Response to the CASA Users Committee Annual Report 2022

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1 Table of Contents

Overview

This document is the official response from the Common Astronomy Software Applications (CASA) group to the recommendations of the 2022 CASA Users Committee (CUC). The recommendations of the CASA Users Committee along with the full context of Committee discussion are contained in the Annual report dated 15 December 2022.

We wish to thank the CASA Users committee for their time and effort. The recommendations in their annual report are constructive and beneficial to informing CASA strategic goals and decision making. The CASA development team agrees with these recommendations in most instances and will strive to satisfy the commitments in our response over the next year.

Below we discuss the recommendations that the committee has explicitly called out in their document. We have maintained the section numbering from the CUC annual report to simplify cross-referencing between the documents. In this document we have extracted and summarized the recommendations of the users committee (in black) from their report and provided the response of the CASA project (in blue).

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

2022 Endorsements/Recommendations:

1. Fixing a firm plan for the CASA to ngCASA transition in a measured, careful way is incredibly important.

   Yes, we agree. This is also a priority for internal stakeholders who require stability for current telescope operations as well as the CASA development team itself who will have to balance training and code rewrites or adaptations while also maintaining support for current usage modes.

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).

   Once we have a clear understanding of these impacts of our plans, we will communicate this information appropriately.

3. Continued work on the delivery of calibrated MSes to users.

   The CASA team will convey this suggestion to the DMS-Systems group, and share it with colleagues at the NAASC (North American ALMA Science Center) and the SRDP (Science Ready Data Products) group who are responsible for the delivery of calibrated MSs.

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

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.

   Yes, we will note this recommendation from the CUC. Our current proposal for what CASA6 and CASA7 might look like as we evolve has been driven by similar requirements from internal non-pipeline stakeholders as well.

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.

   We will continue to explore career paths and options for building and sustaining a

skilled team, long-term. Yes, we should/will advertise our job postings through the CASA mailing list and the CUC itself.

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).

   We will continue to pursue avenues for further integrating CASA in the astronomical literature.

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.

The CASA team and DMS management thanks the CUC for their feedback regarding the scope of the CUC. We are currently looking into expanding the scope of the CUC to also include other user-facing aspects of DMS.

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.

   The CASA team and DMS management thanks the CUC for their input regarding the future charge and organization of the CUC. We are currently drafting a new Terms of Reference for the CUC along the suggestions in this CUC report. This document will be sent to the CUC for feedback when ready.

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.

   To facilitate geographic diversity and inclusion, and based on the successful past CUC meetings, the CASA team recommends virtual meetings as the preferred avenue going forward. This can include an in-person component.

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).

   Next CUC face-to-face meeting we will organize a private Zoom meeting room for CUC members only. This year's meeting showed that such a private Zoom room is essential. We will also explore possibilities for asynchronous communication.

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

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.

   This concern is shared by our internal stakeholders as well. As a result, our transition plan already includes what we may call CASA7 which is a mix of CASA6 and new features imported from ngCASA and wrapped within a familiar user interface. As of now, the long-term support plan for the existing code base (CASA6/7) is for bug fixes to continue for the foreseeable future, but new feature development will transition to ngCASA, wherever feasible, and be made available to users alongside the rest of existing CASA6/7. If this plan changes, we will include it in the 'communication of the impact to external users' as requested above.

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.

   We will keep this in mind when training new staff and in balancing ongoing and future assignments. Some recently hired staff already have some fraction of time allocated to learning about and maintaining the current code base.

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.

   The CASA team will convey this suggestion to the DMS-Systems group. It is already a DMS priority to preserve access to historical data and software to analyze it.

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

   The ngVLA and ALMA projects have software design reviews scheduled for Spring 2023, for the purpose of evaluating ng-data processing plans for both CASA and the Pipeline.

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.

We will evaluate this point as part of the DMS-systems design work. There are already intentions of looking for collaboration opportunities with other observatories (e.g. SKA), after we first generate a viable end-to-end concept that we can justify for the ngVLA and ALMA-WSU.

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).

   Once finalized with internal stakeholders such as ngVLA, VLA and ALMA, the expected data format for optimal use with ngCASA will be clearly documented and shared. Support for import/export with archival/existing data formats (either directly or via an intermediate conversion) is also likely to continue for internal use as well, and procedures to do so will also be documented.

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.

Once some architectural design decisions are completed, the CASA team will organize training to broaden the knowledge of CNGI/ngCASA technology internally within the team.

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

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.

   We will work on formalizing and advertising the use of CARTA within CASA, as a full and preferred alternative to the CASA Viewer, over the course of this year.

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.

   The CASA team will forward this feedback to the CARTA team.

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.

   The CASA team will forward this feedback to the CARTA team.

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.

   The CASA visualization team is currently in the process of testing and verifying this new interactive tclean GUI. We will explore how to best document and advertise this new GUI when ready.

6. If possible, maintaining a consistency in UI between the different visualization tools

(CARTA, interactive tclean, ms plotters) would help users.

While there are significant differences in functionality and scope between the individual GUIs, we agree that maintaining consistency wherever possible is important.

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.

   The visualization team will continue working on tools which leverage CASA's new, scalable technology to replace functionality in the current PlotMS which is not performant for modern data sizes. The current PlotMS will continue to be supported until all key functionality is replaced.

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.

   NRAO/DMS is currently working to articulate the wider software context in which CASA will operate. Once this wider context is understood, we will work to express the architecture, scope and design of visualization within the ngCASA environment.

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

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.

We thank the CUC for recognizing ARDG's contributions and for endorsing continued collaboration with the production software team (the CASA group). We plan to do our best to continue this as in the past.

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.

   The timeline for release of the code via CASA distribution that can use the GPU is CASA's longer term plan and isn't yet imminent. The suggestion is however noted and for this we will work with the CASA team closer to the release date.

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.

   We thank CUC for endorsing this work. We agree with the sentiment of this suggestion. The official priority for this work at NRAO however is purported to be low.

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.

   We agree with the assertion here (it will be advantageous to reuse CASA core base for ARDG work), and we are in the process of developing a path forward for this to happen. ngCASA definition is currently fluid and therefore how this may affect its development remains TBD.

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.

   We thank the CUC for endorsing strategic thinking to enable use of ARDG expertise for various aspects of the ngCASA. This thinking will become clearer as the ngCASA plans mature.

7.6 Archival Data Processing, Pipelines, and SRDP

2022 Endorsements/Recommendations:

7.6.1 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.

   We thank the CUC for this suggestion. There is an archive improvement project that is currently underway in conjunction with DMS and SRDP where John Tobin is the product owner and is working with an Agile development team over the next year to smooth out many of the rough edges on the current archive. Regarding archival data, it is in the SRDP plans to enable users to recalibrate archival datasets with the current pipeline, which is feasible for data going back to ~2013; the timescale for implementing this feature is ~1-2 years given competing priorities.

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.

   We agree that enabling data from multiple projects to be viewed in a single CARTA session would be useful, VLASS+VLA data is the most straightforward. ALMA+VLA and/or ALMA+VLASS is more difficult because the data are not co-located, but we will take this suggestion under advisement for development prioritization. Cutouts for VLASS images are available from our CIRADA partners (cutouts.cirada.ca), as such, this capability has not been a high priority for the NRAO archive.

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.

   We thank the CUC for this suggestion. It is in our plans to support hosting data from VLA and ALMA large programs (and some other large datasets). Our plans seem relatively similar to MAST's HLSPs, and development resources to implement this capability in the NRAO archive have not been available. We will take the CUC recommendation into account for future prioritization.

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.

   We thank the CUC for their suggestion and we will consider it further. Our current position for appropriating data from the community has been in the context of large programs with a well-curated datasets. We agree that there could be benefit from ingesting user-generated data and making it available in search returns, but we would need to carefully consider the implications.

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.

   As noted in the response to recommendation #1, there is an archive improvement project underway, which aims to address many of these shortcomings. If there are specific features that the CUC regards as critical that are not present, it would be helpful to have them described directly in separate correspondence if too lengthy for this report.

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).

   We thank the CUC for this feedback, we plan to continue community outreach in various formats in the future.

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.

   We thank the CUC for this recommendation, we will investigate fitting this into the archive development plans.

7.6.2 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.

The CASA team will continue to balance the priorities from our different stakeholders, and acknowledges that pipeline development also directly benefits the general user community.

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.

   We acknowledge the importance of knowledge retention and transfer and we will implement measures to ensure that knowledge and expertise are appropriately documented and shared across the team.

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.

   We agree that user and community confidence is crucial for the successful acceptance of the automated self calibration feature. We will incorporate a more systematic testing approach to evaluate fidelity and reproducibility, which will help to build confidence among users and the broader community. We appreciate your support and look forward to sharing our progress with you in the coming year.

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.

   We will take your recommendation into consideration and work on developing, and communicating, introductory material and tutorials to make working with the pipelines more accessible to new users and students. We will also monitor the situation regarding the pipeline's usage as a major user-facing interface for CASA.

7.7 OS Support

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.

   To offer further flexibility to users, the CASA team is also in the process of adopting ManyLinux. The current model of building ManyLinux compatible wheels and using those as a base for the tarball installations has proven successful and allows Casa to run on most systems. We plan to upgrade our infrastructure to support more recent ManyLinux distributions in order to remove legacy dependencies and to support the latest Linux distributions.

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.

   In addition to providing ManyLinux compatible wheel installations, Casa is exploring ways to implement our graphical user interfaces in pure Python, which would make them essentially operating system agnostic. We are also working on making the build Casa build system more accessible and compatible across various platforms.

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.

The CASA team will continue to support Mac OS to their best possible extent, but currently has limited build resources to keep up with the frequent Mac OS updates, which often leads to unavoidable delays regarding Mac OS support. We will try to keep those delays manageable for users. The pipeline is currently not supported for Mac OS.

7.8 Documentation

7.8.1 CASAdocs and CASAguides

2022 Endorsements/Recommendations:

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

   The CASA and CASA-VLBI reference papers are now published and advertised as the default citation for the CASA software.

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.

   Plotms is a GUI, and listed directly under the API section (where also the orignal 'task list' link is located). The API section is deliberately chosen to provide the external interface definition for CASA, but we acknowledge that this can be confusing for science users. We will include this CUC request in the CASA Docs work that is planned for 2023.

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).

   We will consider adding a video explanation of CASA Docs if resources permit.

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."

   This is a good recommendation that we will include in the CASA Docs work that is planned for 2023.

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.

   The VLA instrument team is meticulous in updating the CASA Guides with each new VLA pipeline version of CASA. We will communicate with other stakeholders (e.g., ALMA) to address this CUC concern.

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.

   We will include this recommendation in the CASA Docs work that is planned for 2023.

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.

   We will include this recommendation in the CASA Docs work that is planned for 2023.

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.

   We will include this recommendation in the CASA Docs work that is planned for 2023.

7.8.2 User Service

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.

   It is part of the CASA Docs work that is planned for 2023 to shorten the Known Issues section. Our goal is to limit the Known Issues to those bugs that are intended to be solved in the foreseeable future. All other Known Issues will be documented as part of the code limitations elsewhere in CASA Docs.

2. A pathway for users to provide feedback about CASA documentation would be helpful.

   The CASA Bug Report system that we plan to launch in 2023 will include the option for users to provide feedback on (inconsistencies in) CASA Docs.

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.

   The CASA Bug Report system that we plan to launch in 2023 will include an internal review that includes impact on CASA staff time, effect on user satisfaction, and identification and fixing of bugs. We welcome to discuss the outcome, and path forward, with the CUC at the next face-to-face meeting.

7.8.3 Outreach

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.

   The CASA team will continue these outreach activities. Over the past 6 months, the CASA Team gave general CASA introductory talks at ADASS 2022, the VLA Data Reduction workshop, the ALMA ambassadors workshop, and the Virtual Astronomy Software Talks (VAST) series.

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.

   We will explore such pathways for DMS to facilitate communication and collaboration across the community. The CASA team currently does not have the personnel to staff a Youtube channel.

3. Funded data reduction visits are valuable and the CUC recommends increasing the level of advertising associated with these programs.

   Funded data reduction visits are provided by the NAASC. We will discuss with the NAASC team how CASA can contribute to advertising these programs.

4. NRAO community day events and the ALMA Ambassador program are valuable and the CUC strongly endorses them.

   The CASA team will remain active in helping out with the NRAO community days and ALMA Ambassadors program. We have also used these opportunities to familiarize the user base with general CASA use.

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.

   We will evaluate and explore these options. Currently, student training is done via the science-time of a few staff members, via the Reber fellowship, a post-doc (in one recent case), and summer/co-op projects, but it is not yet a planned sustainable pipeline.

7.9 Support for Other Interferometers

7.9.1 VLBI

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.

   For fixing bugs in the existing functionality there is a direct link of the CASA VLBI developers at JIVE to the NRAO helpdesk. Tickets related to VLBI functionality are being handled and resolved, these are a few per year at most. For improvements of the existing functionality a stakeholder requirements plan is in place in which EVN and VLBA have listed which functionality is needed. Several updates are planned for upcoming CASA releases.
   In the context of the ngCASA developments and the move to a new build system we need to be careful which improvements are still to be implemented in the old system and which will have to wait. This discussion is continuously ongoing as part of our monthly meetings. Funding is secured at JIVE for implementing the existing VLBI functionality in DASK and XArray.
   The development of tutorials is currently limited to dedicated schools and workshops. The online EVN data processing manual is constantly updated with new functionality for continuum data processing.

   NRAO is committed to creating more VLBA CASA Guide tutorials in the coming years, as CASA VLBA capabilities grow and as time of the limited VLBA staff permits. A short-list of possible tutorials is ready, including one covering some basics of spectral line work that can currently be done. However, several of the proposed tutorials require additional tools to be included in CASA before they can be created.

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.

   The use of the Jupyter-CASA kernel by the CASA VLBI team has been well received by users. It was used for the European Radio Interferometry School (ERIS) that was hosted by JIVE in 2022

   The CASA team has started to adopt Jupyter notebooks together with native modular CASA to provide users with examples, thus far mostly on a few advanced aspects of data processing. For example, a notebook on advanced CASA simulations is frequently used by the community. These Notebook examples are currently listed under “Community Examples” on CASA Docs. We foresee that this list of Notebook examples will grow substantially over the next years, as also a growing number of CASA team members are adopting this format for documenting examples of new features.

Both the native CASA notebooks and Jupyter-CASA notebooks will be used in the upcoming CASA VLBI workshop.

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.

   Pending finalization of ngcasa technology choices in 2023, it is most likely that performance improvement campaigns will focus on adapting current and future VLBI-related applications to the new ngcasa framework, rather than attempting to re-engineer (and potentially destabilize) current implementations, except for exceptional cases. As noted above, considerable care will be exercised in choosing where and how to optimally proceed with new development and maintenance, including for performance.

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.

   This is mainly a matter of encouraging use of the current system aggressively in the spectral line case, gathering feedback, and refining the implementation as needed. There may be some potential for this sort of validation at the CASA/JIVE VLBI Workshop coming up in 2023 June 5-9.

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).

   We will review these interfaces and make sure development tickets are generated for improvements in value rendering.

7.9.2 GMRT

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.

It is great to see this development. We have added a link to this GMRT website on the CASA Docs chapter on 'Pipelines'.

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.

   Thank you for bringing this to our attention. We intend to continue evolving towards more modularity and flexibility in our reduction and analysis routines, so that it is easier for multiple observatories to assemble or run custom solutions for only the parts that need modification. In the ngCASA design, primary beam correction is likely to be a standalone method that could be replaced as needed. In current casa6 though, we have also had a (long-standing) contradictory requirement to more tightly integrate widebandpbcor within tclean itself, which we are satisfying via what is expected to be a more numerically accurate solution. The ability to use this option for the GMRT will depend on the ease of specifying external PB models to use.

4. The CUC encourages the development of a more general way to incorporate primary beams from other instruments into CASA tasks.

   It is currently possible to specify primary beam models for use with tclean in CASA6, and this has been demonstrated in internal example notebooks. We will look into more obvious and formal user-facing documentation (and tests) of such capabilities for both simulation and imaging. For ngCASA, we expect to more clearly separate observatory-specific and observatory-agnostic parts of our code and auxiliary data, with the goal of making it easier to add/edit information for other observatories.

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.

   Thank you for forwarding this nice CASA uGMRT tutorial. We created a GMT section in the NRAO CASA Guides where we added this link: https://casaguides.nrao.edu/ To keep the content current with new CASA releases, we recommend the uGMRT team to update this CASA Guide regularly, and contact us if CASA input is required or links change.

7.10 Single Dish Support

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.

   We will continue to improve offline atmospheric correction in 2023. In addition, we have already started a research and development of better spectral line identification and subtraction of spectral baseline to further improve the quality of baseline subtraction. We expect that a prototype implementation will be available in 2023 either on CASA or on Pipeline.
3. Exposing calibration (Jy/K) information more directly is useful to improve reproducibility and functionality.

   Since basic functionality is ready as a new calibration type of gencal task, we will finalize the development in 2023. The last item is to advertise the functionality to public uses and to use it consistently throughout the observatory operation of ALMA.

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.

   We have included the use-case of planetary observations in our upcoming development cycle, alongside other bug fixes in related code that were requested by internal stakeholders as well, and the addition of appropriate tests to ensure that this continues to work as the code around it evolves. We may contact CUC members as needed for information about the use-case to cover.
2. In particular we strongly urge the CASA team to fix the “fixplanets” task.

This work is included in the above note.

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.

   The use-case of ephemeris object imaging will be considered for ngCASA.

Thank you for providing this additional information about the ephemeris object use-case. We will include it for context in the work we have scheduled and for future plans.

We will include 'derotation' as a feature requirement for planetary analysis and evaluate how best to provide the feature.

The 'phaseshift' task already available in CASA6 is a replacement for 'fixvis' and supports ICRS coordinates for a phase center. We would appreciate feedback on whether this already addresses the mentioned issue or not.

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.

   We will discuss this with our colleagues at the NAASC, VLA, and IT services.

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.

We will continue to refine our development and testing practices to make CASA more robust and will summarize our experiences at next year's meeting.