Abstract

The Advanced CCD Imaging Spectrometer (ACIS) is CXO's premier science instrument, most often regarded as a spacecraft system. The 8 front illuminated ACIS CCD detectors was observed to be much worse than expected.

- Initially observed “5 years worth of degradation in a single perigee passage”
- Damage mechanism identified as “soft” protons to 200 keV degrading energy in CCD substrate (the back two illuminated CCD's are immune to the same damage mechanism)

The graining incidence optics used to focus the short wavelength X-rays are also efficient at focusing the soft protons from the space environment onto the observatory focal plane which degrades the energy resolution and charge transfer efficiency of the Advanced CCD Imaging Spectrometer front-illuminated CCD's.

Overview

- The most often requested science instrument onboard CXO (ACIS) cannot be operated in high flux, soft proton environment within the magnetospheric and solar particle events due to a CO damage mechanism from ~100-200 keV protons.
- The ACE EPAM instrument provides the only data source available for directly measuring the soft protons in interplanetary space that damage ACIS CCD's.
- No other users of ACE EPAM RSTW data have been identified to date, it appears that CXO is the only program using the EPAM instrument for its planned use.
- Current NOAA plans to discontinue ACE RSTW data starting late 2014 or early 2015 when the Deep Space Climate Observatory spacecraft becomes the primary NOAA space weather data source from Solar Earth 1L Lagrange point, and DSCOVR does not have instrumentation onboard to monitor the proton energy range required to protect the ACIS detector.

ACIS

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Damage to the ACIS detector has been successfully mitigated through a combination of careful mission planning, autonomous on-board radiation protection, and manual intervention based upon real-time monitoring of the soft-proton environment.

Manual intervention for soft proton events in interplanetary space is based on monitoring 115 - 195 keV proton fluence using data from the P9 channel of the Electron, Proton, and Alpha Monitor (EPAM) instrument on the Advanced Composition Explorer (ACE) spacecraft.

NOAA Space Weather Prediction Center (SWPC) currently provides ACIS/EPAM as a component of the Real Time Solar Wind (RTSW) data stream. ACE/EPAM is the only data source for real time measurements of the ~100-200 keV proton environment primarily responsible for damage to ACIS CCD's in interplanetary space.

Current CXO ACE EPAM Data Requirements

- CXO requires real-time ACE EPAM data for monitoring and implementing manual interruptions of CXO science operations if necessary, ACE Science Center Level 2 (verified and Browse (unverified) science products are not updated often enough to be useful for operational support
- Access to 5-minute average ACE EPAM RSTW data product (status quo) is the preferred option for CXO since it allows continuous monitoring of our radiation mitigation strategies to continuously monitor the proton damage in the ACIS CCD detectors and the importance of real-time data sources that are used to protect the ACIS detector from system space weather events.
- However, data rates are negotiable as ACE proton data is a fluctuating issue, with long exposure periods to soft proton flux required for significant damage to CCD's
- Lower real-time data rates are acceptable as long as sufficient information is available to estimate soft proton fluence, ACE EPAM RSTW data rates at up to once per hour can be used by CXO to monitor soft proton environment.

The Future of ACIS Real-Time Data

The ACE/EPAM RSTW records are the only real-time data currently available for detecting soft (~100-200 keV) proton events in interplanetary space that impact the ACIS instrument.

NOAA plans to replace ACE with Deep Space Climate Observatory (DISCOVER) in late 2014
- DISCOVER will become the primary NOAA-space weather plasma data source
- ACE RSTW coverage will be discontinued
- DISCOVER carries a MAGWAC/PAM instrument to detect solar wind and magnetic field measurements
- No replacement for non-thermal EPAM, 30-200 keV energetic particle instruments on DSCOVR

DSCOVR is planned to be an interim solution for an ACE replacement with release of an RFP for a full replacement after DSCOVR is successful.
- Full ACE replacement satellite could have a more complete set of cold plasma, energetic particle instruments including an EPAM replacement with a gap in service for a few years for the real-time energetic particle data.
- No one has been authorized by Congress so it is all uncertain at best
- The gap could be many years

Loss of ACE/EPAM soft proton data will impact CXO operations.

Are there other spacecraft or space weather users that require the RTSW ACE/EPAM data for operations that will be similarly impacted?

The CXO Program would like to know...

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Introduction to the Chandra X-ray Observatory (CXO)

CXO Launching 23 July 1999 onboard STS-93

Current status:
- 1.6 Re x 23.7 Re x 74", ~63.5 hour Mission Period
- ~3-week primary mission science
- Currently in 29°-54° yaw extension
- Planning for 3° to 2014 and 4° to 2023

The table above indicates Solar Cycle 24 events where ACIS science data was lost due to radiation events. Autonomous “auto” events are triggered by a high flux of solar energetic particles that generate high count rates in either the anti-coincidence shield of the high resolution Camera (HRC) or the EPNM E1300 channel. The on-board radiation monitoring system sends a signal to autonomously move the ACS instrument from the focal plane position to a protected location that cannot be accessed by the soft protons for these events. Manual events require operator intervention based on ground based monitoring of the ACE P9 channel from the NOAA RTSW data stream. In addition, there is one period of high solar proton due to a high flux proton event from the adjacent Command Telemetry Unit that put the spacecraft in safe mode. Of note is that four out of fourteen events that result in lost science observations are manual events due only to soft protons that would not have triggered the autonomous protection systems, leaving the ACIS instrument vulnerable to additional radiation degradation.

The above graphs represent two examples of periods with lost ACIS science observations (gray boxes) and the corresponding temporal variations in the radiation environment measured over a range of energies by GOES and ACE instruments. Radiation interruptions during the current solar cycle show how the solar wind and energetic particles of some ions including autonomous HIC events, a single event upset that put the spacecraft in safe mode, and the manual events based on the ACE P9 flux rates. The autonomous HIC at 350-500 keV is observed based on high energy solar particle events and sometimes a high flux of soft protons, but not always, from the high flux of soft protons. The ACE P9 instrument is the only source of real time data that can be used to guard against soft proton events that are not accompanied by high energy particles. All of the on-board autonomous systems are driven by high energy particle events. The following table indicates solar cycle 24 events where ACIS science data was lost due to radiation events. Autonomous “auto” events are triggered by a high flux of solar energetic particles that generate high count rates in either the anti-coincidence shield of the high resolution Camera (HRC) or the EPNM E1300 channel. The on-board radiation monitoring system sends a signal to autonomously move the ACS instrument from the focal plane position to a protected location that cannot be accessed by the soft protons for these events. Manual events require operator intervention based on ground based monitoring of the ACE P9 channel from the NOAA RTSW data stream. In addition, there is one period of high solar proton due to a high flux proton event from the adjacent Command Telemetry Unit that put the spacecraft in safe mode. Of note is that four out of fourteen events that result in lost science observations are manual events due only to soft protons that would not have triggered the autonomous protection systems, leaving the ACIS instrument vulnerable to additional radiation degradation.

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