Report on Chandra Users' Committee Meeting, September 12-3, 2018

Overview:

The committee is very pleased with the mission operations of Chandra and the responsiveness of the observatory staff to the needs of the users. The mission is still operating very effectively, with only minor, gradual reductions in capability over its mission lifetime that is now nearly 20 years. The mission is still producing high-profile science, most of which is now focused on topics that were initiated by Chandra itself, and topics that have arisen due to discoveries and developments outside X-ray astronomy. Chandra's status as a premier NASA mission is thus maintained, even though Chandra has now achieved most of the goals for which it was originally built. As Chandra continues to be the world-leading observatory for high angular resolution high energy astrophysics, it will continue to be of essential importance for a wide variety of fields of astronomy.

The mission team has also been doing an excellent job supporting the community effectively, in the face of growing operational constraints. We appreciate the efforts being made to understand the extent and the origins of demographic biases in proposal selection in order to be prepared to deal with them in the most effective and fair manner. We also appreciate the continued development of software, accessibility improvements, and making the software more effectively integrated with the outside tools, preferred by the community, in ways that will have legacy value that goes beyond just Chandra.

The committee found this meeting to be very productive, as well. We appreciated the manner in which the presentations maintained continuity for the committee, highlighting how things have changed from last year and what has been done in response to last year's recommendations. Furthermore, the one issue that had been a serious concern in recent years, the source catalog, has now been dealt with in a very satisfactory manner. The bulk of the catalog is in excellent shape, in terms of both data quality and quality of user interface, and the remaining extremely challenging fields are on track to be completed very soon.

Chandra Status Report

A CXC contract extension is in the process of being negotiated with NASA. . The present contract runs through 2019, the extension potentially continues to fund the mission through Sep 2030. A base period up to 2024 plus 2 option periods of 3 years is anticipated, ending with a 3 year closeup.

The present lease for the Operations Control Center (OCC) ends on 9/30/2019. CUC was informed that OCC relocation to Burlington, MA is in progress and that the IT installation started in 1 Aug 2018. Construction is ongoing and planned to be completed in early November. Transition to operations in the new location is planned to take place in March 2019. The staff has been updated on the OCC relocation details. The data system operation group moved to Cambridge Discovery Park during August 2018 and data processing servers will soon be moved

to 60 Garden St**.** Because of the costs associated with the move, and a delay in receipt of the final FY18 funding, , there have been some delays in awarding grant funding. It is expected that these problems will be resolved early in FY19

CUC was informed that NASA has modified the frequency of Senior Reviews to 3 years following the recommendations in the report by NAS committee in "Extending Science". The next Senior Review will be held in 2019 and it will involve a 2.5 day long panel review that will take place in the Boston area at the end of February. A full proposal is required prior to the review panel visit, with a deadline in early February. Details on the preparation plans were provided in the Director's report.

The CUC was informed that the spacecraft status is stable and all instruments are operating well. Thermal control is a continuing challenge, but is being managed. There are concerns about future angular momentum increase as the orbit evolves towards the next low perigee, this issue is presently planned for and managed satisfactorily. The ACA camera is affected by warming and radiation and workarounds are in place. Globally, there is no loss of efficiency, but some aspects of the operation planning are becoming more challenging. The spacecraft subsystem status is stable and spacecraft consumables will last several decades. The rate of buildup of the ACIS contaminant is decreasing, so a bakeout will probably not be performed in the near future.

Mission planning has proceeded with no major problems. There were six load interruptions due to fast ToO and DDT proposals in the past year, and two radiation alert load interruptions. Efficiency is still very high. Data processing is going very well with one day average delivery. Grants were awarded to scientists in a prompt fashion (~1-2 weeks on average, with the exception of a temporary issuance delay starting from August 2018).

Outreach has included 16 press releases in the last year, 3 Chandra images which were included in 2017 Reuters Best Pictures of the Year in Space, and some virtual reality developments. A number of outreach efforts are designed with intention to reach out to young and underserved populations. CXC support of National Science Olympiad is continuing as well as public exhibits. Lots of outreach material is sent to schools and museums. As also outlined in the Director's report, CXC and MSFC staff are currently active in the Chandra 20th anniversary preparations. Several events are planned for the 20th anniversary of the Observatory, including a scientific symposium in Boston in December 2019 and an event at the National Air and Space Museum in August of 2019.

Director's Report

A summary of the DDT programs was provided, and some of the programs were described in detail (e.g., GW170817). In the case of GW170817, when it came out of sunblock in early Dec 2018, none of the triggered GO programs included late-time follow-up observations. However

many groups were interested in obtaining observations. For this scenario, the Director assumed the role of PI of a DDT proposal and the interested groups were included as co-Is. The data were made public immediately. The CUC found this approach good and appropriate under the circumstances. There was some concern that poor-quality papers can be released in the mad dash to be the first to publish, and the CUC indicated that it would be best to have such observations handled in the peer review process, whenever possible.

The DDT allocation had increased last year allowing for observations of non-transient sources that would benefit from rapid follow up. An example of a good opportunity resulting from this change was presented (a system of protoplanetary disks with ALMA observations). Furthermore, the special call for DDT proposals related to Pathfinder Science for a Chandra Successor Mission (CSM) was discussed. This opportunity generated several good proposals and resulted in the awarding of three proposals in diverse areas of astrophysics.

Preparations for the next senior review (with expected proposal due date in February 2019) are now underway and science topics are being collected. A schedule of preparation plans was provided.

The possibility for SAO-CXC becoming member of SDSS-V was discussed. The goal would be to obtain optical/near-IR spectroscopy of a substantial subset of CSC 2.0 X-ray sources (includes >300,000 sources and ~2% of the sky). The processed spectra would be obtained by the CXC, and released to users on a ~1 year timescale, providing an enhanced impact of Chandra data and a benefit to the broader community. The Committee considers this SDSS collaboration to be a reasonable use of resources and supports doing this.

The Director highlighted several events that are in preparation to commemorate the 20th Anniversary of Chandra in 2019. These include a dedicated scientific symposium in December, special sessions and plenary talks (at AAS, HEAD, APS, and AAAS), books, magazine articles, and public outreach events. The CUC suggested inviting people of interest including, e.g., family members of Chandrasekhar and astronauts from the Columbia STS-93 launch.

Proposal Cycle Update, Plans for Future Cycles, and Gender Equity Issues

Dr A. Prestwich reported on the status of several programs. A summary is given in point form. The CUC discussed several outstanding issues and we give our recommendations below:

- Cycle 20: Overall the peer review process ran smoothly. The numbers of proposals submitted (526) and the numbers approved (156) are in line with long term trends. One possible trouble spot was among the Very Large Programs (VLPs). While 6 Ms was allocated between LPs and VLPs, there were no VLPs awarded time. The CUC discussed whether the VLP proposals failed to make the case for the time, or whether a

bias exists in the current review process. It was noted that two VLPs were approved under the same circumstances in the previous call and that there had been explicit feedback from the panels that this year's VLPs were not of sufficient quality to accept any of them.

The CUC strongly supports the VLPs and they think that the program should remain in place to keep up the scientific vitality of the Chandra mission.

We encourage the members of the Large proposal committee be given a presentation ahead of their deliberations on the science impact of projects of different sizes, including VLPs. A majority of the CUC supports the recommendation that a fixed allocation be given for VLPs. Several mechanisms were discussed how to continue implementing > 1 Ms proposals given the limited amount of observing time (~18 Ms) available each cycle. Ideas include guaranteeing the award of VLPs in alternate years, borrowing time from future cycles, using unallocated DDT time, etc. However, we prefer that the CXC has maximum flexibility to implement VLPs as they see fit.

The committee also recommends consideration of a category even larger than VLPs. Because programs much longer than 1 Ms are extremely hard for panels to award, the committee recommends that the CXC staff have a call for pre-proposals, similar to the one done for the first stage of the Chandra Successor Mission call. The committee does not take a strong position about whether the call for an even larger proposal category should be done, but only that it be seriously considered. If and only if the quality of the science discussed in the pre-proposals is viewed to be sufficient, then an explicit call for extremely large proposals should be made.

- Cool Altitude Targets (CATS): The CUC received an update from our Spring 2018 meeting. The plans to build a CATS catalog are well advanced. There will be a call for White Papers to solicit ideas for suitable catalogs with good science justification. There is a sensible plan in place to ensure that GO targets are given priority over CATs. One outstanding issue that was discussed by the CUC was how the community, and white paper lead, might be notified when a CATs target is observed. ***We recommend that the CXC reviews the size of the CAT program to assess whether there needs to be a dedicated allocation of archival funds to ensure that the CAT data is used.***

- Gender Statistics: At our request, the CXC has carried out a comprehensive study of the age distribution of gender statistics, to complement the work that had already been ongoing regarding gender statistics without accounting for age. This was an excellent report. We think that the results of this study should be prepared for publication. In brief, the trends for the last several cycles show that the acceptance rates for males and females, relative to participation rates, are statistically indistinguishable. Significant

differences show up when comparing success rates as a function of career stage (early, middle, late career). Early career female researchers are doing slightly better than their male counterparts, while senior female researchers are doing worse. The same trend is visible in similar HST panel data, although with Hubble there is also an overall bias.

- ***The CUC suggested that the authors of this study look at the number of co-investigators on female and male lead proposals at each career stage as a measure of "connectedness."*** The hypothesis is that the bias might arise due to the smaller peer network or some form of cumulative disadvantage that could be perceived as a reduced scientific leadership role of female researchers relative to male pears.

- ***The committee agrees with the CXC's decision not to anonymize proposals at the present time and only to consider doing so if the Hubble experiment indicates that this improves equity.***

- NASA Hubble Fellowship Program (NHFP): This was the first year that the three prize postdocs (Sagan, Einstein and Hubble) were folded into a single program that was run from STScI. Dr Paul Green, who had previously run the Einstein Fellowship program, was involved in this year's selection process. There were 350 applicants and these applications were split between 50 reviewers on 6 topical panels.

  The CUC was pleased to see that there were 7 Einstein Fellows awarded out of a total of 24 NHFPs. The merging of these three programs seems to have gone well and the selection process seems to have run fairly. Going forward, there are some unresolved issues about the annual postdoc symposium. It is expected that Fall 2018 will be the last of the annual Einstein Fellows meetings. Discussions are underway on how best to conduct an annual NHFP program with at least 72 Fellows from multiple locations. ***We encourage the CXC to update the users' committee on an annual basis until it becomes clear that there are standard procedures that adequately serve the needs of the high energy astrophysics community.***

- Cycle 21: Preparations are in an advanced state of development. The new submission tool (CPS) is undergoing active testing and the feedback so far has been positive. The current plan is to invite outside users for early access in December. The RPS tool will not be offered during Cycle 21, except as a failsafe in the circumstance that the CPS tool encounters unanticipated issues. The CXC is using several different means to notify the user community of this switch well in advance of the Cycle 21 deadline.

CXC Response: thanks for the suggestions regarding gender statistics and programs that are larger than VLPs. We'll evaluate the feasiblity of these programs once the effect of the CAT program on observing efficiency is known.

Mission Planning Updates

The observatory is evolving with time in ways that are making some aspects of planning more challenging. The relevant problems developing involve thermal and angular momentum issues. At the present time and for the foreseeable future, these issues are manageable, but have necessitated the development of the Cool Attitude Target (CAT) program. The targets are in "cool zones" for only about 10 days at a time, so as the list of CATs is assembled, it is necessary to have a broad RA distribution for them across the sky (avoiding ecliptic poles).

The CXC has successfully managed to execute several challenging programs this year. These include programs with strong constraints, programs with moving targets (e.g. comets), programs with large exposure times at extreme declinations and programs with difficulty in acquiring guide stars. In a few cases, offset pointings are needed to deal with a lack of guide stars, and this adds some overheads (of the order of a few ks), but is not otherwise problematic.

Clock efficiency for the mission has stayed very close to 70%. Planning efficiency has stayed close to 93%. Most of the difference between planning efficiency and clock efficiency is due to radiation belt passages, and most of the remaining 7% of the time has been for slewing and acquisitions.

Constraints have been met over 90% of time, and preferences have been met about 75% of the time. Management of situations where the CXC cannot meet observers' constraints is almost always done in negotiation with the observer to minimize scientific impact. The rate of success in meeting constraints and preferences has stayed very near constant, despite the fact that mission planning has become more complex.

Changes in mission parameters have been slow and predictable, allowing mission planning to be adapted to deal with them. The thermal issues are set to be ameliorated with the CATs. Momentum management is becoming more difficult. The biggest issue is not momentum fuel, but the number of thruster firings. Angular momentum pile-up is strongly dependent on Sun and tidal torques. At the present time, proper management of the long-term schedule can deal with the angular momentum issues.

The committee commends the CXC staff both for continuing to meet observers' constraints and preferences and for implementing the CAT program in order to ensure that science productivity of the satellite is maintained as operational challenges increase.

Calibration: Goals, Priorities, Plans

The CUC received a detailed presentation from Dr. J. Drake regarding the multiple current calibration activities being performed by the CXC, and their plans to continue this effort in the future. A number of aspects of the mission calibration are time-dependent and require moderately frequent monitoring, notably detector gain, quantum efficiency and the

level/composition of the contamination known to be building up on the blocking filters; methods to characterize these changes with time have been established, and are being continued as necessary. Significant efforts to map both the time and spatial dependence of the contaminants across the various detectors are ongoing, with an update to the contamination model anticipated for the next few months. Recent observations show that the rate of deposition of the contaminant has slowed for both ACIS-S and ACIS-I (although more so for ACIS-I), which is certainly a positive development. The quantum efficiency of the HRC also continues to be monitored; this appears to be stable for HRC-I (changes are at less than the ~10% level), but is now steadily degrading for HRC-S; nevertheless the reconstruction is currently good to ~1%.

Additional systematic effects are being corrected for the ACIS-I and HRC-S. The spatial dependence of the gain across the ACIS-I3 chip has been fixed; extensions to the rest of ACIS chips where similar issues are seen is still under development and the corrections are expected to be released in Spring 2019. Small offsets (~0.3 arcsec) seen in the zeroth-order positions in the LETGS+HRC-S have been corrected, and are incorporated in the current version of the calibration database. Furthermore, a new sample of sources have allowed the CXC to perform an in-flight assessment of the cross-calibration between the 0^{th} and 1^{st} order data for the ACIS detectors when used with the gratings; this had previously been challenging because the brightness of the sources typically observed with the gratings meant the 0^{th} order data were usually piled-up. For this new sample, the two datasets are found to agree to within ~10%. Calibration is a highly complex issue, particularly for missions with multiple detector configurations, and so the CUC would once again like to commend the CXC calibration team on their continued efforts in this regard.

The CUC was also pleased to note that issues related to future calibration procedures continue to be anticipated. With the continuing degradation of the HRC-S quantum efficiency, a voltage adjustment will be needed in the near future to maintain the performance of the detector; projections show that at the current rate of decline the performance should be acceptable out to ~2020, but the adjustment will be required soon after. A significant re-calibration effort for the HRC will be required after this adjustment is made, so this will only be performed when monitoring of the QE shows that the detector has reached the point that the CXC deems this to be necessary. The CXC is also developing a new observing mode to test the HRC-S calibration by significantly dithering sources across regions of varying thickness in the Aluminum blocking filters. Efforts are ongoing to map out the transition between the 'thin' and the 'thick' regions. Finally, the CXC is also undertaking efforts to empirically determine the point spread function by stacking point sources (primarily stars) with negligible pile-up. With the latest Gaia data release, it is expected that the sample of these sources can be significantly expanded in the near future.

In light of the future calibration plans presented, the CUC did not have many detailed recommendations at the current time. However, a couple of broader points were noted:

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1. The CUC continues to strongly recommend that the current calibration efforts are maintained at close to the same level of commitment. The complex long-term trends seen in many of the key detector parameters (e.g. quantum efficiency, contamination) will continue to require frequent monitoring to ensure the continued success of the mission. The CUC therefore again asks the CXC to continue providing regular updates with the latest data on the evolution of these properties at future CUC meetings.

2. The CUC also again recommends that the CXC calibration team continue to play an active role in the IACHEC collaboration in order to maintain efforts to characterize and understand the cross-calibration uncertainties between the various X-ray missions currently active (e.g. XMM-Newton, NuSTAR, Swift, NICER).

CXC Response:

1. *The CXC calibration team will continue to monitor the ACIS contamination and all detector characteristics at the same level of commitment through periodic calibration observations and timely updates to calibration products. The CXC calibration team will also provide yearly updates on the current state of the detectors and contamination at the yearly CUC meetings.*
2. *The CXC calibration team has maintained a significant presence at all IACHEC meetings. CXC calibration scientists chair several of the IACHEC working groups. There are also several ongoing cross-calibration projects with the present fleet of X-ray telescopes.*

Discussion of contamininant build-up and possible bakeout

In addition to the report on the broader calibration efforts, the CUC also received a presentation from Dr. P. Plucinsky providing an update on the possibility of attempting to 'bake' off the contaminants building up on the filters. In summary, although removing the contamination would significantly improve the low-energy performance of the ACIS detectors, the CXC is not currently considering attempting such a procedure, as the risks are considered too severe. Significant uncertainties remain in the composition of the material, and therefore in its volatility, and so predictions for the duration of the procedure required to remove this material vary wildly. There is a risk that attempting the bake-out could actually increase the level of contamination if the duration of the bake is not well matched to the actual volatility of the material, as it is likely that the surfaces surrounding the filters are also coated, and this material would be loosened and then attracted to the cooler surface of the filters. Furthermore, it is not understood how quickly the contamination would build up again after the bake-out, a major in-flight re-calibration effort would be required after this was performed (potentially requiring as much as ~1Ms of calibration exposure) and, as noted above, the rate of deposition has slowed. Finally, there is a non-negligible possibility that the bake-out procedure could cause damage to the blocking filters themselves, potentially rendering the detectors inoperable.

1. The CUC endorses the decision of the CXC not to attempt to bake off the contamination at the current time. One possibility that was discussed briefly was whether a short trial bake-out period would be worthwhile to empirically test how rapidly the contaminant was removed, but it was noted that this did not mitigate the risk of damage to the filters. The CUC recommends the option continue to be studied, particularly as the understanding of the composition of the contaminating material improves.

2. The CXC notes that the work performed at the IACHEC has helped significantly in developing the understanding of the contaminant, and also provides a means for the lessons learned on this issue from Chandra to be taken into account by future missions. This further reinforces the recommendation of the CUC that the Chandra participation in the IACHEC continues.

CIAO Update

The Chandra analysis software, CIAO, is maintained and developed to include new features, adapt to changing platforms, and address user needs. A new release (V4.10) has been distributed in 2018 with Python 3 as the dedicated programming environment. New features to CIAO include a routine to create pixel masks and a new region module. There is a move away from ChiPS that will be replaced with Matplotlib. An update to Sherpa is included with CIAO that has new functionality to generate an empirical PSF using a finer grid resolution. There were no major problems (i.e., software bugs) to be reported. DS9(V8) has been upgraded to incorporate different WCS header keywords and display command-line error messages. There are 1111 publications to date (mentioning) using Sherpa.

There are ongoing efforts for the next release (V4.11) such as improving the routine for measuring source flux that incorporates multiple observations and properly assessing the background in co-added data. There is continuing effort to improve packing and distribution of the CIAO software.

Significant effort has been made in the documentation of the software tools with more general documents for the wider astronomical community. There are exercises for newcomers in the form of a Jupyter notebook. Flyer-like handouts are available for an introduction to X-ray astronomy and missions. Outreach efforts continue on social media platforms (Facebook, Twitter) and the software team has a presence at international conferences such as the AAS annual meetings, AAS-HEAD, and IAU. The CIAO team offers dedicated software workshops including one in Pune, India, which was attended by astronomers from all over India and supported by CXC staff both in-person and remotely.

CSC 2 Demo

Chandra Source Catalog 2.0 status summary:

- 374k sources detected
- 93.5% completed in terms of source characterization; complex fields (such as M87 and Sgr A*) are still to be completed.

The to-do list:

- Migrations to the archive (not started)
- Limiting sensitivity map: the pipeline has been written and tested; it needs to be run (not started - estimated 10 days worth of work)
- Extended sources processing (⅓ complete)

Usage Statistics: CSC archive view/download: Numbers are picking up; reported factor of 5-7 increase with respect to the earlier 1.1 release.

Recent CSC outreach events included demos at the 2018 AAS and IAU.

CSC2.0 webpage and CSCview usage demo:
The home page is organized in 8 user friendly "buttons", such as "explore CSC2 from the WWT interface". The committee was given a live, interactive demo of the WWT interface usage, including searching wide fields and/or individual sources, building search queries based on a set of properties and and how to link those to the CSC catalog for source selection and properties acquisition. The interface appears to be very intuitive and user friendly. The content is rich and informative.

This has been a major source of concern for the committee over the past few years. Overall, the committee is very pleased to see that the catalog is nearly completed and that the community has been given straightforward access to science ready products.

We encourage the team to ensure that the catalog can be used by other VO tools, such as Vizier and TAP, if plans do not already exist for doing this. We encourage continued monitoring of the science papers that will stem from this massive effort. We note that it is also important to track usage that does not result in papers, because in some cases, the catalog may provide quick feasibility indicators that save considerable time for infeasible projects. We recommend that disproportionate effort not be given to continued reprocessing of the extremely challenging fields as new data come in for them, because of the likelihood that for those fields users will perform their own carefully tailored data analysis regardless of what the CSC provides.

Publicising Chandra Science

The efforts around broadly publicising Chandra science lie at the interface between astronomers, public affairs media and the general public via press releases, media and image releases. Press releases must be based on peer-reviewed and accepted papers, and vetted by CXC and NASA as well as the first author.

Conceptually, the main challenge has to do with translating between two worlds, from one where accuracy is paramount and aesthetics is seldom taken into account, to one where

simplicity and aesthetics appeal are key. Practically, the main difficulty has to do with time constraints, particularly in the presence of embargoes and tighter schedules imposed by faster publication timelines, as journals become fully electronic.

The committee appreciates the importance of sharing science results with the general public and recognises that these efforts play an important role in maintaining and attracting funding, especially for a 20 year old mission.

Inherent risks, related to advertising results from accepted papers that turn out to be incorrect, could be mitigated by running the drafts by a slightly expanded pool of experts (possibly CUC members), although we recognize that this could pose an extra burden on the tight scheduling.

The effort in producing beautiful high impact images is also endorsed.