersecting responsibilities here, but suggests at least monitoring the situation to see how much the pipeline becomes a major user-facing interface for CASA.

7.7 OS Support

2021 Endorsements/Recommendations:

1. *The CUC were pleased to see the addition of the Operating System compatibility page in the new CASAdocs. The knowledge that, although CASA is not fully supported on a given OS, the CASA the team is nonetheless willing to take bug reports/tickets from users is not widespread. This page will help address that.*

2. *Related to the above, the CUC encourages the CASA team to instigate a conversation with the ALMA and VLA Helpdesks, to overcome instances where some users feel they are being rebuffed with "this OS is not supported feedback" by instead directing these users to contact the CASA team via the casa-feedback email address.*

3. *Given the large Ubuntu user-base, the CUC encourages the CASA team to acquire some Ubuntu virtual machines, say for the latest two long-term Ubuntu releases at the very least, so that any possible Ubuntu-specific bugs could be reproduced in house.*

2022 Endorsements/Recommendations:

1. Overall, the CUC is pleased with improvements to OS support over the past year and appreciates the added flexibility, in particular, the addition of OS support for Ubuntu and both the x86 and ARM Mac OS architectures.
2. The CUC appreciates the presentation of the compatibility matrix of the CASA versions and the supported OSs and the broader willingness to interface with users on OS support.
3. We emphasize the importance of continuing to prioritize OS compatibility to reduce barriers to software access. Users often have limited choices in operating systems if they rely on machines supported by their institution. Reducing OS dependence of CASA is also important to allow members of the community to contribute tools and software to enhance the functionality of CASA. Continued improvement and flexibility has real dividends here.

The CUC is grateful for the support of the new MacOS, which includes the ARM architecture. The continued support for MacOS, including pipelines, is important for a significant fraction of CASA users.

7.8 Documentation

7.8.1 CASAdocs and CASAguides

2021 Endorsements/Recommendations:

1. *The CUC appreciates the ongoing improvements to CASAdocs and, particularly, likes the return of the "Task List" and introduction of the "Index".*
2. *The CUC does caution that many users will not be familiar with software jargon, such as "API", and the CASAdocs should be careful with its usage.*
3. *The CUC recognizes that the CASAguides are not the responsibility of the CASA team. Nevertheless, they are the first point of contact for many new CASA users and they need to be kept up-to-date as much as possible. Perhaps encouraging the community to share their own examples, such as Jupyter notebooks via Github, for example, may help with this problem.*

2022 Endorsements/Recommendations:

1. The CUC welcomes the release of two new CASA reference publications this year.

2. The CUC agrees that the “Task List” shortcut in the CASAdocs is a good idea. However, the organization and functionality could be improved. Tasks are organized by topic, but some commonly used tasks do not appear where one would naively expect them to. For example, PLOTMS is not listed under any of the topical drop-down links in the task list, including Visualization, Information, Flagging, or Calibration.

3. The CUC appreciates the ongoing improvements to CASAdocs to make them more thorough and easier to navigate. Essential information, such as OS compatibility, is now available, but may still be cumbersome to locate for first-time users. New and creative ways to help beginners quickly get up to speed with the documentation would be helpful (e.g. a short video tour of CASAdocs).

4. The CUC is pleased with the “Community Examples” section of CASAdocs. However, we caution that it may be difficult for users to distinguish between official examples that are formally maintained and user-contributed content that may or may not function as advertised. Some examples seem more fundamental than others, such as how to run CASA from a *Jupyter* notebook, and should be officially maintained and updated. Other examples may better serve the community on a repository external to CASAdocs, with CASAdocs providing a link with a clear message that the linked page “is not maintained or tested by the CASA developers.”

5. The CUC recognizes that the CASAguides are not the responsibility of the CASA team. However, the CUC reiterates that CASAguides are the first point of contact for many new CASA users. We recommend working with other stakeholders to make updating the CASAguides regularly a priority.

6. The CUC recommends that documentation efforts keep in mind the common practical ways that users interact with the documentation (e.g., Google). Because the CASA documentation has migrated across different platforms over the years, searching for a quick answer with Google or other search engine may lead users to out-of-date documentation. While the CUC believes it is important to keep the legacy documentation for older versions of CASA available online, we recommend improvements to search engine optimization. Clearly marking older documentation to indicate what versions they describe should be an important part of this effort.

7. The AIPS-CASA dictionary is an important reference for new CASA users, especially VLBI users. However, the latest version is linked to CASA 5.4.1 not CASA 6, and does not contain all tasks currently available, (e.g. FRING). The CUC suggests either creating a dedicated page in the documentation for the AIPS-CASA dictionary, or including it in the description of each new release.

8. It would be useful for users to understand the hardware requirements for a typical ALMA/VLA dataset. The CUC suggests making it easier for users to locate the

hardware requirements page by adding a shortcut next to the software requirements details.

7.8.2 User Service

2021 Endorsements/Recommendations:

1. *The CUC appreciates the continued improvements to the CASA website and documentation. We continue to recommend providing CASA testing code to the users so that they assess their own installations.*
2. *The CUC agrees with the plan to avoid having a CASA-specific helpdesk.*
3. *The CUC would like to see the Known Issues and even Helpdesk tickets linked to CASA documentation, if this can be automated in some fashion so that users can avoid unnecessary pitfalls (and the CASA team can avoid additional Helpdesk tickets).*
4. *The CUC would still like updates on the status of submitted/resolved Helpdesk tickets during CUC meetings and it encourages timely responses to these tickets to assure a positive user experience.*

2022 Endorsements/Recommendation

1. The "Known Issues" list on CASAdocs is helpful, but overwhelmingly long. Organizing the information into sub-sections may be helpful to users. It is not clear that all issues that are widely known to experienced users are represented (e.g. "do not attempt to plot an entire MS in PLOTMS" . . .). It would also be helpful to provide a shortcut to the Known Issues page on the CASAdocs home page.
2. A pathway for users to provide feedback about CASA documentation would be helpful.
3. The CUC appreciates and endorses the additional flexibility added by the CASA team in allowing a path to user-submitted bug reports and bug visibility. This represents an important step to address the sometimes frustrating barriers posed by previous helpdesk policies. It will be useful to hear next year how this has gone next year. The CUC will be interested to hear about impact on CASA staff time, effect on user satisfaction that they are being heard, and actual identification and fixing of bugs.

7.8.3 Outreach

2021 Endorsements/Recommendations:

1. *The CUC is happy to hear that the CASA newsletter is continuing and that there are plans for engaging the community during ALMA and VLA events.*
2. *The CUC continues to encourage the development of materials that can be shared to assist the CASA team around the world with outreach to new and existing users. These efforts are certainly helped by the newly available Jupyter notebooks (e.g. CASA-VLBI).*

2022 Endorsements/Recommendations:

1. Continue basic outreach activities that have been effective, such as distributing the CASA newsletter and providing support at data reduction workshops and related events.
2. Explore pathways for DMS to facilitate communication and collaboration across the community. One suggestion would be to support a CASA Youtube channel with video tutorials geared towards beginners and students.
3. Funded data reduction visits are valuable and the CUC recommends increasing the level of advertising associated with these programs.
4. NRAO community day events and the ALMA Ambassador program are valuable and the CUC strongly endorses them.
5. Development of radio scientific software expertise is important to the long term health of the field, including CASA. Consider increasing support for students and postdocs through programs such as the Reber and Jansky fellowships in order to pursue software development research under the guidance of observatory staff.

7.9 Support for Other Interferometers

7.9.1 VLBI

2021 Endorsements/Recommendations:

1. *The CUC is happy to see the continued work on implementing VLBI functionality in CASA, and applauds the excellent work of both the JIVE and NRAO teams on this front.*

2. *The refactor of plotms, mentioned earlier, is particularly important for VLBI, and the ability to plot the cumulative calibration (and/or the cal library) would be a nice addition.*

3. *Ensuring that CASA handles polarization-dependent flagging properly is also especially important for VLBI.*

4. *The CASA VLBI pipeline and guides which are being written by the JIVE team will be a welcome addition.*

2022 Endorsements/Recommendations:

1. The CUC recognizes the great achievement of the CASA VLBI team in completing the core VLBI functionality, as both tutorials describing the entire workflow and an overview publication are now available. We're pleased to learn that 90% of VLBI projects are now supported.

2. This year's publication "CASA on the Fringe" illustrates the significant progress that has been made in the development of the VLBI functionality in CASA. The article does an excellent job of providing an overview of VLBI capabilities and promoting them to a wider audience.

3. The ongoing work on improving/fixing the existing functionality, preparing tutorials, and features for the next generation facilities is of great importance.

4. The CASA VLBI team's experience of preparing the CASA VLBI tutorials/semi-pipelines as the Jupyter notebooks has proven to be successful and accessible to a wide range of users, we hope that the Jupyter notebook environment will be widely accepted for other use cases of CASA.

5. One of the main drawbacks of using CASA compared to AIPS remains slower performance. Although this applies to CASA as a whole, it is important for VLBI experiments because they often contain a large amount of data.

6. It would be great to extend CASA VLBI capabilities to better support spectral line observations, this seems like an important area of software development for next-generation telescopes like the ngVLA.

7. Standard CASA tools do not always work adequately with VLBI data. For example, in the case of high-resolution VLBI data, the Viewer and imfit do not report the beam size / source sizes deconvolved from the beam because the numbers are too small (the reported size is 0.000).

7.9.2 GMRT

2021 Endorsements/Recommendations:

1. *CASA is currently the primary data reduction package for both the legacy and the upgraded GMRT and thus it is a welcome step for GMRT users to interact with the NRAO CASA team through the CUC.*
2. *Currently, the GMRT have modified the widebandpbcor task to implement primary beam correction for the GMRT (http://www.ncra.tifr.res.in/~ruta/IDAP/). The CUC encourages the development of a more general way to incorporate primary beams from other instruments into CASA tasks.*

2022 Endorsements/Recommendations:

1. CASA is currently the primary data reduction package for both the legacy and the upgraded GMRT. Currently GMRT users can make excellent use of the already available CASA tasks but can also modify and adapt the tasks for GMRT usage.
2. An entirely CASA based pipeline CAPTURE has been developed at NCRA and is being widely used by uGMRT users since 2021 (http://www.ncra.tifr.res.in/~ruta/IDAP/index.html). The participation at CUC is helping anticipate some of the changes and preparing for those in the context of the GMRT.
3. The primary beam correction task for the uGMRT has been updated and is now maintained for CASA 6+ versions: the task is called “ugmrtpb” and is a modification of the “widebandpbcor” task. The task is available for users on github. As GMRT users we hope that the CASA team will continue with keeping the versatility of the software.
4. The CUC encourages the development of a more general way to incorporate primary beams from other instruments into CASA tasks.
5. We have put out a tutorial on uGMRT continuum data reduction in CASA (http://www.ncra.tifr.res.in/~ruta/ras-tutorials/CASA-tutorial.html - next update expected in March 2023). If these could be linked on the CASA guides page that would be useful.

7.10 Single Dish Support

2021 Endorsements/Recommendations:

1. *The CUC is impressed by the development and performance gains of the single dish tasks and pipeline. The new offline atmospheric correction based on the algorithm by Sawada et al. (2021), and its incorporation into CASA, is especially welcome for ALMA.*
2. *As the pipelines become more mature, quantifying their validity and accuracy by constructing well-understood benchmarks (e.g., using well-characterized test data and/or simulations) and defining rigorous performance metrics would be a very welcome.*
3. *Improved access to the ALMA calibration database from the pipeline is excellent, it would also be helpful to make sure that the users have a clear path, described within the pipeline documentation, to use this to improve or refine the calibration of their delivered data. This will also be a benefit for supporting other single-dish telescopes in the future.*

2022 Endorsements/Recommendations:

1. The performance improvements are extremely welcome and the CUC was pleased to see these.
2. The improvements to make baseline fitting more powerful and accessible addresses a common use case among users - it would be interesting to hear more next year on specific applications to common use cases.
3. Exposing calibration (Jy/K) information more directly is useful to improve reproducibility and functionality.

7.11 Planetary Applications

2022 Endorsements/Recommendations:

1. Planetary observations using CASA have inconsistent performance across versions, as detailed below. While the CUC understands the support for planetary observations may be resource-limited, it seems important to address as many of these bugs as possible before the upcoming feature freeze. We also recommend including planet related regressions in the testing of new versions to whatever extent possible.
2. In particular we strongly urge the CASA team to fix the “fixplanets” task.
3. We suggest that as part of the ngCASA and CNGI overhaul, planetary science and

general capabilities for large and fast-moving objects be considered in speccing out key capabilities.

Planetary observations always need some extra care, starting with the ephemeris, where the target should be tracked by the telescope, and the frequency should be adjusted according to the line-of-sight velocity, so that spectral lines are not smeared out. Much of this works well, but the ephemeris (tracking the object on the sky and in velocity) does often need to be adjusted after the observations have been taken, due to e.g., updates to the ephemeris (e.g., comets), or to too long a step interval between ephemeris data in the ephemeris file attached to the original ms.

To accomplish this CASA uses the task fixplanets, which interfaces with JPL software and unfortunately broke after JPL updated their software. Fixplanets is further used to remove the planet's motion to look for background sources, subtract the background sources, and then use fixplanets to track the planet again. Given the essential nature of this task, we strongly urge the CASA team to make sure that fixplanets works in the frozen version of CASA 6 and to treat bugs as important to fix (during the meeting we heard that a fix may become available in March 2023, so that is good news).

In general, it would be ideal to factor in planetary observations as a mainline capability of CASA and to plan the CNGI and ngCASA to have such capabilities at baseline. The CUC noted two particular specific feature requests when development becomes active again:

- DEROTATION: In the future it would be nice to implement Sault's derotation technique (https://ui.adsabs.harvard.edu/abs/2004Icar..168..336S/abstract). With higher spatial resolution planet data this becomes more important, though with the increase in telescope sensitivity (ngVLA) perhaps one could obtain maps within a minute of integration time, rather than the hours it usually takes nowadays.

- FIXVIS: Another user requests the need to be able to use ICRS coordinates. Otherwise, we have to "fudge" the coordinate system first using fixplanets.

The CUC was also concerned that tasks related to moving targets may break more frequently when new versions come out. One user mentioned recently that in CASA 6.4, tclean breaks when trying to image ephemeris objects after running cvel (looked like problems constructing the frequency axis). In situations like this we often go back to an earlier version (CASA 5 in this case) and use the old clean, which worked in this case. The fix here would seem to be related to including more regression related to planets and moving targets into the build tests and vetting of new CASA versions. To whatever extent resources allow, the CUC suggests that the CASA team do such testing.

The CUC also notes an issue related to the ALMA pipeline, acknowledging that this is not formally CASA-related. The calibration with large bright sources (like Jupiter) with ALMA is wrong. In (https://doi.org/10.3847/1538-3881/ab3643) the authors state: “Based on an ALMA memo on calibration, we conclude that the system temperature, Tsys, is usually determined on blank sky. This is reasonable for a source that does not contribute significantly to Tsys. However, this approach is not appropriate for very bright sources. For example, for ALMA observations of the Sun, Tsys is determined on the disk of the Sun. A similar approach should be used when observing the bright planets as well.” We encourage ALMA to develop the above approach, which we heard they may have started on. They apparently have a “software” fix for spectral line measurements.

7.12 Build System, Validation, Computer Environment

2022 Endorsements/Recommendations:

1. The compute required for CASA processing of VLA and ALMA data continues to grow (and will grow more with ngVLA and WSU ALMA) and with GPUs the system requirements are becoming more specialized. The CUC commends NRAO DMS and the NAASC and AOC for having a system where users can access observatory resources. The CUC endorses expanding and advertising these capabilities to whatever degree possible, while also acknowledging the challenges in resources and personnel required. In particular, intermediate term allocations (longer than a month or two) seem helpful.
2. As management knows, a very common complaint among CASA users is that capabilities may break from version to version reflecting the complexity of the software. The improved build system, addition of a validation lead, and longer term attempt to unify and simplify the code are all major positive steps to address this and the CUC strongly endorses these efforts and recommends continuing to heavily support them. The CUC will be interested to hear the experience of a full year from the validation lead / management next year.