CHANDRA
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MEMORANDUM

Date: May 22, 2026
From: Jack Steiner
To: Chandra Operations Team
Subject: Elevated Radiation Rates and Marginal Fluence Exceedance without Shutdown the Week of April 01, 2026
Cc: MSFC Project Science, CXC Director's Office
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1 Abstract

On 29 March 2026, an X1.4 solar flare produced a CME with an Earth-directed component which impacted on 01 April 2026 and resulted in several days of elevated ACE-P3 proton rates. Two sequential Chandra orbits experienced attenuated fluence levels exceeding the nominal per-orbit threshold. The first orbit's fluence reached 2.73×10^9, while the second orbit reached 2.17×10^9.

The ACIS operations team elected not to recommend a manual radiation shutdown. Despite the accumulation of excess fluence, we believe this was the right set of decisions. This memo documents the event timeline, operational considerations, and thought process behind those decisions, and is intended to serve as a reference for future radiation events.

2 Introduction

In addition to the onboard *txings* monitor, which is the only autonomous shutdown mechanism currently running on Chandra/ACIS, the Chandra operations team relies on external particle monitors, including ACE, to assess the radiation environment and guide instrument safing decisions. The nominal fluence limit of 2.0×10^9 per orbit provides a guideline for limiting radiation damage to ACIS, with the P3 channel (centered around ~ 150 keV protons) as the primary measure tracking the particles of primary dosing concern.

Solar activity including flares and associated coronal mass ejections (CMEs) can result in sustained or structured enhancements in particle flux. Operational responses must balance protection of the instrument with the scientific cost of interruptions.

In this memo we review the impact on 01 April 2026 of a semi-Earth-directed CME associated with an X1.4-class solar flare and a weaker, later-arriving halo CME associated with a long-duration C-class flare. These events resulted in approximately 3.5 days of elevated ACE-P3 rates at $\gtrsim 10^4$ flux levels spanning two consecutive orbits, both of which exceeded the nominal per-orbit fluence limit of 2.0×10^9.

3 Event Overview

3.1 Solar Context

On 29 March 2026, an X1.4-class solar flare was observed which produced a semi-Earth-directed CME. The event impacted on 01 April 2026 at 11:29 UTC, significantly later than had been predicted by the suite of models on the CME Scoreboard (median difference from predicted to actual arrival of $\sim$ 20 hrs among 14 models posted, with individual predictions having ranged from between 6 and 25 hours early). The WSA ENLIL simulation showed an impact with the FWHM of the density enhancement spanning $\sim$ 12 hours.

Following the CME impact, ACE rates increased, but with a relatively soft profile and in particular the GOES high-energy particle rates were not particularly high. For instance, the HRC-proxy and also the in-development *txings* proxy models both showed negligible enhancement, indicating that an autonomous shutdown was very unlikely. At the same time, P3-rates rose sharply over 1-2 hours reaching a 5-min peak of $\sim 45,000$ and subsequently and holding in the range $\sim 30,000 - 40,000$ for many hours. The 12-hour density enhancement in the WSA-ENLIL was taken as a basis for the fastest timescale over which the particle rates might begin to decline. In fact, what transpired was a much slower decay spanning several days and two full orbits.

Complicating this evolution, a second, weaker CME impacted on 03 April 2026 at 15:02 UTC. This partial-halo CME had been produced by a long-duration C-class flare from 01 April 2026. Unlike the X-class-induced CME, which was significantly delayed compared to predictions, this CME arrived $\sim$ 9 hours earlier than predicted (median among 8 models on the CME Scoreboard page). This caused a shorter-lived enhancement during the declining phase of the primary event, but significantly complicated the forecasting of the particle event. It was therefore not possible to rule out scenarios ranging from a sustained increase in particle rates to a rapid decline in rates following the second CME's impact.

3.2 ACE-P3 Behavior

Figure 1 shows the ACE-P3 proton flux during the relevant period and Figure 2 shows the other ACE proton rates.

The first orbit experienced sustained elevated rates associated with the main CME's impact. The second orbit occurred during the decay phase of the first CME, with a superimposed short-duration enhancement from the secondary CME.

3.3 Orbital Fluence Summary

- **Orbit 1:** 2.73×10^9.
- **Orbit 2:** 2.17×10^9.

Both orbits exceeded the nominal threshold, though the exceedances were modest. The second orbit, in particular, was only marginally above the limit.

4 Operational Discussion

4.1 Real-Time Assessment

During both orbits, the ACIS operations team was closely monitoring the ACE-P3 rates and cumulative fluence. Key considerations included:

- The gradual decline of the primary CME flux.
- The magnitude of the elevated rates (i.e., high enough to be of concern, but also not extremely high).
- The proximity of the fluence values to the nominal threshold.
- The enhancement caused by the secondary CME.
- Limited DSN contacts, in part, owing to Artemis II's launch on 01 April, which coincided with the CME event.

The ACIS operations team engaged in several internal discussions as the events unfolded regarding the benefit of a manual shutdown, with most active discussions focused toward the end of the first orbit, and midway through the second orbit.

4.2 Shutdown Considerations

A manual shutdown was considered but ultimately not recommended based on the following reasoning:

- **Marginal exceedance:** The forecasts for both orbits were expected to only slightly exceed the nominal orbital fluence threshold.
- **Temporal structure:** For a considerable amount of time, rates were observed to be in a steady and slow decline; a possible break was anticipated although never clearly manifested. The second enhancement was expected to be relatively modest (and expected to occur later than it presented) during an overall declining trend.

- **Limited benefit:** A shutdown initiated late in either orbit would have reduced the respective fluence only minimally ($\lesssim 3 \times 10^8$) and specifically would have been significantly smaller than the fluence saved from any recent shutdown.
- **Operational cost:** Interrupting science operations carries non-negligible impact on science, including several priority targets in the load. This was expected to further inhibit the ability for ACIS to present a compelling case for a manual shutdown.

5 Decision and Outcome

The ACIS operations team elected not to recommend a manual shutdown during either orbit. This decision was made after considering both the quantitative fluence exceedance and the qualitative evolution of the radiation environment, and informed by the limited comm schedule which was available as ready decision points and for enacting a manual shutdown.

In fact, the first comm for which the manual shutdown discussion was being assessed following the 01 April CME arrival was canceled, so even had ACIS wanted to call for the shutdown then, this would not have been possible. The next comm opportunity was only 1.5 hours ahead of belt entry and was thus was dismissed as a candidate for manual shutdown (given its expected fluence mitigation of just $\sim 1 \times 10^8$ for that orbit).

In retrospect, a shutdown at that time could have saved $\gtrsim 2.2 \times 10^9$ fluence, given the dose from the next orbit, but this would have been at rather severe science cost, and it is hard to imagine this case having been seriously entertained by the wider Chandra project. Noting that the flux levels remained at several times 10,000 for $\gtrsim 3$ days, this was a very difficult radiation storm to assess. Had it been a factor of 2x higher in flux, the decision to shut down would have been very clear. Conversely, had it been 2x weaker, the decision to continue would likewise have been very clear. The middling flux and long duration made this pernicious CME impact an important edge-case for consideration of potential future storm behaviors by the ACIS operations team. Ultimately, this writer feels that we made the right call in continuing science operations, but this event does not lend itself to a clearcut assessment.

6 Lessons Learned

This event highlights several considerations relevant for future operations:

- **Threshold interpretation:** Should the nominal fluence limit be treated as a strict criterion rather than a guideline for a manual shutdown?
- **Temporal context:** The time structure of radiation enhancements is key in forecasting (e.g., steady or slowly declining trends vs. expectation of a sudden break) can

significantly impact decisions and the salience of shutdown arguments in edge-cases like this.

- **Secondary events:** Smaller CMEs occurring during decay phases can introduce additional complexity and may alter the overall risk assessment.
- **Shutdown timing:** Late-orbit shutdown decisions should consider whether meaningful fluence reduction is achievable. Should ACIS establish a rule-of-thumb guideline (e.g., in fluence saved per day of shutdown) to aid in our assessment of risk-vs-cost?

7 Summary

A solar event associated with an X-class flare produced elevated ACE-P3 rates over two consecutive Chandra orbits. Both orbits slightly exceeded the nominal fluence limit, resulting in a total attenuated fluence of 4.90×10^9 accumulated over the two orbits (i.e., $\sim 25\%$ of the annual budget). Nevertheless, at no point in the evolution of the storm did the ACIS operations team determine that a manual shutdown was warranted.

The decision was based on the marginal nature of the exceedance, the declining trend in flux, the limited comm opportunities available, and the limited expected benefit of a shutdown. This case provides a useful reference for handling similar borderline radiation events in the future.

8 Notes

ACE data were obtained from `ftp://mussel.srl.caltech.edu/pub/ace/browse/`.

ACE fluxes are given in units of particles s^{-1} cm^{-2} MeV^{-1} sr^{-1}, and ACE fluences are in units of particles cm^{-2} MeV^{-1} sr^{-1}.

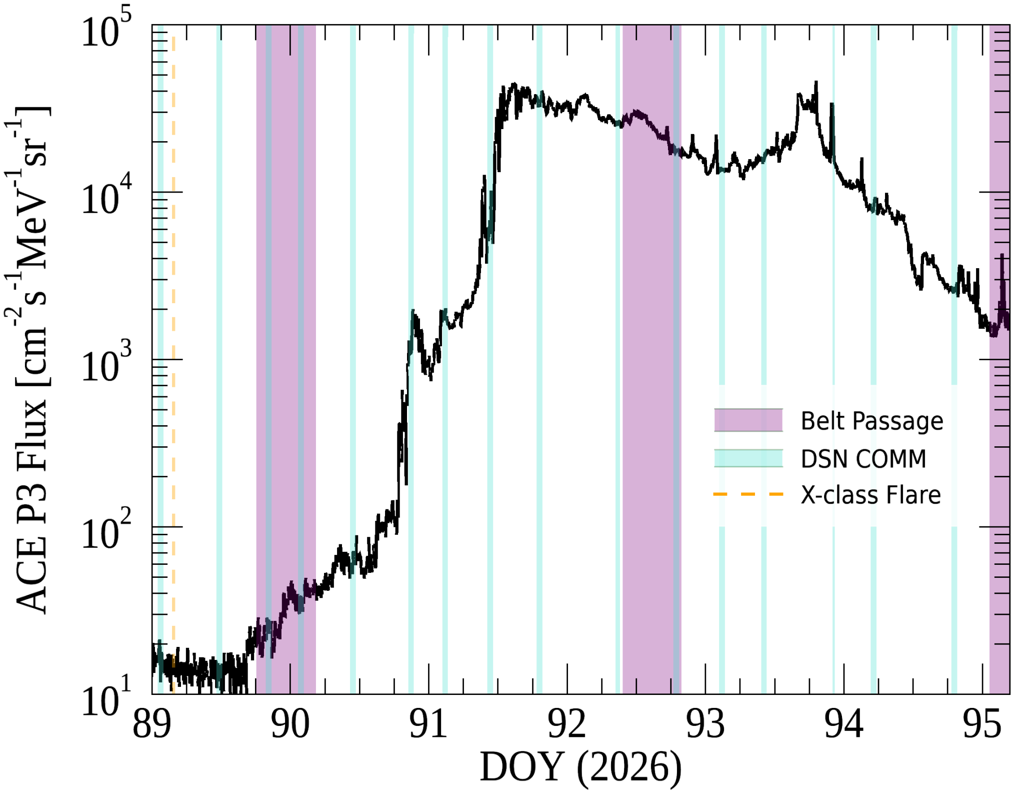

Figure 1: The ACE P3 flux associated with the X1.4 flare and Earth-impacting CME as well as a secondary enhancement from the smaller CME-impact during the decay phase. Shaded regions indicate belt passages (purple) and DSN comms (blue).

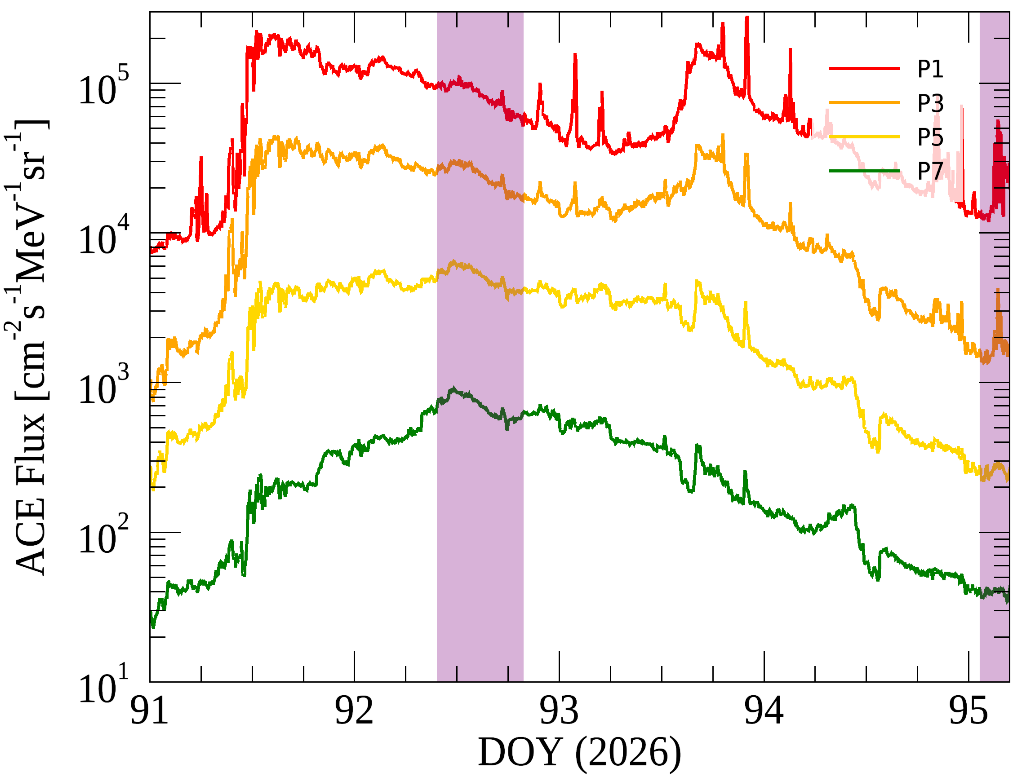

Figure 2: The response across ACE EPAM's proton bands to the 01 April CME impact.