Chandra Users' Committee Meeting Final Report

2021 November 8 and 12

Overview

The CUC was happy with the continued performance and management of Chandra. In particular, the committee commends the CXCs efforts to improve operations and work conditions, swiftly and successfully mitigate the impact of anomalies on observatory efficacy, and make thoughtful plans for future operations.

The CUC recognizes that recent increases in interest in new time-domain scientific areas (e.g., gravitational wave events and fast radio bursts), along with challenges in controlling the thermal balance of the observatory, have resulted in a rising burden on mission operations staff and observation planning. As transient science continues to increase in activity (e.g., with the Rubin observatory and future LIGO runs), and thermal issues continue to become more of a problem, these burdens will continue to increase. However, meeting these critical challenges will certainly result in outstanding future science, and the CUC is strongly supportive of the CXC hiring the additional mission planning and/or engineering staff to appropriately navigate these challenges.

Finally, we also wish to extend our gratitude to Dr. Andrea Prestwich for her decades of service at SAO and the CXC, and wish her well in her future endeavors.

Chandra Status Report

CXC Manager Dr. Ed Mattison provided a status report to the CUC, focused primarily on managerial and budget matters, particularly the most recent budget request to NASA, funding for Covid-related excess costs during FY21 and FY22, and staff reductions and other cost saving measures. In addition, he outlined the spacecraft and instrument status and major operational activities.

The spacecraft and instruments are performing OK. All center operations are normal (and mostly remote). 2022 is the Senior Review year, with proposals due on Feb 11, 2022. NASA extended the CXC contract through 2024 for mission operations + 3yrs of close out activities. FY20+21: increased costs due to pandemic [SAO staff took less leave than average, resulting +$1.3M cost]. Budget is ~flat going forward. Current budget is ~150 FTE. Possible reductions up to 12 FTE (high-risk scenario). NASA approved a moderate-risk scenario of -6 FTEs in FY22 (current fiscal year) with reduced guaranteed observing time funding.

Mission operations are all very good. Temperature control is becoming more and more challenging, and low perigee in 2022-2024 will require more careful mission planning. Science Instruments are all performing well, although two anomalies occurred in the last year: (1) an August 31 anomaly of the LETG [resolved on Oct 15]; and (2) an anomaly with the unit interface on Oct 23, promptly recovered with only 97ks lost.

Data delivery continues as usual, with data typically available within 1.5 days, and grant issuance occurs within 2-3 weeks from initial observations, as usual.

The CUC is very pleased to see that the spacecraft and instruments are continuing to operate well, and that mission activities are being carried out as normal and with high efficiency.

Director's Report

CXC Director, Dr. Pat Slane, gave a status update on Chandra and CXC operations, a summary of the Director's Discretionary Time usage, a distillation of the recommendations from the Time Domain Work Group, a status update on the Chandra "Cool" Targets, and a summary of the importance of and preparations for the upcoming Senior Review.

The operation of both Chandra and the CXC continue to be in good shape. The spacecraft encountered two anomalies since the last CUC meeting. One, a reset of an Interface Unit (IU) to the on-board computer, is believed to have resulted from a particle event changing a status state. This has been observed several times in the past, and recovery was quick and nominal. The other was an anomaly associated with insertion of the LETG. As discussed in detail in Dan Patnaude's presentation, this was diagnosed and tracked to understandable thermal issues for which software adjustments were introduced to compensate. Work on the latter provides ample demonstration of the high-quality work done by the Operations teams on anomaly resolutions, but also serves as a reminder that additional support in this area will be important as the CXC continues to face challenges with an aging spacecraft.

Data processing and work on the CSC continue on pace, and Cycle 23 targets approved at the successful summer review are being integrated into the upcoming long-term schedule. The Cycle 24 Call for Proposals is under development, and work is underway on our proposal for the upcoming NASA Senior Review.

The DDT program continues to be competitive and continues to produce high-impact science results across a range of topics, including transient novae, a ULX, a gravitational wave event, a fast radio burst, and an observation of Saturn.

The Chandra Cool Targets catalog has continued to provide opportunities for important science while helping to manage the temperatures of various spacecraft components, and it may need to be augmented with additional targets, which would be done through a call for white papers.

The upcoming Senior Review will assess proposals for funding to continue operations in the extended operations phase. The proposals are due 2022-Feb-11, and work has already begun. A draft proposal is expected in mid-December.

Recommendations from the Time-Domain Working Group (TDWG) were received by the Director. The TDWG concluded that Chandra is doing well to support the diverse time-domain community; no areas are "shut out" by current policies and procedures. Several new initiatives could provide important enhancements in time-domain science. These considerations, along with others, are under review for potential new initiatives proposed to the Senior Review.

The CUC had extensive discussion of two specific recommendations by the TDWG.

- *The CUC agrees that proposing PIs should be given an option to allow the CXC to perform a quick search of their data "for the fast release of any possible information that might allow better and faster planning" for follow-up observations of transient events.*
- *The CUC agrees that gravitational wave transient follow-ups warrant a different approach than the traditional GO program with a six-month proprietary period. The prompt availability of these observations to the entire community would be beneficial in a number of ways, especially in the planning of additional observations at X-ray and other wavelengths. The TDWG suggested a white-paper or workshop approach to develop a community-endorsed set of trigger criteria and plan for follow-up observations. While some members of the CUC believe such a plan could be beneficial, others doubted that the community could come to an agreement. This would be most problematic in cases where the identity of the electromagnetic counterpart is not fully certain at the time when the ToO is requested. An alternative approach that the CUC discussed would be for the CXC to restrict the proprietary period to 48 hours for all Target of Opportunity observations of new GW transients proposed through GO programs. The CUC did not reach a consensus on the best approach.*

As we highlight in the overview, given the increasingly complicated aspects of mission planning and the disruptions that ToO observations cause, the CUC urges the CXC to request additional support to augment (or at least maintain) capabilities to meet the demand of time-domain science in future cycles.

Mission Planning Update

Dr. Scott Randall summarized the status of the Chandra Mission Planning, explaining the different thermal (and other) constraints that are now putting tighter limits to the dwell times as a function of pitch angle. In addition to the science instruments themselves, other systems that must be taken into account to control the overall thermal balance are the thruster valves and the ACA. Temperature limits on the thruster valves have recently become a major factor in weekly planning, severely limiting the maximum dwell capability of Chandra below a solar pitch angle of about 80 deg. Another point of concern is the increasing temperature of the ACA, which may make some fields unobservable (at least in some epochs of the year) due to the lack of stars bright enough for acquisition and tracking.

Several strategies were considered to mitigate these problems, including (1) development of auto-scheduling software to help build the long term schedule; (2) promoting longer dwell times for HRC high-pitch observations; (3) lowering the the temperature required for the ACIS heater to turn on; (4) conducting "hot" ACIS observations for targets with <300 counts that are tolerant of lower-precision calibrations; (5) making new observing constraints available to proposers; and (6) making a star-field evaluation tool available to users.

In addition to the thermal constraints, the low perigee altitude in 2023 (1048 km) will make it necessary to take into account the "momentum balance" in the planning. ToOs/DDT performance continues steady, due to the development of new procedures and tools. Nevertheless, response times could be delayed by up to 10 hours in order to pre-cool. The use of new software (developed in collaboration with STScI) to

build the LTS looks very promising, saving a lot of effort and time. Despite the challenges imposed by thermal (and other) constraints, Chandra observing efficiency remains high.

The CUC commends the CXC staff for maintaining the high efficiency of the Observatory, meeting all the observational requirements despite the increasing difficulty in the planning imposed by thermal and operational constraints.

Proposal Cycle and Future Plans

Dr. A. Prestwich provided Chandra Director's Office highlights of the last 6 months, including a virtual summer workshop on "Novel Methods in Computing and Statistics for X-ray Astronomy", as well as the Cycle 23 peer review and future Cycle 24 plans.

The workshop had 400+ registrants, which is considerably more than can be accommodated for an in-person meeting. In addition to talks, the workshop hosted multiple tutorials and discussion sessions.

The Cycle 23 review followed the new Dual Anonymous Peer Review (DAPR) format. Overall, the new process went well. In a post-review survey, 69/72 respondents rated the process as "good, very good or excellent." Proposers were conscientious in their attempts to anonymize the proposals and only one proposal was returned without review due to non-compliance. Challenges include multiple questions on grey areas involving the requirement for proposals to be anonymous versus information that needs to be in the proposal and negative comments from volunteer levelers/monitors who found the role tedious and frustrating.

For the next cycle (Cycle 24), the continued challenges in managing thermal issues with the satellite will result in further splitting of longer observations into smaller segments. The CXC anticipates segments of 10-20 ks may be common in the future. As such, two new constraints were introduced for proposers, including (1) if an observation must be split, the proposer can specify within how many N days the split observations must be completed; and (2) a new flag is introduced for phase-constrained observations, requesting proposers address whether split observations need to cover unique phases.

It is anticipated that in the next few cycles additional observing time will become available (~0.6-1 Ms per year) as a result of a new low-perigee searson. Most of the extra time is expected to go to the Large and Very Large projects, which are highly oversubscribed; however, the final decision should be based on the actual oversubscription for received proposals.

The CUC was pleased to hear that the virtual review and workshop were largely successful and that attendees were happy. We appreciate that the hosting of virtual events and the new DAPR requirements are new territory and require additional effort. The CUC was also satisfied with the consideration of past recommendations and reiterate support for both (1) the development of the Resource Cost "pull-down" tool for proposal preparation and (2) the use of a clear set of deadlines for proposal reviewers to help stay on track and set expectations at reviews. On the latter point, the CUC suggests that invitation emails for virtual reviews emphasize that reviewers should plan to be present for the entire time of the review.

The CUC was also primarily supportive of applying the added low-perigee time to the Large and Very Large panels due to the strong impact of these programs (in terms of publication citations and long-term usage) and high oversubscription rates. However, to a lesser extent, the CUC recognized that this added time could also benefit the GO program by spreading the resource among more projects.

Regarding future CXC hosted meetings, the CUC recommends that efforts be made to accommodate hybrid meetings. The value of in-person interactions, including discussions of talks and collaborations outside of talks, is simply too great to switch entirely to a virtual format for such meetings.

HRC and LETG Anomaly Update

Dr. Dan Patnaude provided the status update on the Chandra High Resolution Camera (HRC) and the Low Energy Transmission Grating (LETG) anomalies encountered in 2020-2021.

The HRC suffered a major power anomaly on August 24, 2020, which caused secondary science data to be corrupted and unreliable. After 1-week, a successful attempt was made to run the HRC on the B-side power supplies with no indication of issues. In early September 2020, the HRC anticoincidence shield (PMTs) were powered, and everything looks nominal. Over the months of October and November 2020, HRC team conducted test observations, and noted count rates for source and background are consistent with expectations. HRC instrument, SOT, and CAL teams conducted independent analyses of the observations. No evidence for errors were found in the onboard processing of event positions at the HRC aimpoint. Also, no changes were found in the PSF after the switch to B-side power supplies. Probable cause of the anomaly was an electro-mechanical failure in the DC-DC converter, or multilayer ceramic capacitors. The HRC anomaly trained the new team and there are planned improvements over the next couple of years.

On August 31, 2021 the LETG insert switch engaged for half seconds faster than previously seen, but the OBC software and OTG hardware all performed nominally. Most likely the root cause of the fault was OTG support K-constants in OBC FSW. It was also identified that the motion control electronics (MCE) contains temperature sensitive components and when combined with flight software related to the LETG insertion, leads to speed variations in the insertion. On October 15th, the flight software was patched to account for the heating of the MCE and the LETG was restored to nominal operations. Several HETG moves have been executed since resumption of normal OTG operations. The first LETG insertion with the updated flight software is tentatively scheduled for the week of November 15.

The CUC was pleased with the CXC's ability to respond quickly to the HRC and LETG anomalies and were happy with the detailed and thoughtful investigations that were conducted to identify the causes (for the LETG anomaly in particular).

CIAO Update

Dr. Jonathan McDowll provided an update of Chandra's data analysis software CIAO, and its usage. The time spent on CIAO is roughly half on user support and half on new software developments. CIAO

download demand remains high and help desk tickets are steady. This team has continued its responsiveness to needs of the users and the median time to resolve user ticket requests is less than 1 day. Even though there was a significant spam attack on the helpdesk in April, which required a one month downtime on the website request form, users could still get help via email. Although the website is now working, it no longer supports pdf uploads.

The CXC continues maintaining and improving CIAO's algorithms, interfaces and documentation. Here we outline some of the highlights of the recent software advancements.

- One significant change to CIAO in this December's release (4.14) will be that the Prism file viewer has been retired, replaced with a similar capability within DS9. This lets CIAO build without the GTK graphics package which was causing portability issues. There are additional improvements to the DS9 interface and to DS9's CIAO analysis menu; improvements to the adaptive binning tools; and to Sherpa's filtering and grouping capabilities. The widely used specextract script is being rewritten to improve its robustness and performance. The past year also saw release of the new version of the srcflux script which can handle multiple combined observations (previewed at the last CUC).
- The documentation has been improved in several areas and the Sherpa documentation is now better integrated with Python, with ahelp files generated from python docstrings. Sherpa was refactored, leading to a performance speedup of roughly a factor of 2. A lot of new features have been added to Sherpa as well.
- Software development in tools like the updates to dmnautilus and the development of dmradar provide new capabilities to help with data analysis, and efforts have been devoted to making specextract more efficient.
- A long-standing bug was recently discovered in the vignetting calculation for exposure maps; it affects the maps at the one percent level so most users will not have to worry about it.
- Continued support of software on Linux and Mac operating systems. Due to the nature of Mac, it can be time-intensive to update for the latest operating system updates.

Finally, the analysis software team continues its outreach work to train scientists in using this analysis software. In the virtual AAS setting, more scientists attended talks, forgoing hands-on sessions, but this may change as we go back to in-person meetings.

The CUC was happy with the software improvements and outreach activities. These activities facilitate better scientific studies with Chandra data, and we encourage the continued appropriate support for them into the future. The CUC applaud the addition of a zenodo reference for this software to better cite, and hence document, its use.

Chandra Source Catalog & Data System Initiatives

CSC 2.1 Status and Projections

The Chandra Source Catalog (CSC) 2.1 release will add to the CSC all the Chandra data collected in the 2014-2021 timespan. This release will allow routine catalog processing by the Chandra pipeline operation group. It has required some algorithmic changes to substantially reduce the amount of manual intervention in the data processing, as well as major infrastructure changes to the software to make it robust and operational (the previous release of the catalog, CSC 2.0 was run directly by the software developers with considerable science oversight). The 2014-2021 Chandra data also required re-calibration before being processed for CSC 2.1.

To minimize the processing time, the software was modified to allow for incremental processing, so that new data can be added to previous processing without rerunning the catalog ab initio. A dedicated cluster (felix) was acquired and set-up to allow speedy catalog processing. The CSC 2.1 software and hardware system will allow future frequent incremental releases of the CSC to the scientific community.

In previous communications to the CUC, the CXC had projected that the production of CSC 2.1 would start around January 2022. Based on the complexity of the scientific validation of the new software over the summer, which required two additional months for testing, the CXC is now revising this estimate to mid-March 2022.

The detailed status of the CSC 2.1 is as follows:

- The bulk of the 2014-2021 data has been reprocessed and we are confident that the last issue cases will be all solved by December.
- The algorithmic software has been delivered for science testing on schedule and has been successfully tested. These upgrades include: (1) Improvements to stack astrometry, which eliminate almost all manual detection matching and which tie the Chandra astrometry to the Gaia frame, providing the best Chandra absolute astrometry; (2) Better estimates of positions and positional errors for crowded areas; (3) Improved MCMC sampling method for the posterior probabilities for fluxes and hardness ratios (pymc3) that substantially increases the number of sources for which a flux can be measured.
- Significant infrastructure upgrades to allow for operational CSC production have been completed and are now being tested. These include: (1) hybrid processing (mixing previously CSC processed and new data), (2) reprocessing capabilities and (3) science Quality Assurance (QA) triggers and analysis.
- The full system test has started. This test is meant to stress-test the system with complex data sets and to optimize the processing strategy. This test is scheduled for 8 weeks, concluding in mid-Jan 2022. During this time period, the Operations team has a copy of the system on a smaller cluster, where they acquire familiarity and develop the operational monitoring system to work with all the new features.
- The next step will be a full end-to-end test by the operators, to formalize operational procedures on the fully operational system, test their operational scripts in depth, and address QA staffing and strategy.
- A final ‘wrap-up’ software patch is then anticipated (2 weeks).

- CSC 2.1 operations start in Mid-March.

Processing will follow a modified chronological order: approximately date-ordered single-and few-obsid stacks (new sky) will be prioritized. Multi-obsid stacks that are resource-intensive to process (but source-rich) will be interleaved for operational efficiency.

The CSC 2.1 properties and data products will be made available in the public database as they are processed. The CXC will then provide a final, frozen catalog release after all processing has been completed.

CSC 2.0 Activities

The CXC has conducted a user survey of the CSC 2.0, which shows that both tabular data and data products are important to the users. CSC presentations and demos were done by CXC staff, and documentation was developed (as well as demos) illustrating how to access the CSC from Jupiter notebooks. The CDA has begun to track explicitly the use of the CSC in published papers, as part of the Chandra bibliography. Science activities that include cross-matching the CSC with several multi-wavelength catalogs show ways to characterize the CSC sources and extract catalogs for further scientific analysis. A list of CSC sources with optical counterparts were delivered to the SDSS group to be used for SDSS V spectral observations, following an agreement between Chandra, the CfA and SDSS. These spectra will be available to the Chandra users.

The CUC is happy with the progress made on the Chandra Source Catalog and commends the CXC for the forethought it is giving to future developments of the CSC.

The CUC was given a series of proposed enhanced services that the CXC could potentially provide, including (1) searching new Chandra data for past CSC entries to identify variable, (2) performing analysis of Chandra data related to sources identified in external alerts, (3) providing multiwavelength catalog properties of X-ray sources from other observatories (e.g., WISE, PanSTARRS, etc.), (4) enabling ChaSeR data archive to provide aggregate information from the CSC to users in its interface, and (5) providing subpixel resolution data products for sources in photon-rich fields.

Regarding these proposed activities, the CUC strongly supports the development of a capability to detect new transients or significant source variability (i.e., option 1 above). However, the Committee feels that in order for this to be of significant value to the community, the results need to be reported within 24 to 48 hours of the observations. The Committee understands this may require doing a first rapid pass just to detect time variable sources and going back later to do the full analysis of the CSC, but we think preliminary results that provide clear detection of time variability, and along with a good position and a crude light curve would be extremely valuable. It was less clear to the Committee that the CXC should devote resources to matching older CSC sources to variables found in the SDSS (option 2) or multiwavelength data sets (option 3), as investigators are likely to perform this work themselves, regardless of availability. Similar reactions were found in the CUC regarding subpixel resolution data products (option 5); these products are unlikely to be sought after by non-expert users, and the committee expects that expert users will likely want to perform these analyses themselves. There was support in the

CUC for providing new aggregate information in ChaSeR (option 4), as this information could be very helpful to users and may give the CSC added visibility and usage.

Calibration: Goals, Priorities, and Plans

Dr. Larry David gave the update on the Chandra calibration goals, priorities, and plans. Calibration measurements to estimate the contamination have been completed for this year, which are a combination of pointed observations, raster scans, and dithers, and based on the results, the contaminant is still increasing. Since the trend follows the already established model of the contamination increase no update was needed this year.

Next the gain calibration for ACIS was presented, and here the CUC was asked to weigh in on a new calibration strategy, called the hybrid method, which will increase the achieved accuracy on the gain from 0.3 % (requirement) to 0.7%. The issue here is that it is getting harder to obtain enough cold ECS data (T <- 117.2 C) in the time allotted for calibration (only 25% of all the data is cold) because Chandra is getting increasingly warmer. This year 170 ksec had to be taken out of the science program, and this could easily increase to 700 ksec over the next two years. The method currently used (and in the past) to obtain 0.3% in gain is: 9 observations of CasA on each of the ACIS chips (18ks per chip). Using all the previous data of CasA taken this way, a Principal Component Analysis (PCA) was performed, and this showed that with the PCA and a central observation of CasA on each chip, the time needed for the calibration can be drastically reduced, but at the cost of accuracy in the gain calibration, which would increase to 0.7%.

The CUC discussed this issue and it is a concern that more and more time will have to be taken out of the science program. The members of the CUC, however, were not able to evaluate if the increase in knowledge of the gain from 0.3% to 0.7% would significantly impact science. The recommendation of the CUC is therefore to solicit input from that part of the community for which this might impact their science. The CUC would like some clarification on whether by switching to the hybrid version they can switch back to the original version at a later date to recover the 0.3% in gain. Also, if going forward with the hybrid and only adding the central image to the PCA, will the accuracy of the hybrid method decrease further in the next couple of years? Will it be necessary to complement the hybrid method every couple of years with the full complement of data?

For the gain calibration of the HRC/LETGS, they increased the HRC-I/S High Voltage (HV) to put the detector gain back where they were 3-5 years ago. The calibration products in the pipeline now recover the flux to 2% over the course of the mission after the change. For the HETG they use a 0.5Ms PKS 2155-304 observation to adjust the 1, 2 and 3rd order efficiencies.

PSF monitoring is performed semi-annually with ARLac, and in the last couple of years there has been an increase in the observed HPD. It is still small, the changes at 90% is less than a pixel, and the source of it is most likely due to the aspect camera and has no correlation to temperature. Astrometry monitoring shows that the pointing is off by ~1 arcsec. A mitigation strategy would be to improve the aspect camera's tracking, which has been degrading due to temperature increases.

NASA Hubble Fellowship Program and SDSS-V

Dr. Paul Green reported on the NASA Hubble Fellowship Program (NHFP). The program is sponsored by NASA, administered by the Space Telescope Science Institute (STScI), and scientific leadership is among three leads representing the three science "flavors": Einstein (Dr. Paul Green, CXC), Hubble (Dr. Andy Fruchter, STScI), and Sagan (Dr. Dawn Gelino, NExScI). Since 2018, the program has covered a wide range of astrophysics interests to NASA's mission and unites three original fellowship categories. In 2021 twenty-four fellows were selected out of 406 candidates. The review involved seven topical panels, each including seven reviewers and a chair. Twenty-seven offers were made, of which three recipients declined. The 2021 NHFP Fellows Symposium was held Oct 25-29 remotely and included four special non-science sessions for the Fellows.

The recent policy change to the program now allows a) up to 4 years post-PhD for extenuating circumstances (blanket extensions for 2022 applications due to the pandemic), b) all NHFP hosts must offer employee status for fellows, c) fund collaborator or graduate student travel to support research, d) fellows can accept honoraria, and e) expands host institutions to include NASA research centers (Goddard, Marshall, and Ames).

A NASA Review Panel finalized an intensive review of the NHFP to consider possible improvements. In addition to their strong endorsement of the importance of the fellowship, the panel offered 32 recommendations for consideration by NASA, in consultation with the NHFP Leads. There was broad agreement to draft a mission statement, to enhance the consideration of inclusive leadership potential in the selection, and to provide annual workshops for stakeholders on, e.g., career paths, mentoring, and inclusion.

Selection of the 2022 class of 24 NHFP Fellows (application deadline has passed as of the writing of this report) will occur in January 2022. The review of the applicants will be fully remote and will use a new rubric to make grading more balanced and consistent.

SDSS-V project has accumulated several thousand optical spectra of Chandra Source Catalog counterparts during its early plugplate program. Several thousand more are already in the SDSS archive. Spectroscopy will soon transition to robotic fiber placement. CXC is planning to serve both pipeline parameter information and digital spectra for CSC counterparts to the public.

The CUC is pleased to see that the NHFP continues to provide a supportive community through annual Symposiums and has implemented the previously discussed changes to the terms of benefits. We commend the NHFP scientific leads for actively involving fellows in discussing how to be more family-friendly and inclusive.