TWENTY FIVE YEARS OF MISSION PLANNING:

Staying Cool When Things Get Hot

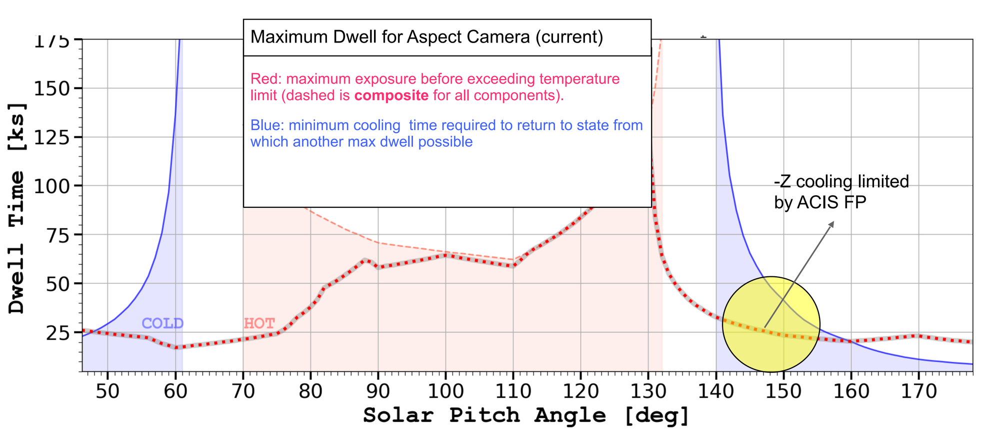
Scott W. Randall, for the Science Mission Planning Team
(Daniel Castro, Ewan O'Sullivan, Joshua Wing,
Tara Dowd, Iris Wang, and Kevin Paggeot)
Chandra X-ray Center, Smithsonian Astrophysical Observatory

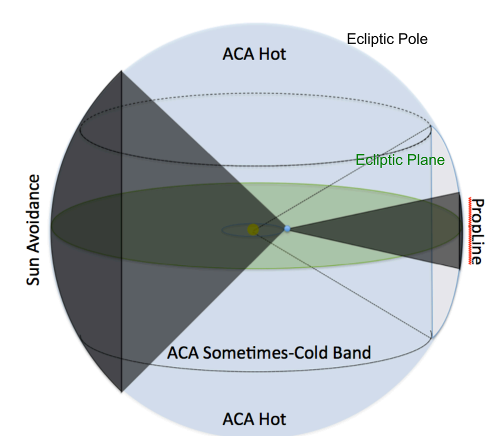
Mission Planning Goals

The main goal of mission planning can be summarized as maximizing Chandra's science and observing efficiency while meeting the science, engineering, and operational constraints. There is a great deal of complexity encapsulated in this deceptively simple statement. In particular, Chandra's mean temperature has been rising steadily since launch due to the slow breakdown of its multilayered insulation. This impacts Chandra's ability to acquire and track guide stars, and limits the amount of time that it can spend observing at any given solar pitch angle, as there is a limiting subsystem temperature at all solar pitch angles. As a result, mission planning has become a delicate balance of heating and cooling between the various subsystems by carefully managing the observing schedule. Despite these challenges, Chandra's performance remains very strong, with current observing efficiency, TOO and DDT response, and science constraint compliance all on par with historical values. This has been achieved by several proactive software, procedure, and policy changes to anticipate and mitigate the effects of evolving operational constraints.

Challenges

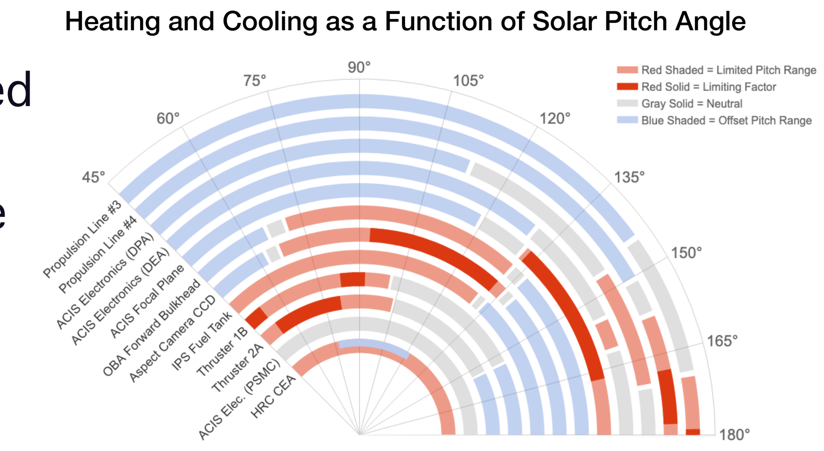
Maximum Dwell and Cooling Times





- Depending on its solar pitch angle, different parts of the spacecraft are heated and cooled with widely varying time constants
- Thermal constraints limit the amount of time Chandra can observe at a given pitch angle (the maximum dwell time)
- Once reached, a maneuver to a cooling pitch angle is required to maintain balance
- Each area of the spacecraft has upper and lower temperature limits, and observations need to be carefully planned (week-to-week and over the course of a year) to stay within those limits

Heating and Cooling as a Function of Solar Pitch Angle



- Time spent at "Hot" solar pitch angles needs to be balanced with time at "Cold" pitches to allow those parts of the spacecraft that were heated to cool

Strategies

Proactive Software, Procedure, and Policy Updates

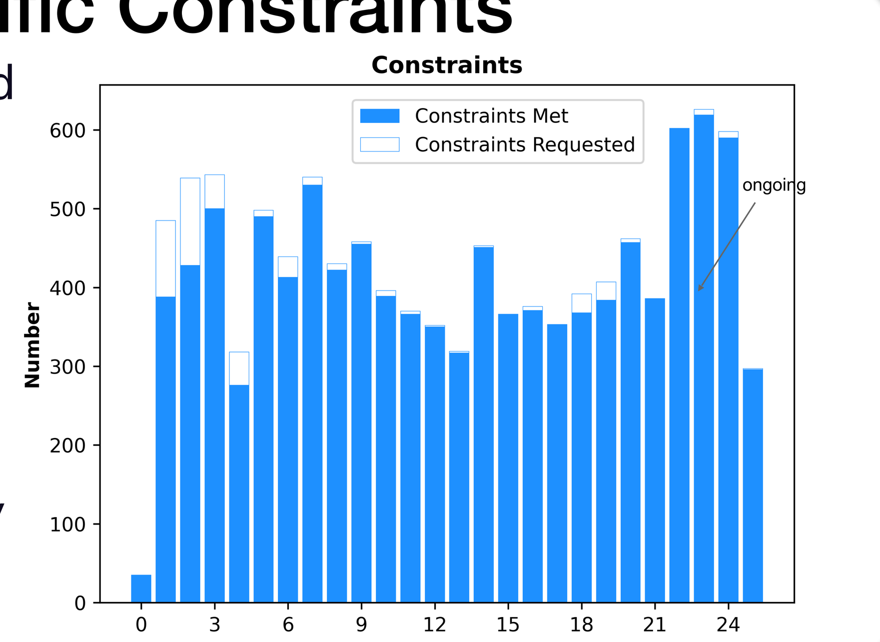
Notable updates from Science Mission Planning and other CXC teams include:

- Routine "step increases" to thermal limits, when possible, followed by monitoring to evaluate performance and support future increases
- The construction and implementation of various metrics (based on, e.g., thermal, momentum, and sky distribution considerations) and associated limits to quantify whether or not the collection of targets in a given week is "good" when constructing the Long Term Schedule (LTS)
- An AI-based "auto-scheduler", to help find viable solutions to the complex problem of laying out the yearly LTS, based on defined metrics and other constraints
- Implementation of the Chandra Cool Targets (CCT) program, to provide a pool of lower priority but scientifically valuable targets that can be used, as needed, to manage thermal issues during detailed scheduling without incurring a loss in observing efficiency
- New detection algorithms for the Aspect Camera Assembly (ACA), to improve the detection threshold and offset the impact of the increasing temperature of the ACA's CCD
- A community-facing Resource Cost Calculator tool, to better quantify the scheduling impact of proposed programs

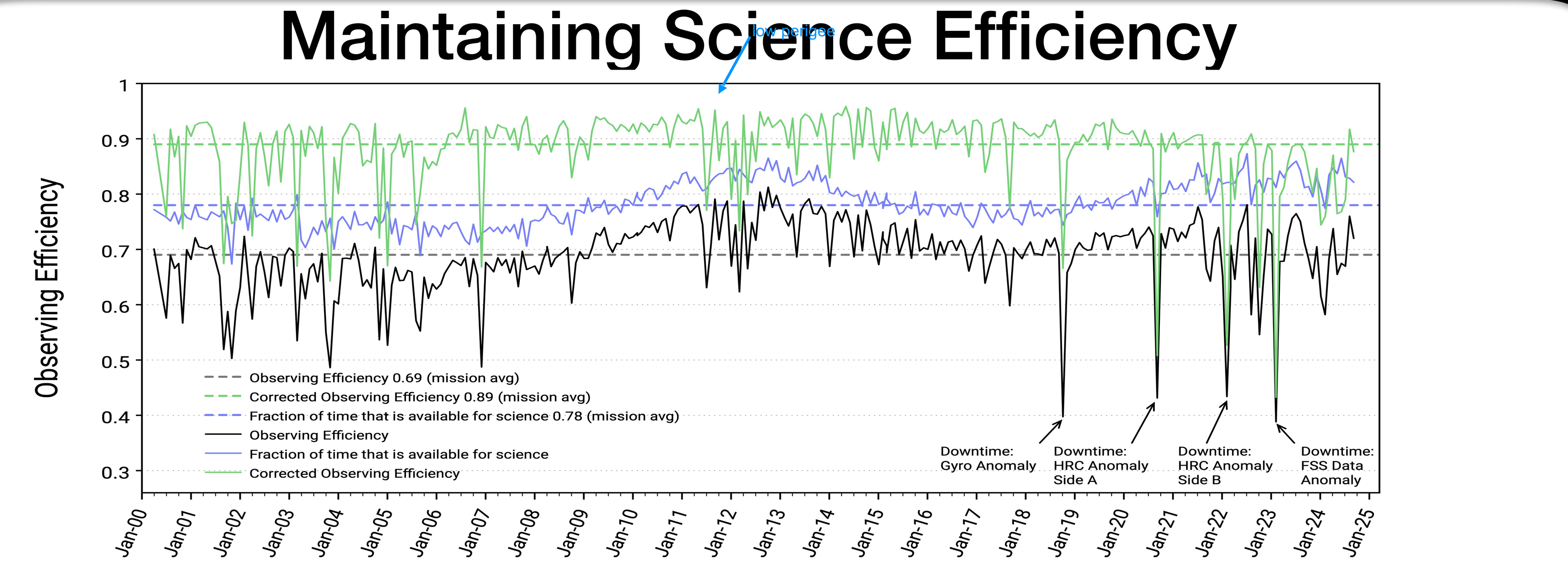
Outcomes

Meeting Scientific Constraints

- Continue to meet nearly all peer-reviewed scientific constraints
- Almost all missed constraints are due to interruptions from solar flares, or other unanticipated operational events
- This is achieved while planning around thermal constraints and observations of transient sources (targets of opportunity [ToOs] and director's discretionary time [DDT] programs)



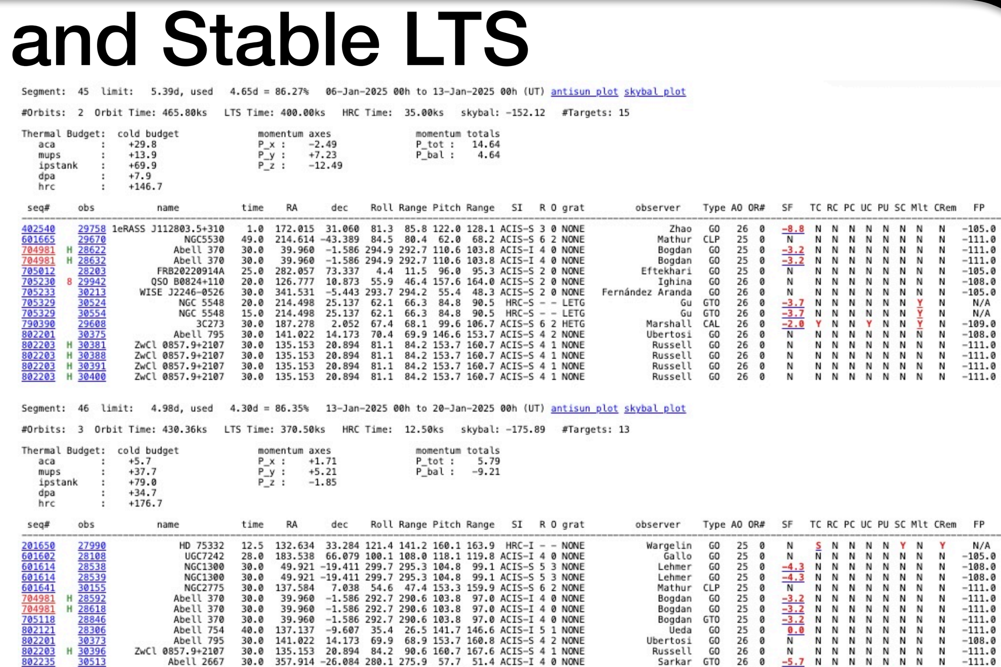
Maintaining Science Efficiency



- Continue to use spacecraft time efficiently despite growing planning complexities

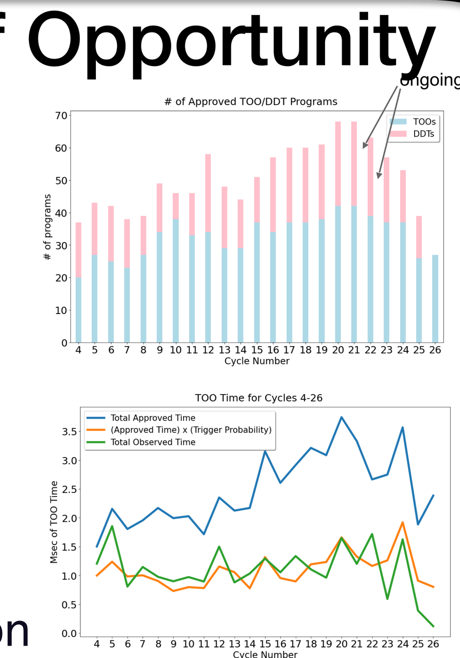
Efficient and Stable LTS

- The Long Term Schedule (LTS) extends through the end of the observing cycle
- Targets for each LTS bin are carefully chosen to help manage thermal and other constraints
- The latest LTS Page can be found here:



Observing Transients and Targets of Opportunity

- Continue to observe transient sources within specified response windows (ranging from as few as 24 hours to more than 30 days)
- Observations of transient sources need to take into account current thermal conditions of the spacecraft
- Often involves revising the Long Term Schedule to accommodate ToOs/transients
- CCTs can be used, if needed, to balance the thermal environment of the spacecraft and fit in a ToO observation



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