Project Scientist's Report

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Now in its 18th year of operation, the *Chandra* X-ray Observatory continues to provide unique capabilities for high-resolution X-ray imaging and spectroscopy, enabling high-impact research by the astrophysics community. Last year, *Chandra* successfully completed its biennial incremental Senior Review, which stated the following: "There appears to be no impediment to many more years of X-ray observations under the CXC stewardship. The 2016 Senior Review Panel enthusiastically endorses the recommendation to extend the mission through 2020 and beyond."

The *Chandra* Team is dedicated to maximizing the scientific performance and observing efficiency of the Observatory over the next decade as ESA and NASA develop next-generation facility-class X-ray missions. As noted in the Project Scientist's Report in the previous issue (#23) of this Newsletter, three issues are gracefully degrading the Observatory's performance as it ages: (1) thermal warming, (2) radiation damage, and (3) molecular contamination. Here we provide a brief update on the status of each of these issues, which are in fact intertwined.

Degradation of the multilayer insulation (MLI) blanketing the Observatory continues to complicate temperature control of several subsystems and components. However, through sophisticated mission planning—including limits on number of active ACIS CCDs and on pointing duration at thermally unfavorable orientations—accompanied by judicious relaxation of some temperature limits, the observing efficiency has remained high (nearly 70%). The ACIS utilizes passive radiators to cool its focal plane and housing to about −119°C and below −60°C, respectively; heaters on the detector housing were disabled to keep the focal plane as cold as possible, in order to minimize the charge-transfer inefficiency (CTI) of the radiation-damaged CCDs (item 2 below). However, other subsystems utilize heaters only, with no capability for cooling. Such cold-biased subsystems can provide thermal control only if the unregulated temperature is cooler than the desired set point. In some cases, this is no longer the case and the subsystem has "lifted off the heaters"—i.e., the temperature remains above the set point and thus is no longer regulated by the heaters. While this situation does not yet present thermo-mechanical problems, there is potentially an issue concerning molecular contamination (item 3 below), as components out-gas and off-gas more rapidly at higher temperatures.

After radiation damage of the ACIS front-illuminated CCDs during 8 unprotected radiation-belt passes immediately after opening the ACIS door, the CCDs have exhibited acceptably slow rates of CTI increase. In the previous issue of this Newsletter, we noted the potential loss of real-time space-weather monitoring of CCD-damaging low-energy protons, due to NOAA's plan to stop providing the real-time data stream from the Advanced Composition Explorer (ACE) after the Deep Space Climate Observatory (DSCOVR) became its primary real-time space-weather satellite at L1. Fortunately, even with full coverage of DSCOVR, NOAA has been able to provide nearly 70% coverage of ACE, which is adequate for the *Chandra* Team to monitor the intensity of protons that could damage the ACIS CCDs. In addition, solar activity is very low and expected to remain so through solar minimum in 2020 or so. For the record, the most recent stoppage of science due to a radiation event was in 2015 June.

Molecular contamination continues to accumulate on the (cooler) ACIS optical blocking filters, diminishing the instrument's response at low energies. Indeed, since about 2012, the rate of accumulation has been noticeably higher than earlier in the mission and changes in the atomic-edge structure indicate at least two contaminant species. This increased accumulation rate may possibly result from warming of surfaces within the Observatory (item 1 above). As mentioned in the previous issue of this Newsletter, the *Chandra* Team is revisiting the 2004 decision not to bake out the ACIS. Accordingly, a detailed study of the risk/benefits of baking out is currently in progress. In support of this study, Project Science is exercising its contamination-migration simulator to investigate various bake-out scenarios. Concern about temperature-dependent degradation of the CTI (item 2 above) imposes a constraint on the maximum acceptable bake-out temperature. In addition, uncertainties in the contaminants' volatilities and the possible presence of complex physical effects (mixing of multiple components, surface migration, thickness-dependent emissivity, etc.) limit the fidelity of the simulations. Consequently, the primary objective of the simulations is to ensure that the bake-out does no harm—such as leaving more contamination on the filters after the bake-out. ▪