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April 22, 2005
NAS8-37716
DR SDM02

AXAF-I

MIT CSR

ACIS

Advanced X-ray Astrophysics Facility

AXAF - I CCD Imaging Spectrometer

ACIS Science Instrument Software Requirements Specification

Submitted to:

George C. Marshall Space Flight Center
National Aeronautics and Space Administration
Marshall Space Flight Center, AL 35812

Submitted by:

Center for Space Research
Massachusetts Institute of Technology
Cambridge, MA 02139

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(ACIS)

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Acronyms and Abbreviations

ACIS	AXAF-I CCD Imaging Spectrometer
ADC	Analog to Digital Converter
ADU	Analog to Digital Unit
ASC	AXAF Science Center
AXAF-I	Advanced X-ray Astrophysics Facility
BEP	Back End Processor
CCD	Charge-Coupled Device
CCSDS	Consultive Committee for Spacecraft Data Systems
CEI	Contract End Item
CRC	Cyclic Redundancy Check
CSR	Center for Space Research
CTU	Command and Telemetry Unit
DAC	Digital to Analog Converter
DCS	Double-correlated Sampler
DEA	Detector Electronics Assembly
DMA	Direct Memory Access
DPA	Digital Processor Assembly
EGSE	Electronic Ground Support Equipment
FEP	Front End Processor
GSE	Ground Support Equipment
GSS	Ground Support Software
HETG	High Energy Transmission Grating
HKMUX	Housekeeping Multiplexer
HRC	High Resolution Camera
ICD	Interface Control Document
Kbps	1024 bits per second
MIT	Massachusetts Institute of Technology
MSFC	Marshall Space Flight Center
OBC	On-board Computer
OCC	Operations Control Center
PRAM	CCD Controller - Program Random Access Memory
RAM	Random Access Memory
RCTU	Remote Command and Telemetry Unit
ROM	Read-only Memory
RTX	Real-time Executive
S/C	Spacecraft
SI	Science Instrument
SIS	Science Instrument Software
SRAM	CCD Controller - Sequencer Random Access Memory
TBD	To be determined
TBR	To be reviewed
TBS	To be specified
TDM	Time-division Multiplex

TLB	Translation Look-aside Buffer
VCDU	Virtual Channel Data Unit

ACIS Science Instrument Software Requirements Specification

MIT Center for Space Research

36-01103 Rev. I

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1.0 Introduction

The AXAF-I CCD Imaging Spectrometer (ACIS) Science Instrument Software is being developed by the Massachusetts Institute Technology, Center for Space Research (MIT-CSR) as part of the ACIS Digital Processor Assembly (DPA). The DPA resides on-board the Advanced X-ray Astrophysics Facility - Imaging (AXAF-I). The DPA Science Instrument Software is responsible for acquiring and processing image data from the ACIS CCD Imaging Spectrometer and transferring the processed data to the AXAF-I Command and Telemetry Unit (CTU), which is then responsible for sending the information to the ground.

1.1 Purpose

The ACIS Science Instrument Software Requirements Specification defines and describes the operations, interfaces, performance, and quality assurance requirements of the ACIS Science Instrument Software. The requirements described in this document are derived from the ACIS Contract End Item (CEI) Specification, and the AXAF-I to Science Instrument (SI) Interface Control Document (ICD).

1.2 Scope

This document applies to the ACIS DPA Science Instrument Software. It does not provide information for the Ground Support Software (GSS), which is maintained separately as part of the Electronic Ground Support Equipment (EGSE).

This document supplies information applicable to the SDM02 Software Requirements Specification and generally follows the format specified by IEEE 830-1993 Section A-5.

By mutual agreement, MSFC Software Management and Development Requirements Manual MM8075.1 which supersedes MA-001-006-2H, forms the basis for this plan.

1.3 References

TABLE 1. Reference Documents

Part Number	Version	Title
MSFC MM 8075.1	January 22, 1991	MSFC Software Management and Development Requirements Manual
MIT-CSR 36-05001	September 22, 1995	AXAF-I to Science Instrument Interface Control Document (TRW IF1-20 CM07A)
MIT-CSR 36-02104	C	DPA Hardware Specification and System Description
MIT-CSR 36-02205	C	DPA to DEA Interface Control Document
MIT-CSR 36-01101	07	Contract End-Item Specification for the ACIS
MIT-CSR 36-01201	Rev. 01	ACIS Program Management Plan
MIT-CSR 36-01206	Rev. 01	ACIS Configuration Management Plan
NU920102	1991	Nucleus Real-Time Executive (RTX) system from Accelerated Technology, Inc.
NU910701	1991	Nucleus RTX Reference Manual from Accelerated Technology, Inc.
NU910702	1991	Nucleus RTX Internals Manual from Accelerated Technology, Inc.
IEEE 830	1993	IEEE Guide to Software Requirements Specifications

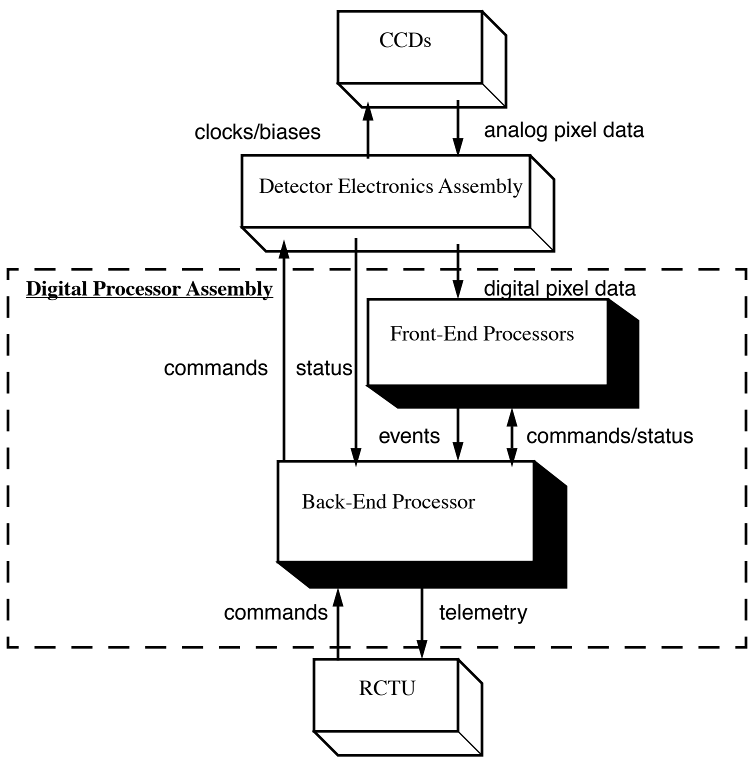
2.0 Overview

This section provides an overview of the key ACIS hardware components and clocking modes. This section is intended for information only, and does not describe all of the details of the various items.

2.1 General Description

Figure 1 illustrates the top-level interfaces to the DPA which affect the Science Instrument Software. The un-shadowed boxes are devices and the shadowed boxes contain processors which run portions of the ACIS Science Instrument Software.

FIGURE 1. DPA Interface Overview



The Back End Processor receives commands and sends telemetry to and from the Spacecraft via a Remote Command and Telemetry Unit (RCTU). The Back End Processor also controls the CCDs via the Detector Electronics Assembly (DEA), loads software into the Front End Processors, and acquires science data from the Front End Processors. The DEA drives the CCD clocks and biases, and passes the raw CCD pixel data back to the DPA's Front End Processors. The DPA Front End Processors reduce the raw pixel data into a series of candidate X-ray events, and transfer these events to the Back End Processor for further processing and inclusion in downlink telemetry.

2.2 CCD Description

This section provides a brief description of the CCDs and their arrangement. Refer to "Microcircuit, Charge-Coupled Device, (CCD) Monolithic, Silicon" (MIT-CSR 36-02308), and the "CCD-Description (CCID-10)" (MIT 36-02103) for detailed descriptions of the CCDs.

2.2.1 CCD Arrangement

The CCDs are the X-ray detectors for ACIS. When placed in the focal plane, the CCDs detect X-rays focused by the High-Resolution Mirror Assembly. When out of the focal plane, the CCDs are illuminated by X-ray calibration sources.

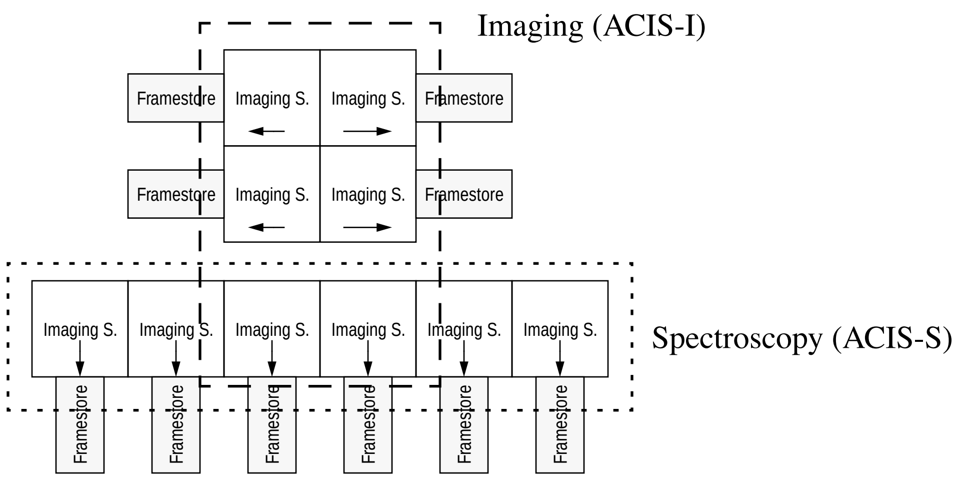
ACIS contains a total of 10 CCDs. Each CCD consists of a 1024 x 1026 Imaging section, a 1024 x 1026 Framestore section and two serial output registers, each with two output nodes.

When viewed along the focal plane axis, the CCDs appear approximately as shown in Figure 3. The 10 CCDs are grouped into two arrays:

- Imaging (ACIS-I) - Typically used without the High Energy Transmission Grating (HETG) to perform imaging and timing studies of an X-ray source or of multiple and diffuse sources spread over a wide area on the sky.
- Spectroscopy (ACIS-S) - Typically used in conjunction with the HETG to perform detailed spectroscopy studies of the target X-ray source or of images over a narrow area of the sky.

Six CCDs are used for each array, where the two most central Spectroscopy CCDs can be used for both Spectroscopy and Imaging.

FIGURE 2. Simplified CCD Arrangement



2.2.2 CCD Description

Each CCD consists of four main sections, as shown in Figure 3:

- 1 Imaging Section - The Imaging Section is the "exposed" area of the CCD. The Imaging Section contains 1024 columns by 1026 rows of pixels. For hardware and telemetry efficiency reasons, rows 0 and 1 are not used for imaging.
- 2 Framestore Sections - These are used to buffer rows of pixel data while they are being transferred out of the Serial Output Registers. Each Framestore Section corresponds to one half (512) of the Imaging Section columns, and have the identical number of rows as the Imaging Section (1026). This document refers to the Framestore Sections jointly as the Framestore.
- 2 Serial Output Shift Registers - These hold one row of pixel data and are used to shift pixels to the output nodes. There are four extra "dummy" pixels connecting the ends of the output registers to their respective output nodes.
- 4 Serial Output Nodes - These amplify and transfer the analog pixel data to the DEA

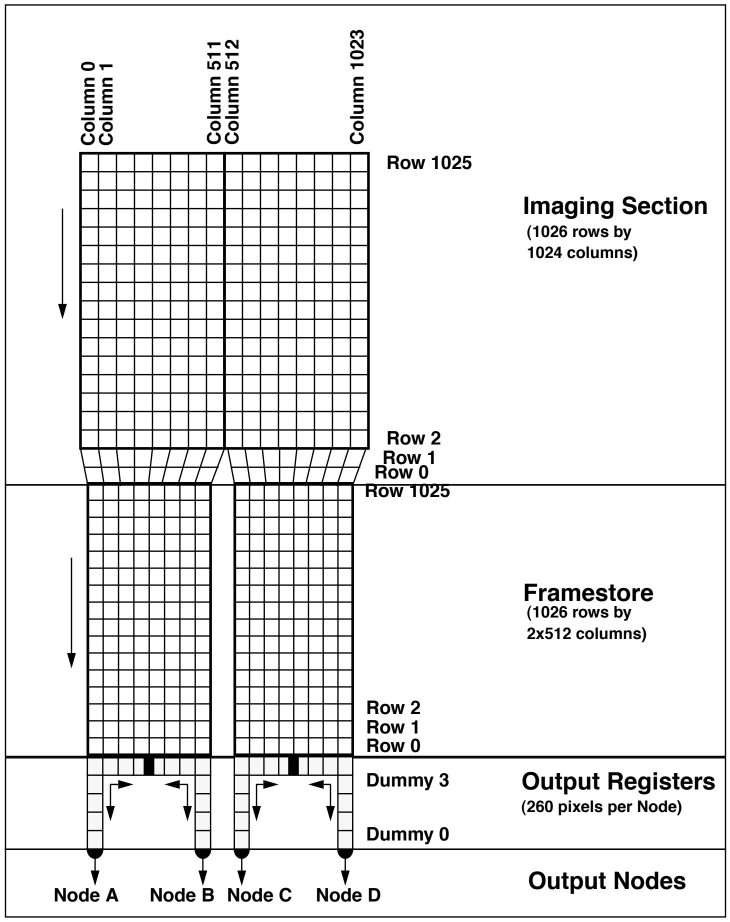
All rows and columns in the Imaging Section are clocked in parallel. The same applies to the Framestore. If rows are clocked in the Imaging Section, but not in the Framestore, the Image Rows are summed into row 0 of the Imaging Section. However, if the Framestore rows are clocked into the Serial Output Shift Registers without transferring the rows out of the output registers, the transferred Framestore rows are summed into the output registers. As rows are clocked in the Imaging Section, the effect is to clear the contents of the Imaging Section. Clocking the Framestore only clears the Framestore if no charge is transferred down from the Imaging Section.

Each Serial Output Shift Register is split into two halves. Each half has an associated output node. The hardware allows the output register halves to be clocked in following ways:

- Full-Mode: Split the two halves, and clock pixels from one half to one node and pixels from the other to the other node.
- AC-Mode: Join the two halves and clock all pixels to the left output node.
- BD-Mode: Join the two halves and clock all pixels to the right output node.
- Diagnostic-Mode: Split the two halves and clock pixels from both halves towards the center, producing no signal at the output node. This clocking method is useful for determining system noise at the output nodes.

As the charge from the pixels is shifted along the registers, the effect is to clear the output registers.

FIGURE 3. Single CCD Pixel Flow Overview

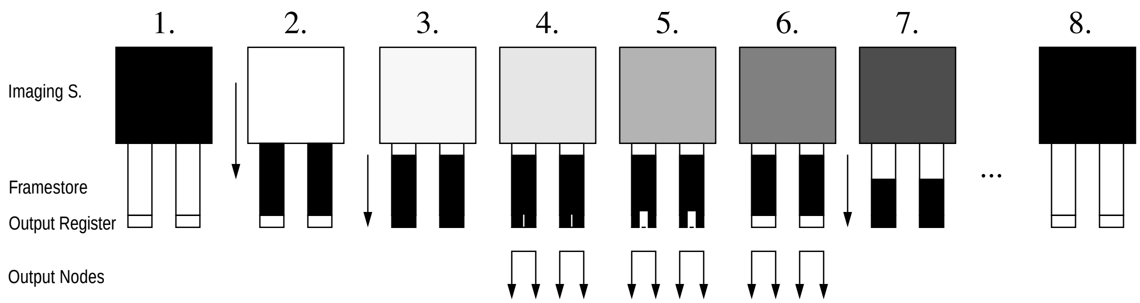


2.2.3 Timed-Exposure Clocking Mode Description

An observer uses Timed-Exposure Clocking Operation to cause the CCDs to act like a photographic camera, exposing the CCDs for a period of time, and then capturing the acquired image.

When a CCD is being clocked in a Timed-Exposure fashion, the entire contents of the Imaging Section are transferred into the Framestore. Then, each row of the Framestore is clocked into the Serial Output Shift Registers and each pixel of the row is shifted out of the register halves to the corresponding output nodes. Meanwhile, the next image is being exposed in the Imaging Section. Figure 4 illustrates this process for a single exposure (see Figure 3, “Single CCD Pixel Flow Overview,” on page 21 for a more detailed illustration of a single CCD).

FIGURE 4. Timed-Exposure Clocking Example



1. Wait until Imaging Section is exposed for desired amount of time
2. Transfer Imaging Section to Framestore and clear output registers
3. Transfer one row from Framestore to Serial Output Shift Registers
4. Clock 1 pixel from each serial register half to its respective output node
5. Repeat until all pixels have been clocked out of the output registers
6. Clock empty output registers to provide system noise information (overclock)
7. Transfer next row from Framestore to Serial Output Shift Registers
8. Repeat until entire Framestore has been transferred

The analog pixel data is sent from the CCD’s output nodes to the DEA CCD Controller board, which then amplifies, samples, and converts the pixel data to a digital form and transmits the digital pixel data to the DPA’s Front End Processor. The Front End Processor then processes the data as an image.

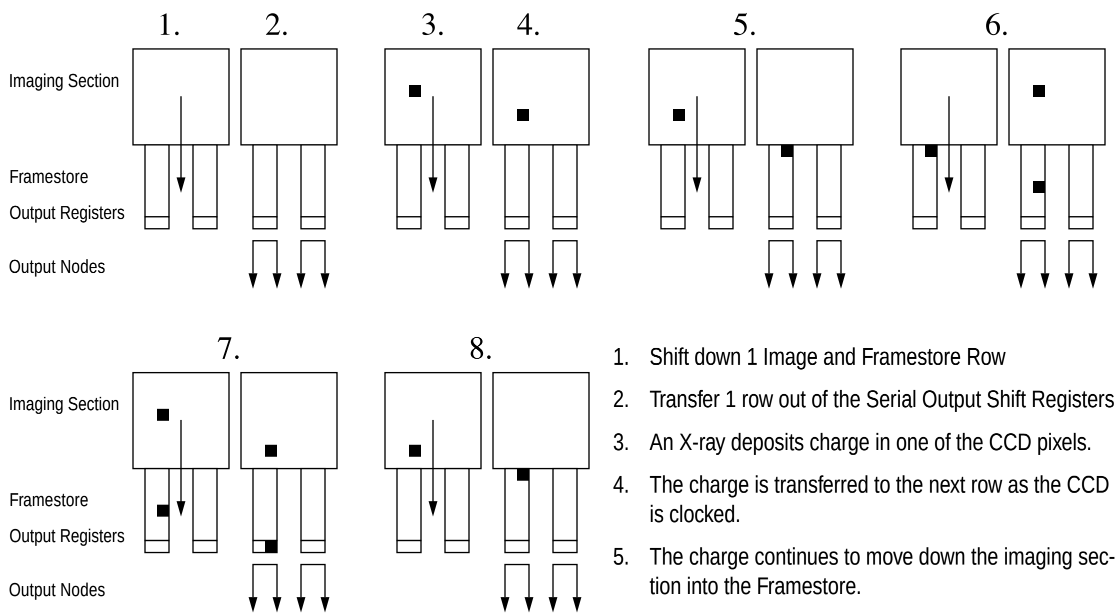
To readout a portion of the CCD (subarray), one uses the same overall procedure, except several rows are transferred from the Framestore to the Serial Output Shift Register before starting to read the output register. This effectively “skips” the first collection of rows and saves the time used to transfer these rows out of the output register.

2.2.4 Continuous Clocking Mode Description

An observer uses Continuous Clocking to obtain fine timing event information from a certain area of a CCD.

When a CCD is being clocked in a continuous fashion, the CCD Imaging Section is shifted down one row into the Framestore, and the Framestore is shifted down one row into the Serial Output Shift Registers. The output registers are then clocked out. This repeats continuously for the duration of the mode. This clocking mode provides a detailed time series of events in each column of the CCDs. The time-resolution of this mode is best for a point-source, and depends on the distribution of X-rays across the rows of the Imaging Section, and on the time it takes to clock the CCD. Figure 5 illustrates this process.

FIGURE 5. Continuous Clocking Example



1. Shift down 1 Image and Framestore Row
2. Transfer 1 row out of the Serial Output Shift Registers
3. An X-ray deposits charge in one of the CCD pixels.
4. The charge is transferred to the next row as the CCD is clocked.
5. The charge continues to move down the imaging section into the Framestore.
6. Another X-ray deposits its charge.
7. Eventually, the charge from the first X-ray is clocked from the Framestore into the Serial Output Shift Register
8. The second charge continues to be clocked through the Imaging Section and Framestore to the output register where it is finally read out.

Summing across rows is accomplished by shifting a number of Framestore rows into the Serial Output Shift Register before clocking out the output registers. This sums the rows as they are clocked into the output register.

Summing across columns is achieved by controlling the integration of the pixel signals at the output nodes as they are being clocked out of the Serial Output Shift Registers.

2.3 Detector Electronics Assembly Description

2.3.1 Overall DEA Description

This section provides a brief description of the Detector Electronics Assembly (DEA). Refer to the “DPA/DEA Interface Control Document” (MIT 36-02205) for a more detailed description of the interface to the DEA. The Detector Electronics Assembly (DEA) is responsible for clocking the CCDs and for converting the analog CCD pixel data to a digital representation and sending the converted data to the Digital Processor Assembly for event detection and processing.

Figure 7, “DEA Interface Overview,” on page 25 illustrates the main components within the Detector Electronics Assembly (DEA) and how each component maps to their respective CCDs. The DEA consists of eleven boards: 10 CCD controller boards, one for each CCD in the system, and one interface board, which contains the focal-plane temperature controller. Each CCD controller board consists of the following software-commandable subsections, shown in Figure 6:

- Command Decoder
- Digital-to-Analog Converter (DAC) Banks
- Sequencer Logic
- Housekeeping Multiplexer (HK MUX)
- Analog-to-Digital Converter (ADC)
- Video Time-division Multiplexer (TDM)
- Double Correlated Sampler (DCS) Pre-amplifier
- Power Conditioning Network (not shown)

FIGURE 6. DEA CCD Controller Block Diagram

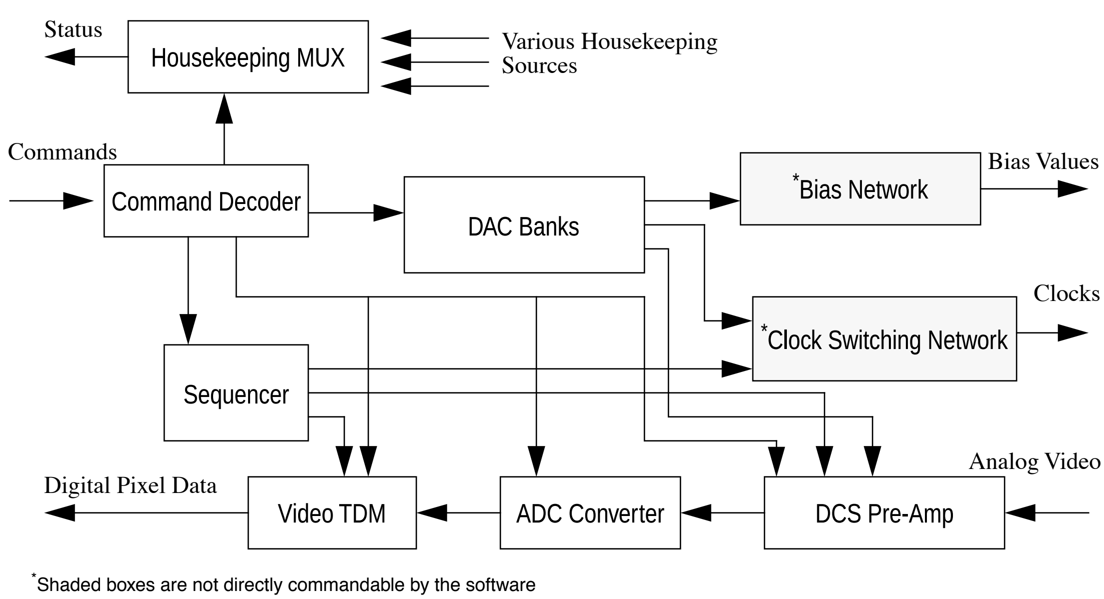
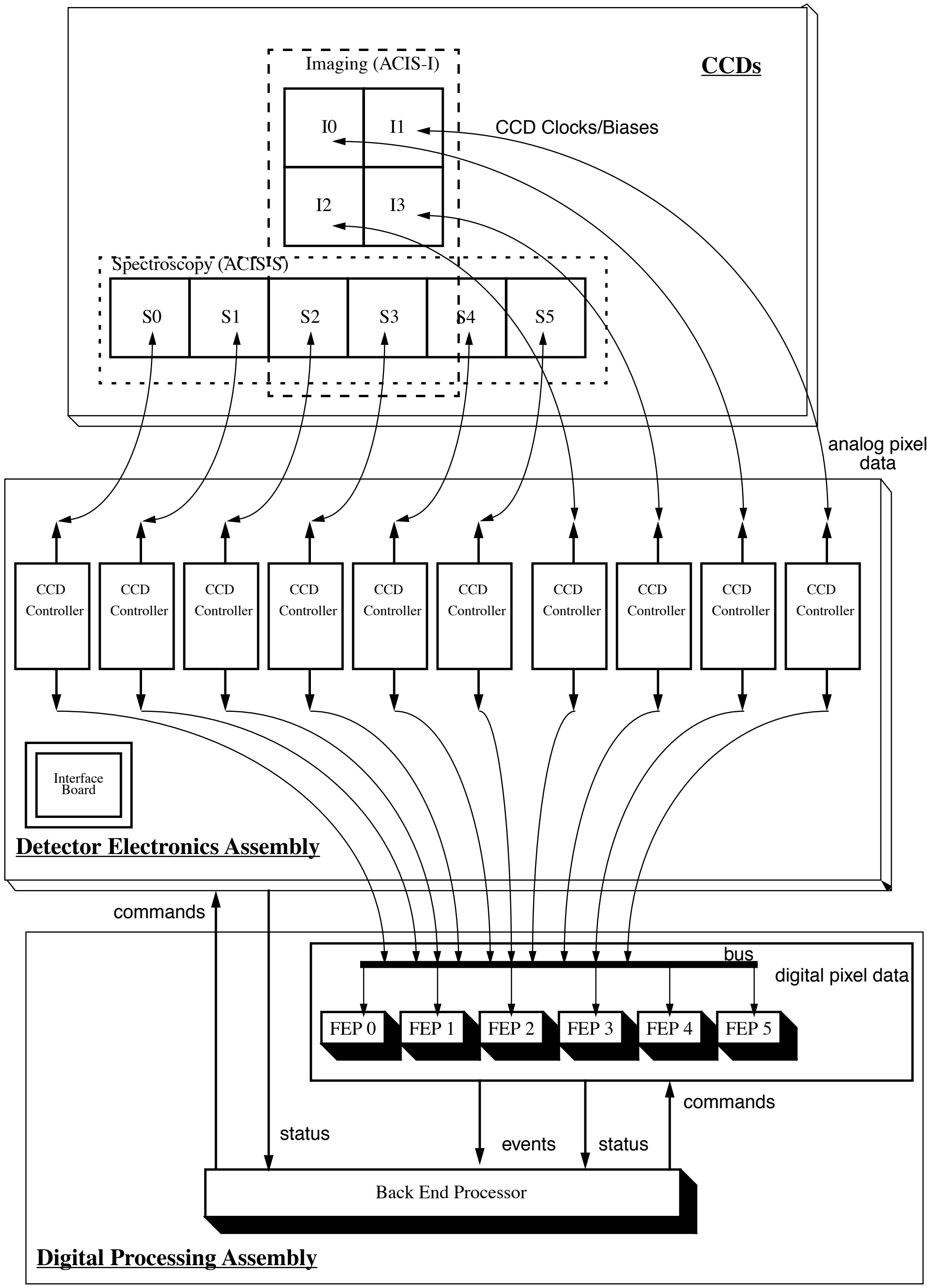


FIGURE 7. DEA Interface Overview



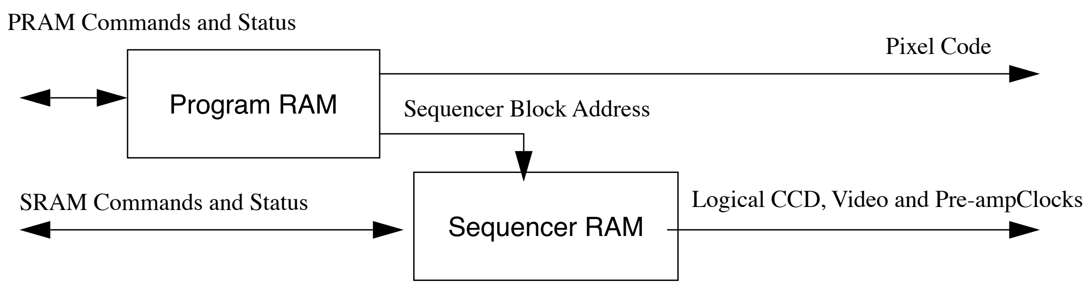
2.3.2 Command Decoder Description

Each DEA board contains command decoding logic, which is responsible for listening for commands from the interface, and, when enabled, for forwarding the received commands on to the appropriate board subsection to be executed. In general, the procedure for commanding the DEA involves first sending a command to enable and disable the various listeners on the DEA boards, and then sending one or more commands to the activated boards. When the command decoder on each board is enabled, it forwards any subsequent commands onto the addressed subsections. When the decoder is disabled, it ignores any subsequent commands until it is re-enabled.

2.3.3 Sequencer Logic Description

Figure 8 illustrates the major programmable components of the sequencer logic.

FIGURE 8. DEA Sequencer Components



The DEA sequencer consists of two main programmable sections, the Program RAM (PRAM), and the Sequencer RAM (SRAM). The Program RAM contains what can be considered the object code for a given CCD clocking sequence. The Sequencer RAM contains the equivalent of microcode. In flight, we expect to re-program the PRAM for each set of CCD clocking options. Although we plan to re-load the SRAM for each science run, we expect to hardly ever have to change the content of the loaded SRAM image.

2.3.3.1 Program RAM (PRAM)

Program RAM (PRAM) contains a series of 16-bit command word pairs. Once running, the sequencer logic executes each of these PRAM pair in series. There are two types of PRAM command pairs:

- Header Block - This PRAM command pair determines the flow of control within PRAM. Among other features, this type of command pair provides the ability to iterate over blocks of other PRAM command pairs.

- Couplet - This type of PRAM command pair instructs the sequencer to “execute” a block of Sequencer RAM (see Section 2.3.3.2). These commands contain bit-fields which specify the index into Sequencer RAM to use, the number of times to “execute” the block and provide a pixel data qualifier (Pixel Code) associated with output pixel values when the block is run.

The instrument software can load the contents of PRAM by command, and may command the PRAM to provide the contents of any given location as a status response.

2.3.3.2 Sequencer RAM (SRAM)

Sequencer RAM (SRAM) contains blocks of 64 16-bit sequencer words. Each bit of a sequencer word corresponds to one of the CCD clocks, Video control signals, or Pre-amplifier control signals. The state of the bit, 0 or 1, indicates whether its corresponding signal should be asserted or de-asserted when the sequencer word is invoked.

When a PRAM couplet command is executed, the PRAM couplet selects which SRAM block to execute and how many times to execute the block. Upon each sequencer clock cycle, the sequencer then sequentially fetches and invokes each SRAM word from the addressed block. The effect is to produce a series of timed state changes on the output clock signals.

The instrument software can load the contents of SRAM by command, and may command the SRAM to provide the contents of any given location as a status response.

2.3.4 Digital-to-Analog Converter (DAC) Banks

The Digital-to-Analog Converter (DAC) Banks provide conditioned levels for the actual clock and bias signals output by a given DEA board. Each level provided by the DAC is commandable by the instrument software.

2.3.5 DEA Housekeeping Information

Various subsections on a given DEA board provide housekeeping values. The instrument software can obtain a given value by commanding a board’s Housekeeping Multiplexer to convert and send a given analog signal in the form of a status response.

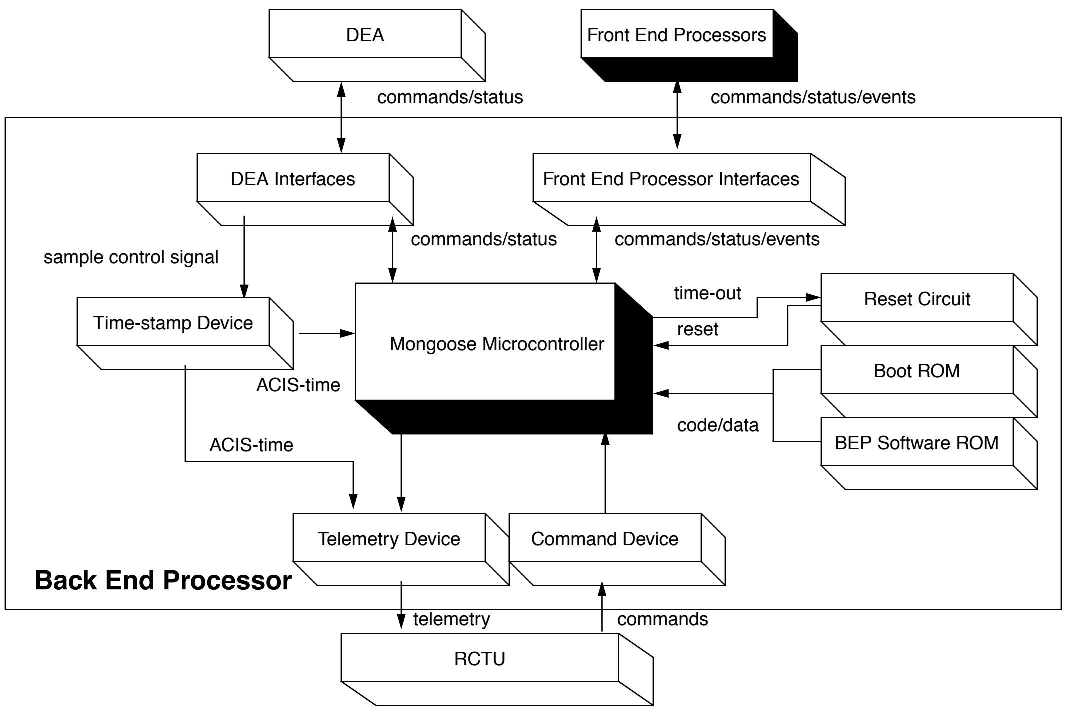
2.4 RCTU Description

The DPA communicates with the outside world via a Remote Command and Telemetry Unit (RCTU). The RCTU connects the DPA's Back End Processor to the spacecraft's Command and Telemetry Unit, which in-turn, communicates with the ground and the spacecraft's On-Board Computer (OBC). The software executing in the Back End Processor receives commands via one of the RCTU's Serial Command Ports, and sends Science Data Telemetry via one of the RCTU's Serial Telemetry Ports. The science telemetry data appears in the "Science Data" portion of the ACIS telemetry stream. The Back End Processor can also control certain bits in the RCTU's discrete telemetry, which appear in the "Engineering" portion of the ACIS telemetry stream.

2.5 Back End Processor Description

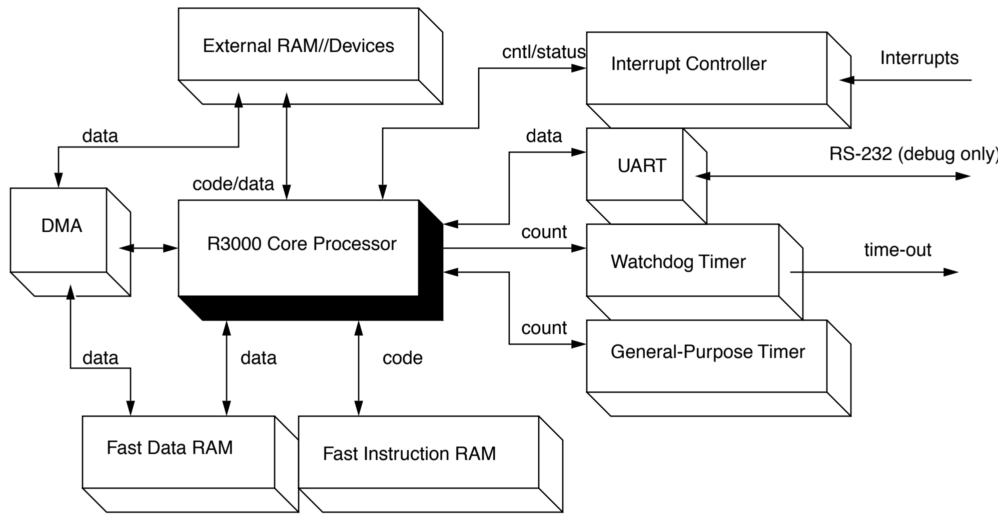
This section provides a brief description of the Digital Processor Assembly's Back End Processor. For a more detailed description, refer to the "DPA Hardware Specification and System Description" (MIT 36-02104). Figure 9 illustrates the major components within the ACIS Back End Processor. Although there are physically two Back End Processors on ACIS, only one of them is active at any time. The ground switches between the two using a discrete command to the hardware. The ACIS software has no built-in knowledge of this redundancy.

FIGURE 9. Back End Processor Overview



The Mongoose Microcontroller consists of a core R3000 processor, a reduced R3000 System Co-processor, and a set of internal devices to assist hardware designers. The System Co-processor is functionally equivalent to a standard R3000, except it does not support address translation (via the Translation Look-aside Buffer), nor does it support a processor version register. Figure 10 illustrates the additional components within, or associated with, the Mongoose.

FIGURE 10. Mongoose Component Overview

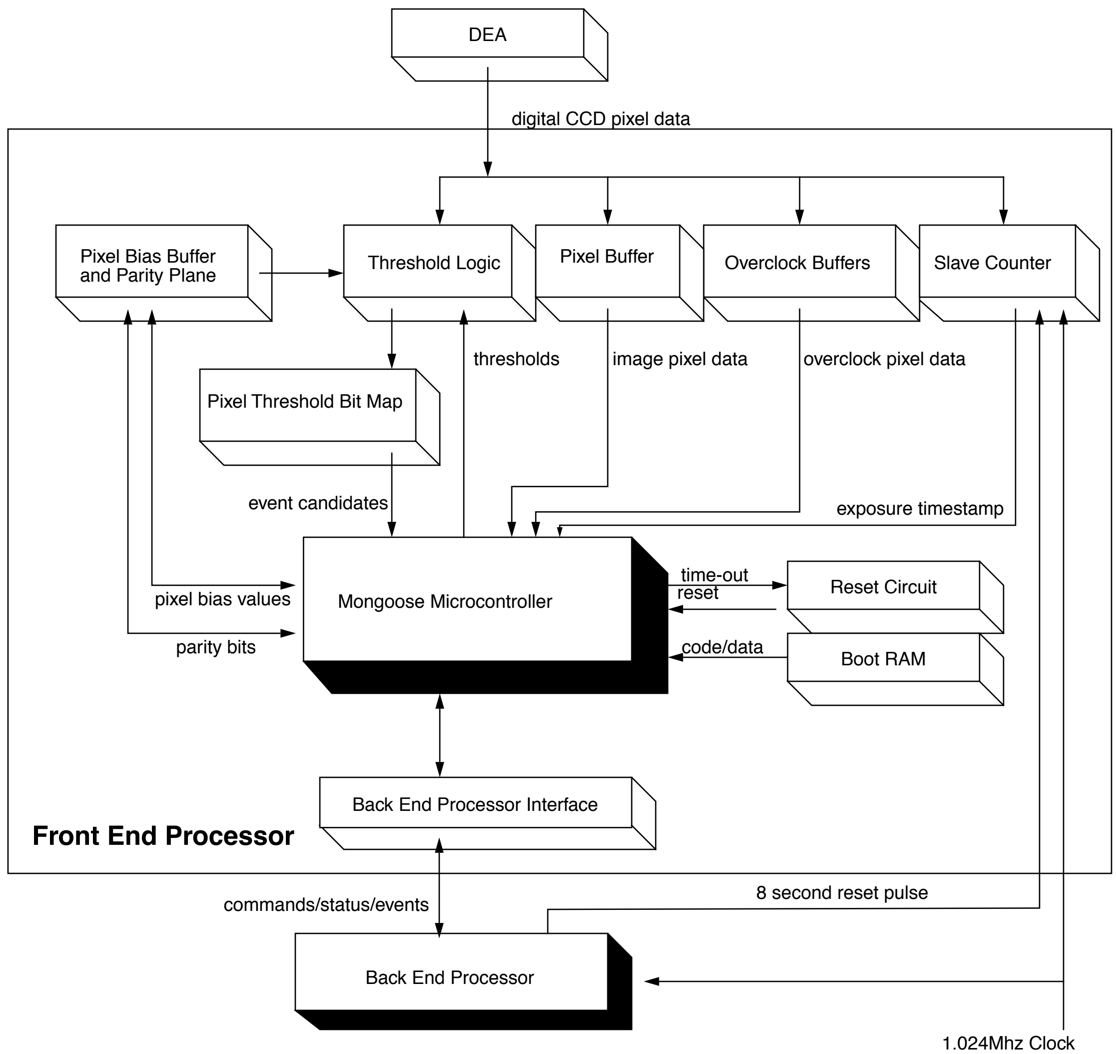


The Mongoose Microcontroller consists of a core MIPS R3000 processor and an on-board DMA controller, external interrupt interface, UART, Watchdog Timer and General Purpose Timer. The chip also has built-in external memory and device interface logic. Rather than providing a Translation-Look-Aside-Buffer (TLB), the Mongoose virtual addresses have fixed relationships to physical memory and memory-mapped devices. The Mongoose does not use tagged-cache, but rather maps the R3000 cache addresses to fixed fast instruction and data RAM locations.The instruction RAM and data RAM are distinct in that the instruction RAM (I-cache) is readable and writable as data only via an interface port, and instructions cannot be executed from data RAM (D-cache). External memory, however, can be read from and written to as data, and can also contain executable code.

2.6 Front End Processor and Hardware Description

This section provides a brief description of the Digital Processor Assembly's Front End Processors. For a more detailed description, refer to the "DPA Hardware Specification and System Description" (MIT 36-02104). Figure 11 illustrates the major interfaces to the DPA's Front End Processors. Refer to Figure 10, "Mongoose Component Overview," on page 30 for the components surrounding the Mongoose Microcontroller.

FIGURE 11. Front End Processor Overview



The Front End Processor is responsible for processing raw digital CCD pixel data from the Detector Electronics Assembly and producing events. It transfers the extracted event information to the Back End Processor for further selection and processing.

The Boot RAM, Scratch RAM (not shown), Pixel Bias Buffer, Pixel Buffer and Overclock Buffers are all memory-mapped into the Back End Processor's address space using a shared-memory interface (not shown).

3.0 Requirements

3.1 External Interface Requirements

3.1.1 User Interfaces

The ACIS Science Instrument has no direct in-flight human user interfaces. All human interaction with ACIS is managed by the AXAF Science Center (ASC) and the Operations Control Center (OCC).

3.1.2 Hardware Interfaces

The detailed ACIS hardware to software interfaces are described in the Digital Processor Assembly (DPA) Hardware Specification and System Description. Figure 12 and Figure 13 illustrate the key interfaces to the DPA's software.

FIGURE 12. Back End Processor Software Context Diagram

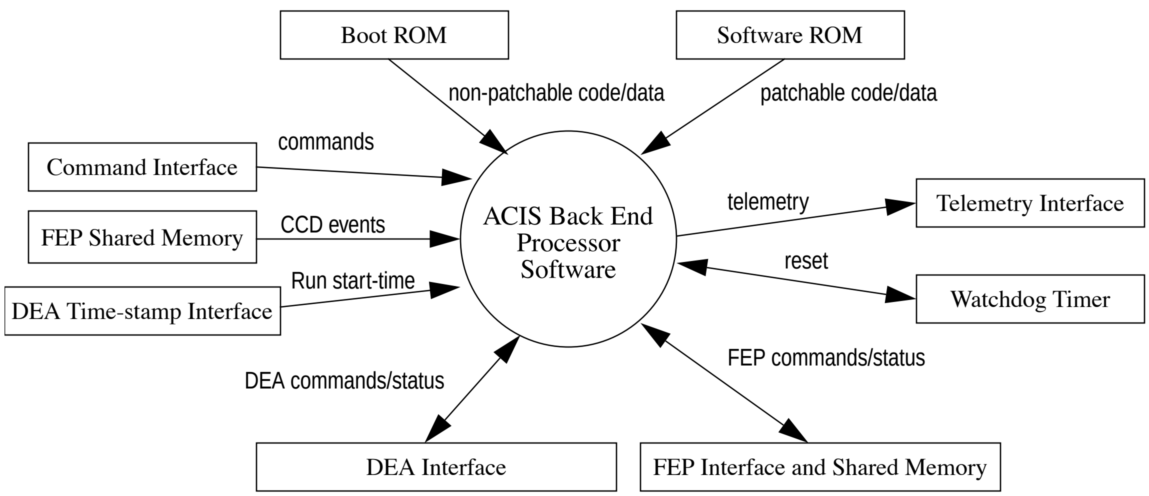
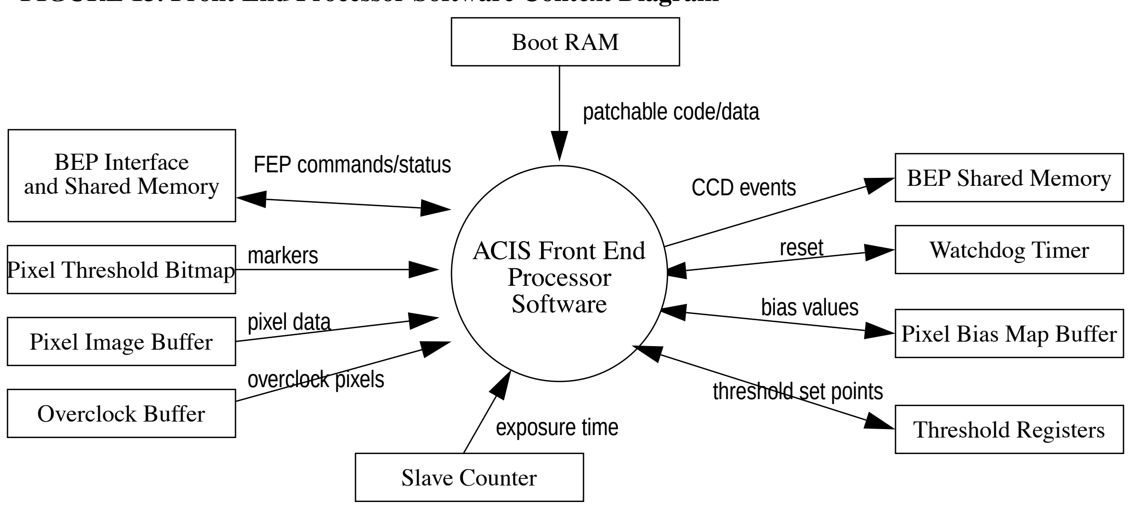


FIGURE 13. Front End Processor Software Context Diagram



3.1.3 External Software Interfaces

ACIS uses a commercial off-the-shelf real-time executive to perform task control functions and provide some resource management services. ACIS is using:

Nucleus RTX system, Product # NU920102, from Accelerated Technology, Inc.

The interface requirements for this product are defined by the Nucleus RTX Reference Manual, NU910701 and the Nucleus RTX Internals Manual, NU910702.

ACIS is planning on using the following capabilities of Nucleus RTX:

- Prioritized, preemptive task scheduler
- Inter-process queues
- Resource locks (semaphores)
- Memory partition management

A detailed list of each used function is provided in the ACIS SIS Detailed Design Specification.

3.1.4 Communications Interfaces

3.1.4.1 Serial Commands

Serial commands to ACIS shall be delivered via the RCTU's Serial Digital Command Channel. All ACIS Science Instrument Software commands are organized into command packets. Command packets consist of a series of 16-bit serial digital command words. Table 2 describes the overall command packet format:

TABLE 2. Serial Command Packet Format

Req	Word #	Field Name	Description
2-1	0	Packet Word Length	This describes the number of 16-bit words in the command packet, including this field. This field can range from 3 to 256.
2-2	1	Packet Identifier	This identifies the command packet in a sequence. This field can range from 0 to 65,535.
2-3	2	Command Opcode	This identifies the operation to be performed by ACIS. This field can contain up to 65,536 values, but only a small subset of possible values are recognized by the ACIS Science Instrument Software.
2-4	3..(Packet Word Length - 1)	Command Data	This area contains any data associated with the command

The information content of the Command Opcode and Command Data areas of a command packet are described later in this document as part of the system features. The exact bit-for-bit layout of this area will be defined later, during the design process, and will be provided as part of the Design Specifications and Operations Manual.

3.1.4.2 Discrete Commands and Flags

Discrete commands to ACIS Science Instrument Software shall be provided using ACIS hardware status registers. Table 3 lists these signals.

TABLE 3. Discrete Commands and Flags

Req	Name	Source	Description
3-1	Reset	Ground Command	This signal resets the ACIS Back End Processor. There is no explicit software monitoring of this signal. This signal will cause ACIS to begin executing its software contained in its Boot ROM.
3-2	Boot Modifier Flag	Ground Command	When asserted, this signal instructs the ACIS Boot ROM software to load code and data via the Serial Command Channel (Load from Uplink), and to execute the loaded code.
3-3	Science Header Synch	S/C Telemetry Clocks	This signal indicates the start of a Science Header Telemetry Frame.
3-4	Radiation Monitor Flag	S/C Radiation Monitor	This signal indicates that the S/C Radiation Monitor has detected a level greater than its current threshold.

3.1.4.3 Spacecraft Telemetry Formats

The AXAF-I telemetry definition consists of several formats. ACIS serial telemetry data appears in two of these formats. **Format 1** is normally used when HRC is the main observing instrument, and ACIS is “next-in-line.” In this configuration, ACIS telemetry is taken at 512bps and stored in the engineering sections of the Format 1 telemetry.

Format 2 is normally used when ACIS is the main observing instrument. In this configuration, ACIS serial telemetry is taken at 24Kbps and is stored in the Science Data portions of the Format 2 telemetry. Table 4 illustrates the overall layout of Format 2’s Science Frame, as described by the RCTU User’s Guide. Sixteen Science Frames make up a Telemetry Major Frame (not shown). The shaded areas contain data formatted and supplied by the ACIS Science Instrument Software, where each contiguous science data region in the Science Frame is numbered from 0 to 63.

TABLE 4. Science Frame - Format 2 (for reference only)

Frame						**Repeat 7 times**		
Minor Frame 0	CCSDS VCDU Header	Engineering	Science Hdr (Minor Frame 0 Only)	ACIS Time-stamp See Section 3.1.4.6	Science Data Section[0]	Engineering	Science Data Sec-tions [1..7]	Engineering
Bytes	6	26	24	4	68	32	96	1
Minor Frame 1	CCSDS VCDU Header	Engineering	Science Data Section [8]			Engineering	Science Data Sec-tions [9..15]	Engineering
Bytes	6	26	96			32	96	1
. . .	. . .							
Minor Frame 7	CCSDS VCDU Header	Engineering	Science Data Section [56]			Engineering	Science Data Sec-tions [57..63]	Engineering
Bytes	6	26	96			32	96	1

When created by the ACIS Science Instrument Software, the science data sections are treated as contiguous.

The spacecraft-generated "Science Hdr" portion of each Minor Frame 0 contains the time-code corresponding to the start of the Science Frame.

3.1.4.4 Serial Telemetry

ACIS outputs serial telemetry information using a DMA device connected to the RCTU's serial telemetry channel. ACIS serial telemetry shall be sent asynchronously to the telemetry frame clocks. When ACIS is the main observing instrument, the telemetry data are sent at a 24Kbps rate, and will appear in the Science Data sections of **Format 2**. When ACIS is "next-in-line", the telemetry data will normally be sent at 512bps and appear as part of **Format 1**'s Engineering Data.

The ACIS Science Instrument Software shall format its telemetry information into telemetry packets. Each telemetry packet will contain a series of 32-bit words. Although each packet is an integer number of 32-bit words, the hardware byte-aligns the words within the telemetry frame (i.e. a packet may start on a byte-boundary within a telemetry frame). Table 5 illustrates the overall format of ACIS telemetry packets.

TABLE 5. Serial Telemetry Packet Format

Req	Word #	Field Name	Description
5-1	Word 0	Start of ACIS Telemetry Packet Indicator	This item starts each packet and is used to locate packets within the Science Frame telemetry stream. This value must be different from any hardware generated or spacecraft generated fill patterns and unlikely to appear within the science data. The value of this field in hexadecimal is 0x0736f4166 ("soAf").
5-2	Word 1 Bits 0..9	Packet Data Count	This item describes the total number of 32-bit values contained in the packet, including the "Start of Packet indicator." The minimum length of an ACIS telemetry packet is 2 long words (8 bytes). The maximum length of an ACIS telemetry packet is 1023 long words (i.e. 4092 bytes).
5-3	Word 1 Bits 10..15	Format Tag	This item identifies the format of the data contained within the packet. This field supports up to 64 formats.
5-4	Word 1 Bits 16..31	Sequence Number	This field identifies the packet emitted by the ACIS Science Instrument Software. This field wraps once every 65,536 packets. When combined with the Science Frame time-stamp, this value uniquely identifies each telemetry packet produced by the ACIS Science Instrument Software.This field allows the ground to determine the number of ACIS packets lost due to a telemetry drop-out condition.
5-5	Words 2 - (Packet Data Count - 1)	Data	This area contains the bulk of the packet's data. The content and format of this data is identified by the Format Tag field described above.

The information content of the Format Tag and Data areas of a telemetry packet are described later in this document as part of the system features. The exact formats of these areas will be defined later, during the design process, and will be provided as part of the Design Specifications and Operations Manual. In general, these formats shall provide enough redundant information to allow data sets to be interpreted in situations where one or more previous data set(s) has been corrupted or lost.

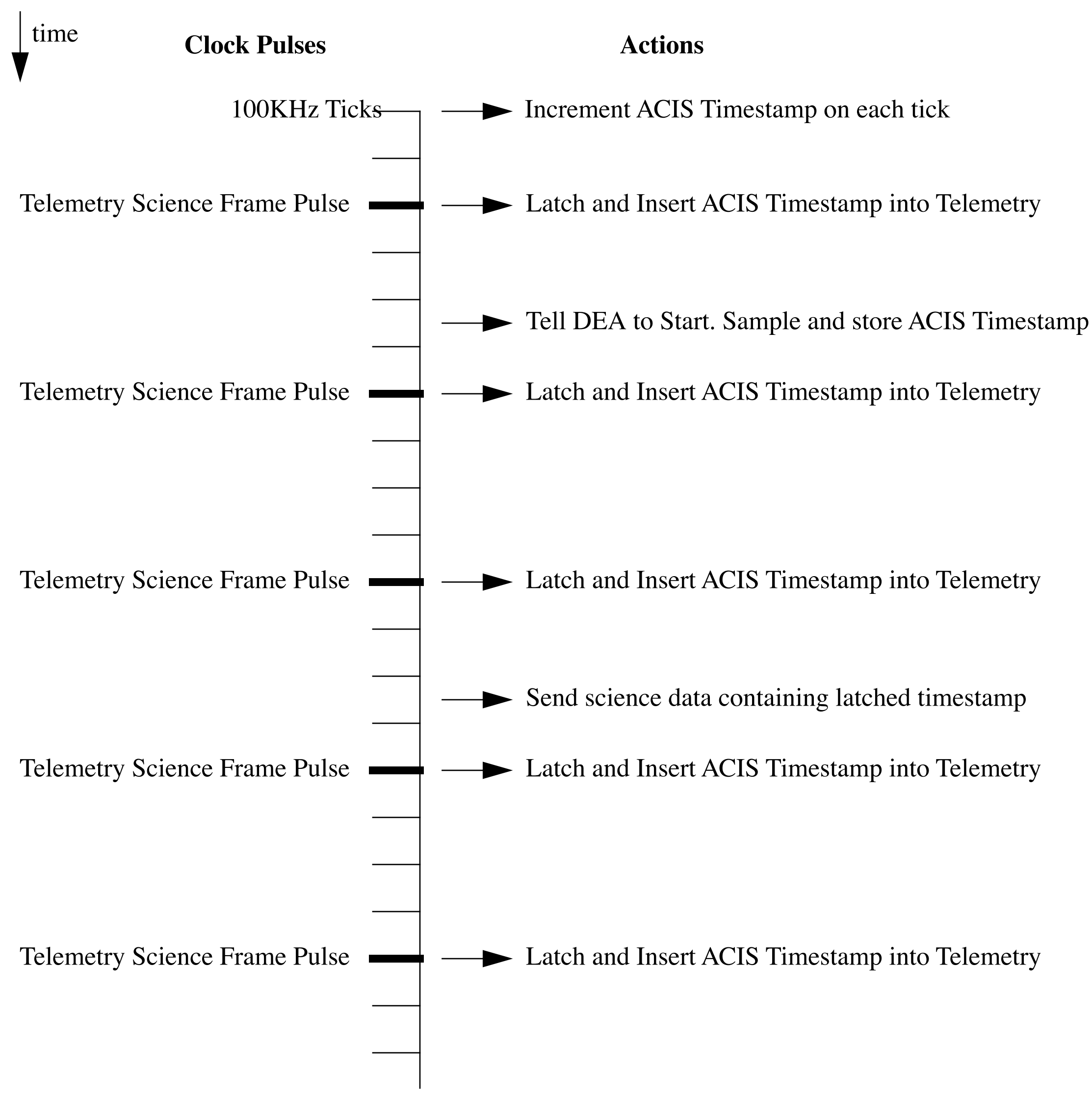
3.1.4.5 Discrete Telemetry

Discrete telemetry from ACIS Science Instrument Software shall be provided using 4 output bits, writable using an ACIS hardware register. These four signals will be sampled relative to each "Science Header Pulse" by the RCTU and included as part of the ACIS engineering telemetry stream.

3.1.4.6 ACIS Science Run Timestamps

"The first 32 bits of the Science Data written by ACIS into Section[0] of Minor Frame[0] (i.e. the first 32 bits following the receipt of the Science Frame Pulse) shall be the value of a timestamp counter specially sampled and inserted into the serial output stream by ACIS hardware. Its value represents the number of ACIS 100 KHz pixel clock cycles since it was last reset or wrapped. This counter will wrap about once per 12 hours. ACIS shall use this same counter to timestamp the start of its Science Runs (see Section 3.1.2 on page 32). This, coupled with the spacecraft supplied timestamp information in the Science Header of each frame, specifies the start time of a run (assuming that the spacecraft timestamp information can be related to universal time). All science data sent by ACIS will be indexed relative to the start of the run, using pixel-clock driven counters (such as exposure counts, or data set counts)."

FIGURE 14. ACIS Science Time-stamping Timeline



The ACIS timestamp inserted by the hardware into the telemetry stream relates the counter with the Science Frame. Given any Science Frame number produced within about 12 hours after the start of the science run (reference frame #), its corresponding ACIS inserted timestamp (reference timestamp) and the number of 100KHz ticks per Science Frame (ticks/frame), the Science Frame number corresponding to a given ACIS science data timestamp is as follows:

If the data timestamp is less than the reference timestamp:

Frame # = reference frame - (reference timestamp - data timestamp)/ticks per frame (EQ 1)

If the data timestamp is greater than the reference timestamp, then the 32-bit timestamp counter must have wrapped once since the data timestamp was sampled (assuming the reference frame is within an hour after the start time):

Frame # = reference frame - (2^{32} - (data timestamp - reference timestamp))/ticks per frame (EQ 2)

NOTE: If the first packet of a run takes longer than 12 hours to appear in telemetry, one must use more robust algorithm that relies on a-priori ground knowledge of the how the instrument has been run prior to the start of the current run).

The computed Frame Number is then used to identify which science header contains the S/C clock corresponding to the time during which the run was started (NOTE: Operations may instead choose to relate the Frame Number directly to Universal Time). Refer to Appendix D - for some guidelines on processing ACIS time-stamps.

3.2 System Features

This section defines the major features of the ACIS Science Instrument Software. Each feature is described in terms of its purpose and the scenario under which it operates. Following the scenario description is a list of detailed requirements concerning the feature.

The scenario descriptions make use of Sequence Diagrams and Data Flow diagrams. Sequence Diagrams script the scenario in terms of a time-line of messages being sent between participants in the scenario. Data Flow Diagrams provide an overview of information flow within the scenario.

The following roles are used to describe the various scenarios:

- Observer

  An "observer" acts as the person, organization, or process which determines the science operations of the instrument. In practice, an "observer" controls the instrument using the various AXAF-I mission planning and control resources, such as the AXAF Science Center, the Operations Control Center, the Deep Space Network, and the Spacecraft.

- Maintainer

  A "maintainer" acts as the person, organization, or process which determines the maintenance operations of the instrument, such as code patches, diagnostics, etc. Like an "observer", the "maintainer" controls the instrument using the various AXAF-I mission planning and control resources.

The command and telemetry description tables in this and subsequent sections define the minimum required information within the described command or telemetry packet. Unless otherwise specified, the tables do not mandate the order of the fields, nor the manner in which the information is represented within the implemented command and telemetry packet formats. The exact command and telemetry formats are described in the ACIS Instrument Program List (IP&CL) software structures definitions.

3.2.1 Configurable ACIS Science Run Execution

3.2.1.1 Purpose

This document defines the term "ACIS Science Run" as distinct from an "Observation." An Observation is the time during which the instrument is pointed at a specific target and data is being taken. An ACIS Science Run is a contiguous period of time during which ACIS is observing a source using a single set of parameters. During an Observation, ACIS may be commanded to start and stop its Science Runs for a variety of reasons, such as to switch configurations or avoid running the CCDs during periods of high radiation. Several Science Runs may be performed during a single Observation.

The mode of the run and the parameters to use for the run are defined using Science Mode parameter blocks. Since there are several types of Science Modes, each with their own sets of parameters, commands and telemetry formats, this section provides simple definitions of these items. Subsequent sections will refine these definitions in the context of the particular mode being defined.

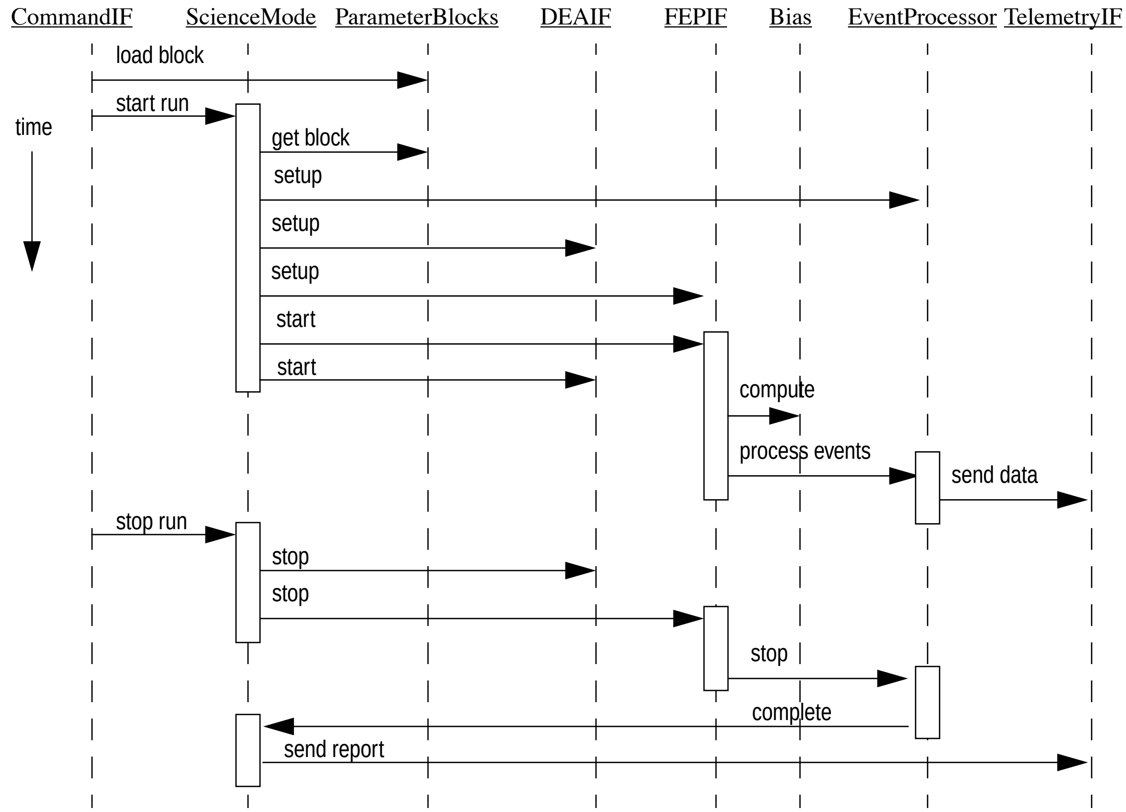
3.2.1.2 Scenario

To perform a Science Run, an observer commands ACIS to accept a set of parameters to use for the run and then instructs ACIS to execute the run. The parameters and commands define the science mode and options to use for the run. ACIS then sets up the hardware and software elements needed for the run, dumps the parameter blocks into the telemetry stream, optionally computes the pixel-by-pixel CCD bias levels or re-uses previous bias levels from the most recently computed set, and proceeds to acquire, process and telemeter event data from the selected CCDs. Aside from custom PRAM/SRAM loads, all CCDs are clocked synchronously, with the exception that parallel transfers (image to frame or frame to output register transfers) may be performed one CCD at a time (staggered) for power reasons. The observer allows ACIS to continue its data acquisition for the desired period of time and then commands ACIS to terminate the run.

Figure 15 illustrates this scenario in the form of an sequence diagram, whereas Figure 16 shows the same concept using a data flow diagram.

If, during a run, the radiation monitor signal is asserted, the instrument aborts the active science run, and disables power to the DEA's CCD-controllers. In this case, the data from the last exposure of the aborted run may be incomplete. Once the radiation subsides, power is restored to the CCD-controllers, the bias maps are recomputed and the run is resumed. The radiation monitor requirements are defined in more detail in Section 3.2.14 on page 132.

FIGURE 15. Science Run Sequence Diagram



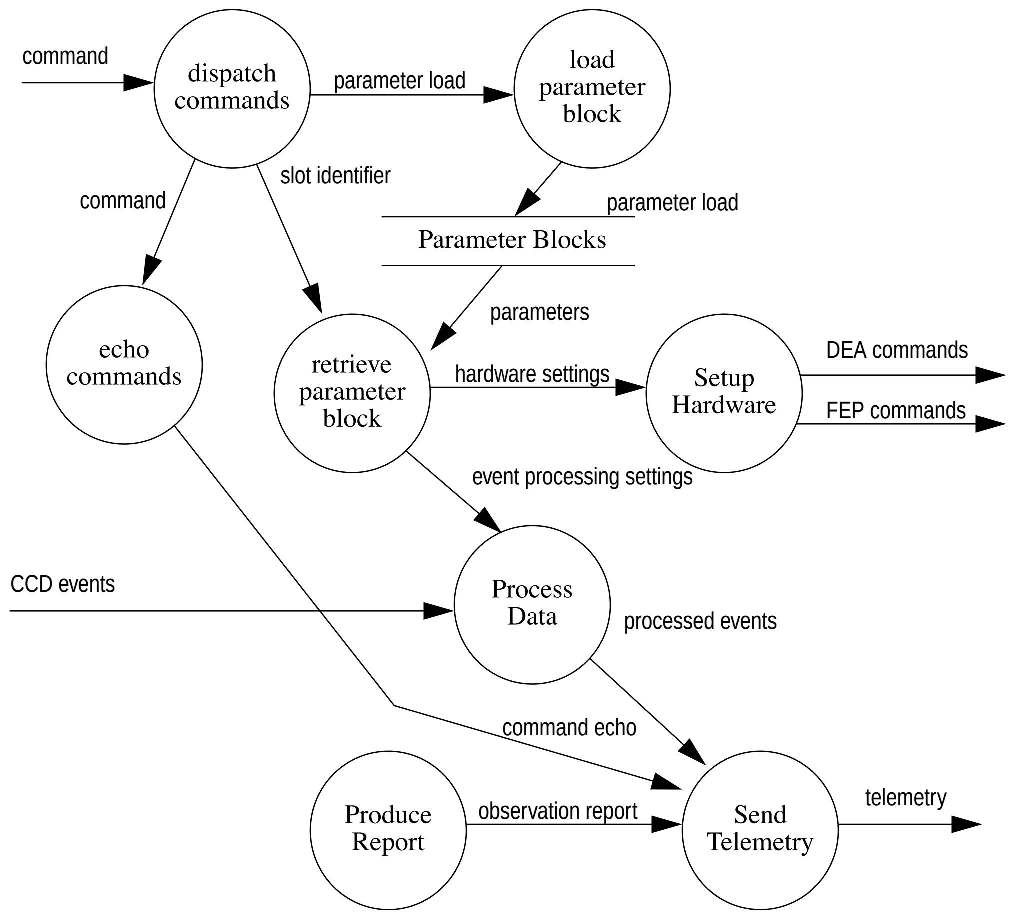
Upon receipt of a "Load Parameter Block" command, the Command Interface (CommandIF) dispatches the command to copy the specified parameter block into a parameter block slot.

When it receives an "Execute Science Run" command, the Command Interface dispatches the command to a Science Mode (ScienceMode). The Science Mode then retrieves the parameter block specified in the command. The Science Mode then configures an Event Processor (EventProcessor) to prepare for events, tells the Detector Electronics Assembly interface (DEAIF) to setup the DEA hardware and PRAM/SRAM sequencer, and instructs the Back End's Front End Processor interface (FEPIF) to load code and parameters into the Front End Processors. The mode then dumps the parameter blocks into the telemetry stream (not shown) and instructs the Front End Processors to start executing. Finally, the Science Mode instructs the DEA Interface to start clocking the CCDs, discarding the initial charge image built up over time within the CCDs.

As the DEA clocks the CCDs, pixel data is produced and forwarded to the Front End Processors (not shown). If a bias computation is needed, the Front End Processors then proceed to use the incoming data from multiple exposures to compute the bias level (i.e. estimate the "zero" level) for each pixel in their respective CCDs. Once the bias has been computed, the Front End Processors enter their main event processing code. This code selects events from the incoming pixel data and forwards the event data to the Back End Processor via the BEP's Front End Processor interface (FEPIF). The Front End Processor interface then instructs the Event Processor to process the events. As the Event Processor selects, processes and formats the events for telemetry, it instructs the Telemetry interface (TelemetryIF) to send the packaged event data.

When the observer sends the command to terminate the Science Run, the Command Interface instructs the running Science Mode to stop the run. The Science Mode, in turn, instructs the DEA interface and Front End Processor interface to stop clocking the CCDs and stop producing events. When the Back End's Front End Processor interface receives an indication from the Front End Processor that the data is complete, it tells the Event Processor to stop. The Event Processor then completes its event processing, and tells the Science Mode that it has finished. The Science Mode then forms an Observation Report and tells the Telemetry interface to send the formed report.

FIGURE 16. Science Run Data Flow Diagram



3.2.1.3 Functional Requirements

3.2.1.3.1 Parameter Block Identifiers

All types of parameter blocks which are used to configure an ACIS Science Run shall contain a ground-assigned 32-bit identifier field. This field shall be echoed by the instrument software into key portions of the science telemetry.

3.2.1.3.2 Load Parameter Block Commands

The ACIS Science Instrument Software shall support commands to load different types of parameters blocks, which ACIS uses to control a Science Run. Table 6 describes the content of a “generic” load parameter block command. The content of each specific type of parameter block is Science Mode dependent and described in later System Features.

TABLE 6. Generic Load Parameter Block Command Packet

Req	Field Name	Description
6-1	Packet Word Length	This indicates the total number of 16-bit words in the command packet.
6-2	Packet Identifier	This identifies the command packet.
6-3	Command Opcode	“Load <type> Parameter Block” command opcode. This instructs the ACIS Science Instrument Software to store the “Parameter Block Data” contained within the packet.
6-4	Slot Id	This identifies the parameter block slot within ACIS to overwrite.
6-5	Block CRC or Checksum	This is used to check the load.
6-6	Parameter Block Data	The remainder of the packet contains the parameter block data.

Upon receiving a Load Parameter Block command, the ACIS Science Instrument Software shall store the contents of the parameter block in its memory into the slot specified by “Slot Id.”

3.2.1.3.3 Pre-loaded Parameter Blocks

ACIS shall be capable of storing a fixed number (at least 4) of Parameter Blocks. This allows the maintainer to build a library of commonly used Parameter Blocks (using a “Load Parameter Block Command”), thus reducing the number of commands required to configure the instrument.

NOTE: This feature is not a prerequisite on the ground systems for using ACIS. It is provided as an optional facility for medium to long-term storage of commonly used parameter blocks.

3.2.1.3.4 Launched Parameter Blocks

ACIS shall contain a set of (at least 4) Parameter Blocks in its software ROM for use during on-orbit checkout and commonly used observational modes.

3.2.1.3.5 Start Science Run Commands

ACIS shall accept and process “Start <Science Mode> Run” commands as described above. Table 7 describes the format for a generic “Start Science Run” command.

TABLE 7. Generic Start Science Run Command

Req	Field Name	Description
7-1	Packet Word Length	This indicates the total number of 16-bit words in the command packet
7-2	Packet Identifier	This identifies the command packet.
7-3	Command Opcode	“Start <Science Mode> Run” command opcode. This instructs the ACIS Science Instrument Software to retrieve the parameter block indicated by “Slot Id” below, and setup and run the requested Science Mode. ACIS will continue to run the mode until commanded to stop.
7-4	Slot Id	This identifies the <Science Mode> parameter block to use for the run. This block may have been loaded just prior to the Start Run command, or may be part of either the pre-loaded library, or one of the blocks provided at launch.

Refer to Section 3.3.6 for a description of the instrument behavior if the reference parameter block is invalid.

3.2.1.3.6 Stop Science Run Commands

ACIS shall accept and process “Stop Science Run” commands as described above. Table 8 describes the format for a “Stop Science Run” command.

TABLE 8. Generic Stop Science Run Command

Req	Field Name	Description
8-1	Packet Word Length	This indicates the total number of 16-bit words in the command packet
8-2	Packet Identifier	This identifies the command packet.
8-3	Command Opcode	“Stop Science Run” command opcode. This instructs the ACIS Science Instrument Software to stop the current science run.

3.2.1.3.7 Compute Bias Commands

ACIS shall accept and process “Compute <Science Mode> Bias” commands which instruct the software to compute and telemeter the CCD pixel bias values without entering its event processing code. These commands cause ACIS to configure and start a science run, as described above, but auto-terminate the run prior to processing the data. When the bias-only run terminates, it telemeters a “Science Report” record (see Section 3.2.1.3.12). Table 9 describes the format for a generic “Compute Bias” command.

TABLE 9. Generic Compute Bias Command

Req	Field Name	Description
9-1	Packet Word Length	This indicates the total number of 16-bit words in the command packet
9-2	Packet Identifier	This identifies the command packet.
9-3	Command Opcode	“Compute <Science Mode> Bias” command opcode. This instructs the ACIS Science Instrument Software to retrieve the parameter block indicated by “Slot Id” below, and setup and run the requested Science Mode to the point where the bias values have been computed. ACIS will automatically stop the run once the bias values have been computed.
9-4	Slot Id	This identifies the <Science Mode> parameter block to used for the bias run.

Refer to Section 3.3.6 for a description of the instrument behavior if the reference parameter block is invalid.

3.2.1.3.8 Parameter Dump Telemetry

ACIS shall dump all parameters prior to the start of a Science Run. Dumped parameter contents shall be embedded with the ACIS telemetry packet format. To ease ground processing of telemetry, if more than one parameter block is used to configure a run (such as a Timed Exposure Parameter Block plus its 2-D Window List), they may be concatenated into a single packet when dumped to telemetry.

3.2.1.3.9 Science Time-stamping

At the start of an ACIS science run or bias run, the software shall read the ACIS time-stamp latch after issuing the command to the DEA to start clocking the CCDs, and prior to issuing any subsequent commands to the DEA. This time-stamp, in conjunction with the time-stamps inserted into the telemetry frames after each Science Header (see Section 3.1.4.3 on page 34) relates the start of the CCD clocking to the spacecraft-generated timecode in each Science Header.

ACIS shall provide this “start of run time-stamp” for both the current run, and the most recent bias computation, with each science exposure or data set, and shall provide a counter with each exposure or data set. This counter, coupled with knowledge of the data set rate, and the time-delay between the issuance of the start command and the start of the first data set, indicates the time at which a data set was acquired (NOTE: The data set rate can be measured using the Front End Processor Slave counters, or derived from the parameters used for the run. The initial time-delay is a function of the clocking mode and the run’s parameters).

3.2.1.3.10 Science Data Telemetry

During a Science Run, the ACIS Science Instrument Software shall produce science data telemetry. Although the format of this telemetry is determined by the particular event processing being performed by the mode, key portions of such telemetry shall contain a code or time-stamp which uniquely identifies the ACIS Science Run.

In general, the science data telemetry for a given run contains the following kinds of packets:

- Science Data Packets - These packets contain the pixel or event data produced by an image or timeseries. Only pixels or events produced by a single CCD are placed into a given data packet. Zero or more data packets are produced for each CCD image. Since these types of packets produce the bulk of the instrument telemetry, a small amount of overhead (in addition to the standard telemetry packet header) is associated with each of these packets. This overhead usually just includes the identity of the CCD which produced the data, and a CCD/Image specific data packet counter.
- Science Exposure Record Packets - These packets are closely associated with a group of Science Data Packets from a given CCD. These types of packets contain image identification information, such as the image counter and science run timestamp, and image production information, such as the number of discarded events or overclock information.

3.2.1.3.11 Telemetry/Performance Saturation Behavior

ACIS software running in the Back End shall process all data generated by the Front Ends. If a Front End finds that it cannot process the incoming data fast enough, or that the Back End is unable to receive it, that Front End shall ensure that the current CCD frame is processed in its entirety and sent to the Back End, if necessary ignoring one or more subsequent image frames. This ensures delivery of complete CCD image frames, but with a dead-time equal to zero or more exposures between each complete exposure. No attempt will be made to synchronize dropped exposures between the Front Ends.

In order to maintain timing, and to track which exposures were discarded, each Front End shall increment its exposure counter when an image is generated by the Detector Electronics Assembly, whether or not that image is sent to the Back End. On the ground, discarded exposures will appear as gaps in the exposure numbers from a particular Front End. For example, if exposure number 1243 is accepted, the next exposure is dropped, and then the subsequent exposure is accepted, the ground would see exposure number 1243 followed by exposure number 1245.

3.2.1.3.12 Post-Science Run Reports

After being commanded to stop a Science Run, or after a Bias-Only run auto-terminates, the ACIS Science Instrument Software shall produce a report of the completed run. Science Run Reports shall contain at least the information described in Table 10. The exact content of a Science Run Report will be described in the ACIS Instrument Program List (IP&CL) software structures definitions.

TABLE 10. Science Run Report Information

Req	Field Name	Description
10-1	Packet Synch	This field marks the start of the ACIS packet within the telemetry stream.
10-2	Packet Word Length	This field indicates the number of 32-bit words in the packet.
10-3	Format Tag	This field indicates the type of data contained in the telemetry packet.
10-4	Packet Sequence Number	This field is used to sequentially number all ACIS telemetry packets.
10-5	Science Run Start Time	This contains the ACIS time-stamp sampled relative to the start of the Science Run. All data produced by the run is relatable to this time-stamp.
10-6	Parameter Block Identifier	This is a copy of a Parameter Block Identifier, contained within the parameter block used to configure the run.
10-7	Termination Reason	This field is used to indicate the reason for the termination of the run, such as a Stop Command, or a Radiation Monitor assertion.
10-8	Termination Time	This is the approximate time, in terms of Back End Processor timer ticks, when the run was ended.
10-9	Data Summary	This item provides some indication of how much information was produced by the run (such as number of exposures, events, etc.). The intent is to provide the observer with a confirmation that all of the run's data has been received.
10-10	Discrepancy Summary	This item provides summary information of any Front End Processor crashes or protocol errors, DEA sequencer errors, and a total count of pixel bias map parity errors uncovered during or after the run.

3.2.2 Timed Exposure Science Mode

3.2.2.1 Purpose

An observer uses Timed Exposure Science Mode to acquire, process and telemeter two dimensional images from the CCD array. An observer uses a Timed Exposure Parameter Block to configure Timed Exposure Science Mode, and “Start Timed Exposure Run” and “Stop Timed Exposure Run” commands to start and stop the run.

3.2.2.2 Scenario

To execute a Timed Exposure Science Run, an observer sends a “Start Timed-Exposure” command to ACIS. ACIS retrieves the parameter block referenced by the start command, dumps the parameter block(s), and proceeds to execute the science run, optionally computing the CCD bias values, and then processing the event data. As the event data is being processed and telemetered, ACIS will optionally compress and trickle the computed bias values into the telemetry stream. The observer allows ACIS to acquire, process and telemeter CCD data for a period of time, after which the observer sends a “Stop Timed-Exposure” command to ACIS. ACIS then stops the run and telemeters a Science Run Report. Optionally, the observer may then decide to recompute the bias values and send a “Compute Timed-Exposure Bias” command. ACIS will then re-compute and telemeter the bias values and then stop.

If the observer requires parameters not already provided by the ACIS parameter library, the observer must issue a “Load Timed-Exposure Parameter Block” command to load the desired parameters for the run. If the loaded parameter block requires custom event processing windows, the observer must also issue a “Load 2-D Window List” command to place the desired window settings into the instrument.

Figure 17 illustrates the interactions involved to configure and start a Timed Exposure Science Run. Figure 18 illustrates some of the Front End processor interactions during the run and Figure 19 illustrates what the Back End processor does with the generated data. Whether or not the Bad Pixel and Column Maps are applied by the Front End or Back End Processors is left for the design phase, and is not shown in the diagrams. See Section 3.2.2.3.13 on page 64 for the detailed requirements of the functionality of the Bad Pixel and Column Map applications.

FIGURE 17. Timed Exposure Setup and Start Sequence Diagram

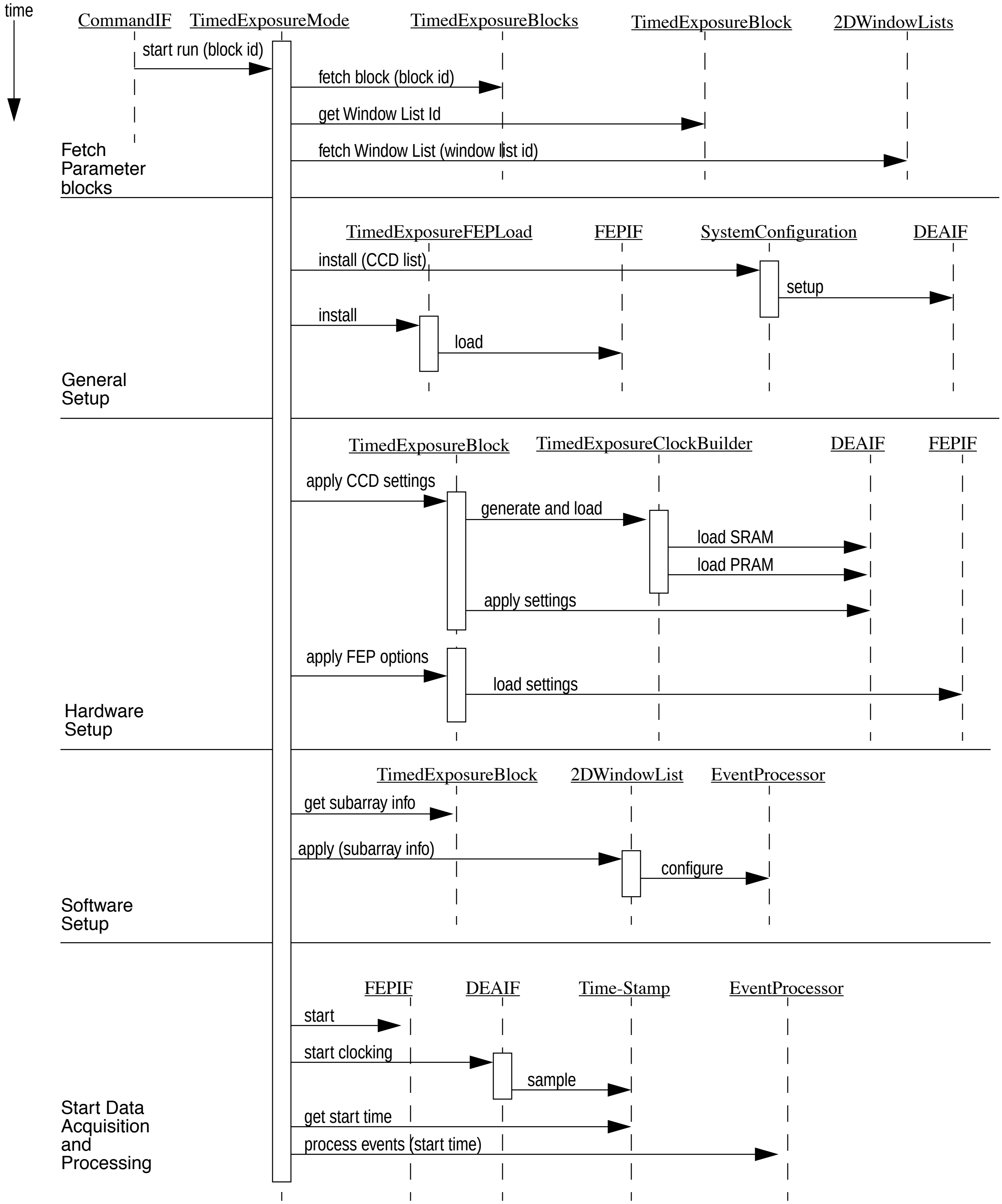


FIGURE 18. Timed Exposure Front End Processor Sequence Diagram

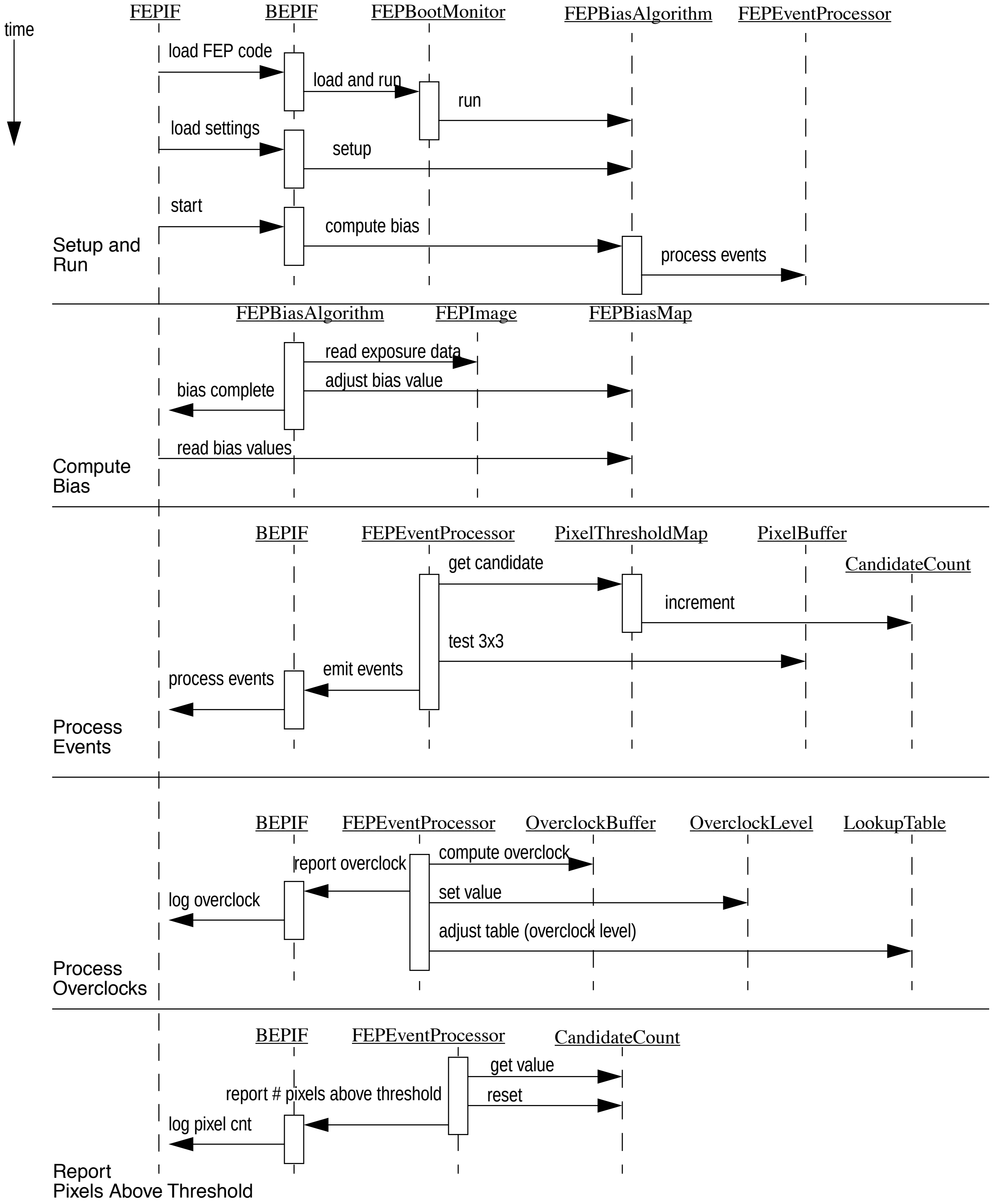


FIGURE 19. Timed Exposure Back End Event Processing Sequence Diagram

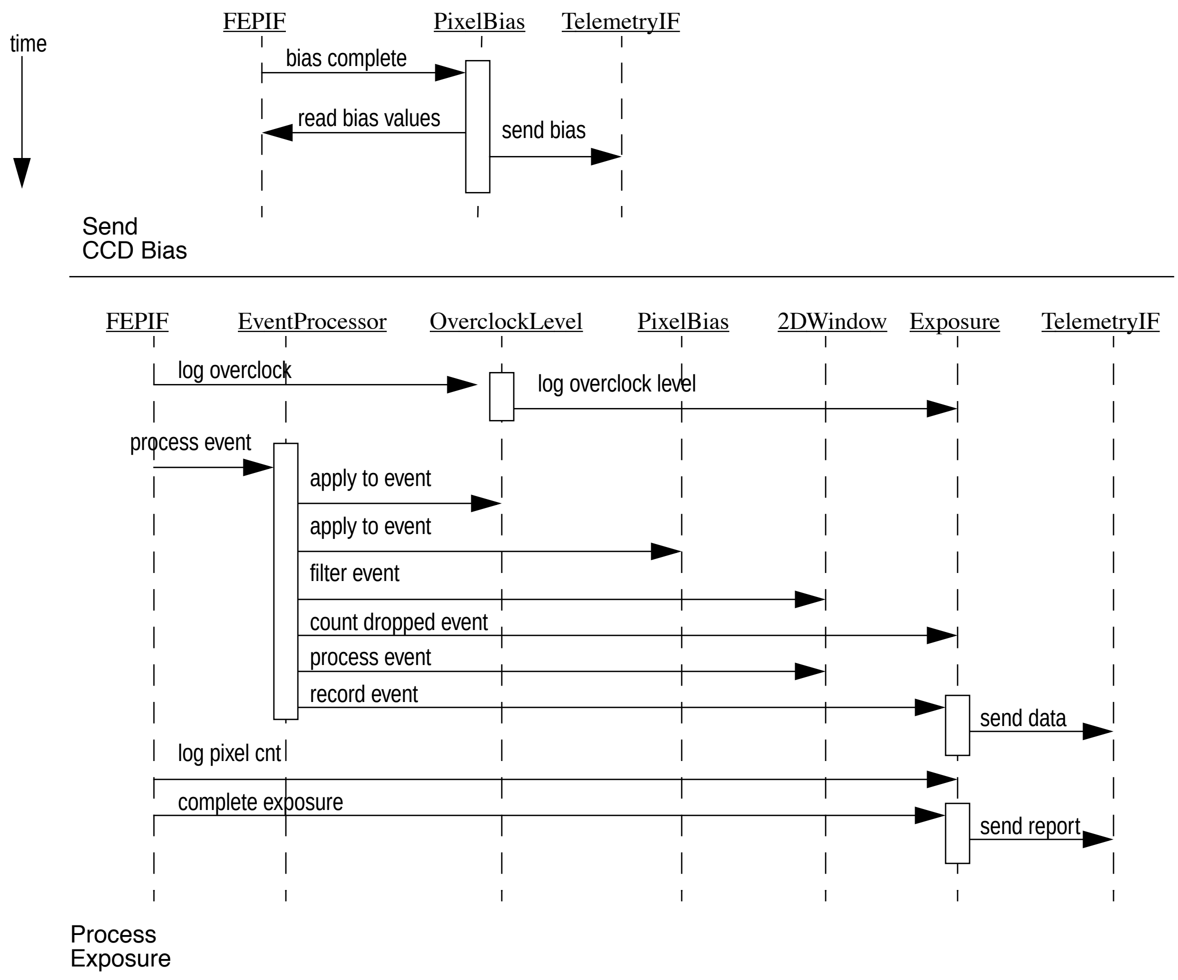
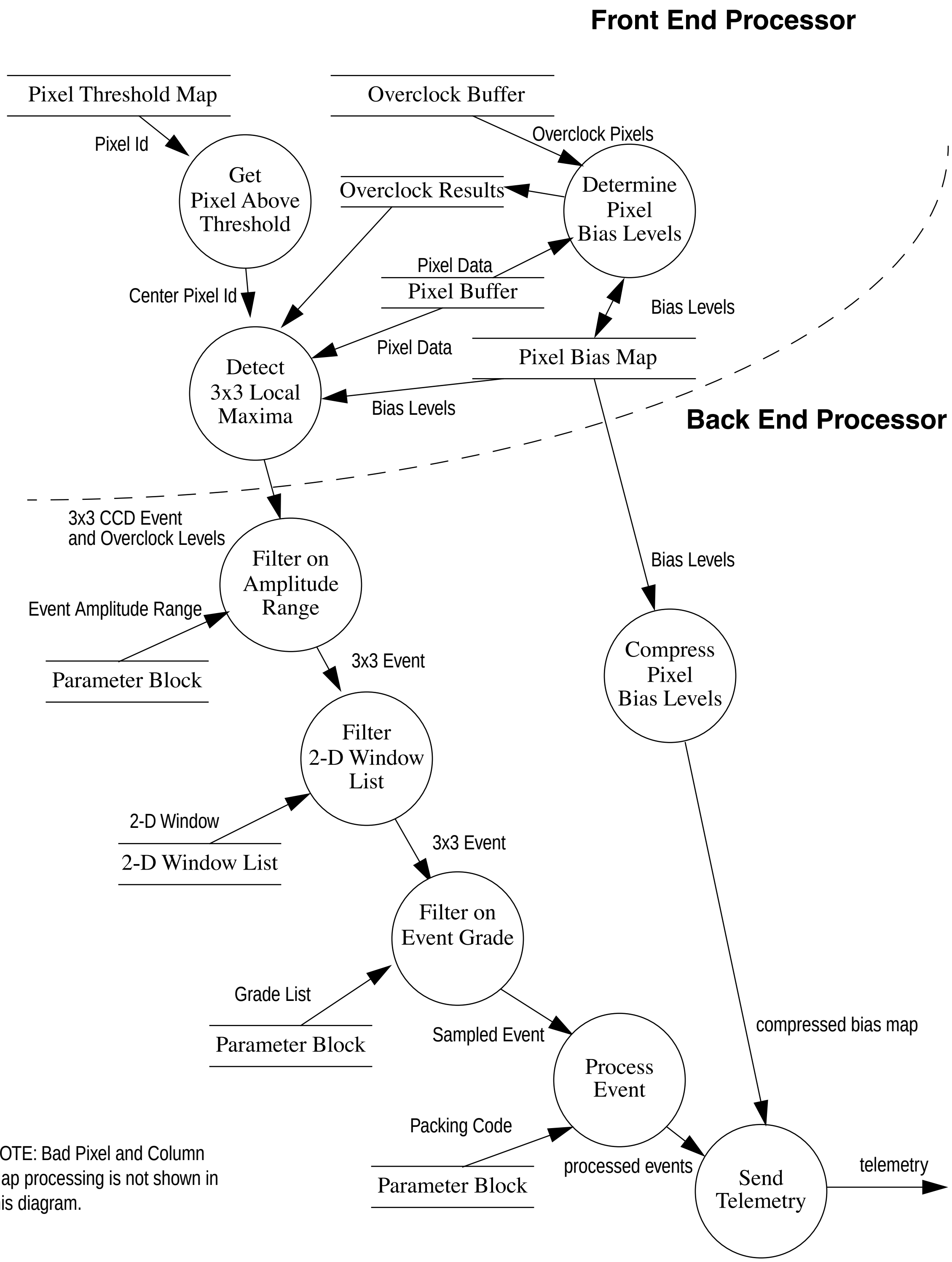


FIGURE 20. Timed Exposure Pixel Processing Data Flow



NOTE: Bad Pixel and Column Map processing is not shown in this diagram.

3.2.2.3 Functional Requirements

3.2.2.3.1 Timed Exposure Parameter Block Content

An observer configures Timed Exposure Mode using a Timed Exposure Mode Parameter Block. Table 11 describes the content of a Timed Exposure Parameter Block.

TABLE 11. Timed Exposure Parameter Block Content

Req	Item	Description
11-1	Parameter Block Identifier	This item is a ground-supplied identifier which is echoed by the instrument software in key portions of the science telemetry.
11-2	FEP CCD Selection	These items specify which CCD a given FEP should process. The items are indexed by FEP Id. Any given CCD may be specified more than once in the set, at the cost of reducing the total number of CCDs being used. CCDs or FEPs which are not powered on (see Section 3.2.7 on page 99) are ignored and will not be used for the run. If there are no powered CCD being processed by a powered FEP, the science run will be aborted.
11-3	Subarray Readout Start Row and Row Count	An observer uses the start row and row count values to effectively shorten the time it takes to transfer an image from the CCDs to the Front End Processors by sacrificing some of the imaging area. The start row and row count specifies which contiguous horizontal swath of CCD rows are transferred from the Framestore back to the FEPs. These two parameters apply to all selected CCDs. The Start Row parameter can range from 0 to 1023, where 0 corresponds to image area row 2, 1 to image area row 3, and so on. (NOTE: Image area rows 0 and 1 are never used), and the Row Count parameter can range from 1 to 1024. If Start Row plus Row Count extends beyond the image area, the software truncates the subarray row count to fit.
11-4	Primary and Secondary Exposure Times	These items control the amount of time that the Image Area of each CCD is integrating data. This does not include the time taken to transfer the Image Area into the Framestore. These values can range from 0 to 10 seconds in 0.1 second increments, and apply to all of the selected CCDs. They are accurate to within one SRAM Major Cycle (~10μs). The CCDs are clocked using the primary exposure time for 1 exposure, followed by the secondary exposure time for "N" exposures. "N" is determined by the Exposure Duty Cycle parameter. If "N" is 0, the secondary exposure time is not used. If both exposure times are used, the bias computation algorithms only use data from exposures integrated over the Secondary Exposure time. NOTE: If Image Area to Framestore transfers need to be performed at different times on each CCD, and the specified exposure time is shorter than can be supported by the number of selected CCDs, the shortest possible exposure time will be used instead of the specified time (i.e. the Image to Frame transfer time multiplied by one less than the number of selected CCDs).

TABLE 11. Timed Exposure Parameter Block Content (Continued)

Req	Item	Description
11-5	Exposure Duty Cycle	This parameter controls how many secondary exposures separate primary exposures. If this parameter is 0, all exposures use the Primary Exposure Time (i.e. the Secondary Exposure Time is ignored). If 1, there is one Secondary Exposure between each Primary Exposure, if 2, there are two Secondaries for each Primary, and so on. This parameter can range from 0 to 15.
11-6	Output Register Clocking Mode	This item controls the clocking mode of all of the CCD's Serial Output Shift Registers. This item can specify either; Full-Mode, AC-Mode, BD-Mode or Diagnostic-Mode. See Section 2.2.2 on page 20 for a description of these modes.
11-7	Number of Over-clock Pairs	This item specifies the number of extra pixel pairs to clock out of each of the Serial Output Shift Registers. Timed Exposure Mode uses these pixels to determine the bias introduced to the CCDs pixel pulse height by the analog electronics. This item can specify 0 to 15 pairs of pixels.
11-8	Video Chain Responses	These items control the response of the Video Subsection in the Detector Electronics Assembly for each CCD. This item selects 1 or 4 electrons per Analog-to-Digital Unit (ADU). These items are indexed by FEP Id. If a single CCD is specified by more than 1 FEP entry, then the last corresponding chain response entry is used for the listed CCD.
11-9	On-chip Summing Select	This item controls whether or not 2x2 on-chip summing is performed. If disabled, no pixel summing is performed on the CCD. If this is enabled, then the charge from pairs of adjacent columns and rows are summed on the CCD. Each measured pixel output from the CCD is the sum of a 2x2 pixel array from the chip.
11-10	Reference to an explicit DEA Load	This is an optional item which allows a maintainer to by-pass the on-board SRAM/PRAM load builder, and load these areas directly. This reference points directly into BEP memory. If 0, then no explicit DEA load is to be used. If not 0, then the item points to the memory block which contains the load image to use. Post-launch DEA load images are uplinked into memory by the maintainer using the Write Memory function of the instrument (see Section 3.2.8.3.2 on page 108), or via a patch. This parameter is intended to be used by the maintainer of the instrument, and should be 0 during normal operations. The format of the referenced SRAM/PRAM load will be specified in the ACIS Instrument Software Detailed Design Specification (AS-BUILT), MIT 36-53200, and shall support different loads into different DEA boards.
11-11	Front End Selection Algorithm	This item specifies whether or not the Front End Processor should supply all pixels to the Back End (Raw Mode), compute histograms of raw pixel data (Histogram Mode), or supply pixels to the Back End whose center is above the current threshold (Event-finding Mode) and whose pulse height is greater (or sometimes equal) to its immediate neighbors (3x3 local maxima).
11-12	Threshold Set Points	These items control minimum pulse-height above or below bias a pixel should have to be considered as an event candidate by a given FEP. Each of these items applies to a specific CCD output node being processed by a FEP. These values can range from -4096 to 4095. These values are not used when the FEPs are processing raw pixels or histograms. One set of four values is specified for each FEP.

TABLE 11. Timed Exposure Parameter Block Content (Continued)

Req	Item	Description
11-13	Reference to Front End Processor Code	This value allows a maintainer to override the standard code and data loaded into the Front End Processor, and provide a special load for the Science Run. This reference points directly into BEP memory. If 0, then no explicit FEP load is to be used. If not 0, then the item points to the memory block which contains the load image to use. Post-launch FEP load images are uplinked into memory by the maintainer using the Write Memory function of the instrument (see Section 3.2.8.3.2 on page 108), or via a patch. This parameter is intended to be used by the maintainer of the instrument, and should be 0 during normal operations. The format of the referenced FEP Load image will be specified in the ACIS Instrument Software Detailed Design Specification (AS-BUILT), MIT 36-53200.
11-14	Event List Packing Code	This parameter is only used when the Front End Selection Algorithm is in "Event Finding Mode". This value is not used when the Front End is processing raw pixels or histograms. This value selects the format to use when sending processed events. Currently, the following event-list formats are supported; Faint-Mode, Faint-with-Bias, and Graded-Mode
11-15	Reference to a 2-D Window Collection	This parameter is only used when the Front End Selection Algorithm is in "Raw Mode" or "Event Finding Mode". This value is not used when the Front End is processing histograms. An observer uses this item to specify a set of 2-dimensional event selection and processing windows to use for the Science Run. If no windows are specified, Timed Exposure Mode shall process all events from the CCDs using the processing parameters specified in this block. See Table 13, "2-Dimensional Window List Parameter Block," on page 58.
11-16	Split Threshold Set Points	These parameters are only used when the Front End Selection Algorithm is in "Event Finding Mode". These values are not used when the Front End is processing raw pixels or histograms. These values specify the threshold above which a neighboring pixel's pulse height must be to be considered as part of an event. These values are used when grading events and computing the amplitude of an event. Each of these items applies to a specific CCD output node being processed from a particular FEP. These values can range from 0 to 4095, and each set is indexed by FEP Id.
11-17	Ignore Bad Pixel/ Column Map Flags	These parameters are only used when the Front End Selection Algorithm is in "Event Finding Mode". These values are not used when the Front End is processing raw pixels or histograms. These values control whether or not to discard events on the basis of the CCD's list of bad pixels and/or columns.
11-18	Grading Selection Bit Map	These parameters are only used when the Front End Selection Algorithm is in "Event Finding Mode". These values are not used when the Front End is processing raw pixels or histograms. This set of values select which event grades to accept. Accepted events whose grades are indicated in this list shall be telemetered. This bitmap consists of a 256 bits, where each bit corresponds to one of the possible grade codes.

TABLE 11. Timed Exposure Parameter Block Content (Continued)

Req	Item	Description
11-19	Event Amplitude Lower Bound and Range	These parameters are only used when the Front End Selection Algorithm is in "Event Finding Mode". These values are not used when the Front End is processing raw pixels or histograms. These parameters select the minimum and maximum amplitudes of accepted events. Events whose total amplitude (function of the 3x3 grid around the event) is less than the lower bound value, or greater than or equal to the lower bound plus range are not telemetered. These field's ranges are governed by the minimum and maximum corrected event amplitudes.
11-20	Re-compute Bias Flag	This item indicates if the software must re-compute the pixel bias values prior to starting data processing.
11-21	Trickle Bias Flag	This item indicates if the software must telemeter the current bias map to telemetry after it has been computed.
11-22	Bias Algorithm Mode	This specifies the type of bias computation to be performed. This field may indicate that the bias be computed using an algorithm which uses entire image frames for each of its iterations (faster, but less accurate) called "Whole Frame Mode", or uses an algorithm which incrementally operates on sections of the bias map (slower, but more accurate), called "Strip" Mode. The remaining bias parameters depend on the selected mode. There is one set of settings for each FEP, and each set is indexed by FEP Id.
11-23	Whole Frame: Conditioning Count	This specifies the number of conditioning exposures used to determine the minimum pixel bias value. This field can vary from 0 to 200 exposures.
11-24	Whole Frame: Approximation Count	This specifies the number of approximation exposures used to locate the actual bias value above the minimum value determined during the conditioning pass. This field can vary from 0 to 200 exposures.
11-25	Whole Frame: Low Pixel Rejection Threshold	This parameter is used to discover abnormally low pixel values after the conditioning process, and is used only if it's value is not zero. If a pixel's value is smaller than all but 1 of its adjacent neighbors by more than this value, it is replaced with the median value of its neighbors. This field's value can range from 0 to 4095.
11-26	Whole Frame: Event Rejection Threshold	During the approximation-to-the-mean phase, this parameter is used to discard pixel samples which potentially contain charge from an event or charged-particle. If a sample pixel's value exceeds the current bias estimate by more than this value, it and its immediate neighbors are not used to adjust the bias estimate. This field's value can range from 0 to 4095.
11-27	Whole Frame: Rejection Threshold for approximation-to-mean	This parameter is used when approximating the mean to prevent samples whose pulse heights are uncharacteristically high from affecting the mean estimate. Pixel samples whose pulse heights are larger than the current pulse height estimate by more than this amount are not included in the estimated mean. This field's value can range from 0 to 4095.
11-28	Strip Mode: Exposures Count	This specifies the total number exposures to use per strip of pixels. This field can vary from 0 to 40 exposures per strip.
11-29	Strip Mode: Mean/ Median Selection	This specifies whether to base the bias value on a truncated mean or median of the pixel samples.

TABLE 11. Timed Exposure Parameter Block Content (Continued)

Req	Item	Description
11-30	Strip Mode: Mean Sigma Rejection/ Median Index	When a mean algorithm is selected, pixel samples whose value is greater than this value multiplied by the RMS variance are not included in the final mean computation. The value can range from 0 to 5. When the median algorithm is selected, this parameters indexes the pulse height to use for the bias out of the sorted list. In this case, the field value can range from 0 to 4095.
11-31	Raw Histogram Exposure Count	This item specifies how many exposures to use when building histograms. This field can vary from 1 to 240,000 exposures.
11-32	Bias Compression Flag	This indicates whether or not to compress pixel bias map values prior to being telemetered.
11-33	Bias Compression Selections	If bias map compression is enabled, these items specify which compression table to use for a given FEP. These selections are indexed by FEP Id.
11-34	Raw Compression Flag	This indicates whether or not to compress raw pixel data values prior to being telemetered.
11-35	Raw Compression Selection	If raw pixel data compression is enabled, this item specifies which compression table to use for all FEPs.
11-36	Initial Frames to Ignore	This specifies the number of whole exposure frames that the FEP is to ignore at the start of a bias calibration that uses this parameter block. If this value is zero, each FEP will start processing all data pixels and overclocks received after the first vsync code. Science data processing, however, always ignores the first two whole exposures.

3.2.2.3.2 2-D Window Lists

Events produced by Timed Exposure Clocking have an originating position within the CCD's Imaging Section. Timed Exposure Mode has the capability to select and process events based on this position. This selection and processing is controlled using a 2-D Window Parameter Block. Table 12 illustrates the content within a single 2-D Window, and Table 13 illustrates the content of a list of 2-D Windows.

TABLE 12. 2-Dimensional Window Information

Req	Item	Description
12-1	CCD Identifier	This selects the CCD (out of all 10) to which the window applies.
12-2	Window Position	This specifies the window position in terms of the bottom-left pixel within the CCD's Imaging Section.
12-3	Window Width	This specifies the width of the window in terms of Imaging Section columns (1-1024).

TABLE 12. 2-Dimensional Window Information (Continued)

Req	Item	Description
12-4	Window Height	This specifies the height of the window in terms of Imaging Section rows (1-1024).
12-5	Sample Cycle	If processing event data, this specifies the sampling frequency of the window. If zero, no events are processed in the window. If one, then every event is processed, if 2, every other event is processed, if 3, every third, and so on. If processing raw pixel data, this specifies whether or not to send pixels who belong to the window. If zero, all pixels belonging to the window are discarded. If not zero, the pixels are telemetered.
12-6	Lower Event Amplitude and Range	When processing events, these items set the lower and upper event amplitude bounds used to select candidate events. Events whose amplitude is outside this range are rejected. When processing raw pixel data, this parameter is ignored.

TABLE 13. 2-Dimensional Window List Parameter Block

Req	Item	Description
13-1	Parameter Block Identifier	This item is a ground-supplied identifier which is echoed by the instrument software in key portions of the science telemetry.
13-2	Window Count	This item identifies the number of 2-D Windows contained in the Window List. This value can range from 0 to 36. This quantity may not actually be loaded nor telemetered, but may be calculated using the length of the enclosing command or telemetry packet.
13-3	Windows[Window Count]	This item is an array of 2-D windows. The content of these windows is described in Table 12. The number of windows in the array is determined by "Window Count."

3.2.2.3.3 Building of DEA PRAM and SRAM Loads

Due to the expected size of SRAM and PRAM loads (greater than 2Kbytes), the ACIS software shall be capable of building the SRAM and PRAM loads needed to perform a Timed Exposure Clocking Mode, as described in Section 2.2.3 on page 22.

The following itemizes the inputs needed by the builder:

- CCD Selections
- Exposure Times and Duty Cycle
- Subarray Readout Start and End Row
- Output Register Clocking Mode
- Number of Overclock pixels
- On-chip summing selection

- The video chain response selections for each CCD
- Optional DEA SRAM/PRAM load override

The output shall consist of a series of DEA SRAM and PRAM load commands to the DEA sequencer.

The CCD Selections specify which DEA boards need to be programmed. Since power constraints require the instrument to stagger large parallel clock transfers (such as Image Area to Framestore transfers), the builder uses knowledge of the total number of CCDs selected to prevent transfers on the different CCDs from overlapping.

The exposure times control the time between the clearing of a CCD's Imaging Section and the transfer of its rows to its Framestore, and the duty cycle controls number of iterations of each type of exposure time.

The subarray readout start and end rows control which contiguous rows of the CCD image to actually transfer out of the Serial Output Shift Registers to the DPA.

The On-chip summing selection controls how the Framestore is clocked into the Output Register and how each pixel is processed at the CCD output nodes.

The Output Register Clocking Mode specifies how to clock out the output registers.

The number of overclock pixels determines how many pixels to clock out of the output registers after each row of image data has been transferred.

The video chain response information controls how the pixel data is processed in the DEA's analog video processing section.

The optional DEA SRAM/PRAM load override instructs the builder to ignore all of the previous parameters and to load the explicitly specified SRAM and PRAM commands.

3.2.2.3.4 Normal Exposure CCD Clocking Operations

These operations address the condition where CCD's exposure time is longer than the time it takes to transfer the image from its Framestore to the DPA. In this mode, ACIS shall program the DEA's PRAM and SRAM to clock the CCDs in the following fashion:

1. Clear the Imaging Section, Framestore and Serial Output Shift Registers.

   This is accomplished by clocking the Imaging Section and Framestore Rows 1026 times, and then clocking all pixels out the output registers a number of times, discarding the output. For Full-Mode and Diagnostic-Mode, (256 + 4) pixels must be shifted out of the output registers in order to clear the registers once. In AC-Mode and BD-Mode, (512 + 8) pixels must be shifted. If overclocks are specified, clock and discard the output registers an additional number of times.

2. Expose the Imaging Section for the duration specified by "Exposure Time."

The exposure effectively starts after the last row of the Imaging section has been clocked into the Framestore, and before the output registers have been flushed. On the first exposure of the run, this can be accomplished by just waiting for the specified period of time. On subsequent exposures, however, this wait period is overlapped with the steps listed below. The effective “do-nothing” time is the exposure time minus the time it takes to copy the Imaging Section to the Framestore and to transfer the image to the DPA.

3. Transfer the Imaging Section to the Framestore.

   This is accomplished by clocking 1026 rows from the Imaging Section to the Framestore and from the Framestore into the output registers. This has the effect of summing any garbage data previously left in the Framestore into the output registers. This operation shall take no more than 60 msec. The goal is to perform this operation as quickly as the hardware allows.

4. Position start of subarray at row 0 of the Framestore.

   This is accomplished by clocking “Start Row+2” Framestore rows into the output register. This places the first subarray row into Framestore row 0. This also has the effect of summing all rows prior to the subarray with the contents of the output registers.

5. Clock out output registers and discard.

   This is accomplished by clocking the pixels out of the output registers and into the output nodes and discarding the data. For Full-Mode and Diagnostic-Mode, (256 + 4) pixels must be shifted out in order to clear the registers. In AC-Mode and BD-Mode, (512 + 8) pixels must be shifted. If overclocks are specified, clock and discard the output registers an additional number of times.

6. Clock desired number of image rows (i.e. “End Row - Start Row + 1”) to the DPA

   This is accomplished by clocking one row at a time from the Framestore to the output registers, and then clocking pixels from the output registers to the output nodes. As each pixel’s data arrives at the output node, it is sampled, and converted to a 12 bit digital representation, which is then transmitted to the DPA. If overclock data is needed, clock and sample the output registers an additional number of times. The readout of the Framestore shall take no longer than 6.5 seconds. The goal is to perform this operation as quickly as the hardware allows.

7. Repeat starting from step 2.

   NOTE: Rows after “End Row” in the Framestore are clocked and discarded as part of 3) and 5). As the Imaging Section is transferred into the Framestore, the rows left from the previous image are summed into the output registers. The summed rows are then discarded as part of 5).

3.2.2.3.5 Short Exposure CCD Clocking Operations

These operations apply when the configured CCD exposure time is less than the time it takes to transfer the image from the Framestore to the DPA (NOTE: This time depends on the subarray parameters). In general, the only difference between this situation and the “Normal Exposure CCD Clocking Operations” is that there is an extra “flush” of the

Imaging Section prior to the start of an exposure. In this mode, ACIS shall program the DEA's PRAM and SRAM to clock the CCDs in the following fashion:

1. Clear the Imaging Section, Framestore and Serial Output Shift Registers.

   This is accomplished by clocking the Imaging Section and Framestore Rows 1026 times, and then clocking out the output registers and discarding the output. For Full-Mode and Diagnostic-Mode, (256 + 4) pixels must be shifted out of the output registers in order to clear the registers. In AC-Mode and BD-Mode, (512 + 8) pixels must be shifted. If overclocks are specified, clock and discard the output registers an additional number of times.

2. Expose the Imaging Section for the duration specified by "Exposure Time."

   This is accomplished by waiting for the desired period of time. The exposure effectively starts after the last row of the Imaging Section has been clocked into the Framestore, and before the output registers have been flushed.

3. Transfer the Imaging Section to the Framestore.

   This is accomplished by clocking 1026 rows from the Imaging Section to the Framestore and from the Framestore into the output registers. This has the effect of summing any garbage data previously in the Framestore into the output registers. This operation shall take no more than 60 msec. The goal is to perform this operation as quickly as the hardware allows.

4. Position start of subarray at row 0 of the Framestore.

   This is accomplished by clocking "Start Row+2" Framestore rows into the output register. This places the first subarray row into Framestore row 0. This also has the effect of summing all rows prior to the subarray with the contents of the output registers.

5. Clock out output registers and discard.

   This is accomplished by clocking the pixels out of the output registers and into the output nodes and discarding the data. For Full-Mode and Diagnostic-Mode, (256 + 4) pixels must be shifted out in order to clear the registers. In AC-Mode and BD-Mode, (512 + 8) pixels must be shifted. If overclocks are specified, clock and discard the output registers an additional number of times.

6. Clock desired number of image rows (i.e. "End Row - Start Row + 1") to the DPA

   This is accomplished by clocking one row at a time from the Framestore to the output registers, and then clocking pixels from the output registers to the output nodes. As each pixel's data arrives at the output node, it is sampled, converted and transmitted to the DPA. If overclock data is needed, clock and sample the output registers an additional number of times. The readout of the Framestore shall take no longer than 6.5 seconds. The goal is to perform this operation as quickly as the hardware allows.

7. Clear the Imaging Section

   This is accomplished by clocking 1026 rows from the Imaging Section into the Framestore.

8. Repeat starting from step 2).

NOTE: Rows after “End Row” in the Framestore and the garbage transferred from the Imaging Section to the Framestore as part of 7) are clocked and discarded during 3) and 5).

3.2.2.3.6 Overclock Processing

If configured to do so, the Front End Processor software on ACIS shall be responsible for computing, reporting and using the overclock levels of its CCD. Overclock data is generated by clocking the Serial Output Shift Registers after all of a row’s pixel data has been clocked out. The clocking operation is under control of the SRAM and PRAM loaded into the DEA’s sequencers. As the overclock data arrives from the CCDs, the Front End hardware writes the selected overclock data to a set of special buffers.

The Front End Processor software then averages the data contained in these buffers to produce an output node-specific overclock level of the CCD. The average is rounded to the nearest integer value.

$$\text{Overclock Level} = \text{SUM(Overclock Data)} / \text{\# Overclock Elements} \qquad \text{(EQ 3)}$$

ACIS uses the resulting overclock levels to control the threshold values for the subsequent exposure(s). The overclock levels are also included with the event data telemetry.

The Front End Processor software shall re-compute and apply the overclock levels every exposure.

3.2.2.3.7 Pixel Bias Map Determination

The pixel-by-pixel bias map values are computed when configured by the parameter block, instructed by a “Compute Bias” command, or when the bias maps are invalid. Prior to processing events, the Front End Processor shall use one or more exposures to compute output node-specific “Initial Overclock” values, pixel-by-pixel bias levels and store the results in the Front End’s Pixel Bias Map.

$$\text{Pixel Bias Map Value} = \text{Computed Pixel Bias} + \text{Initial Overclock} \qquad \text{(EQ 4)}$$

NOTE: If the “Exposure Duty Cycle” parameter is not 0, then only exposures whose integration time corresponds to the “Secondary Exposure Time” parameter (see Table 11) are included in the bias computation.

The algorithm to use to compute the bias is determined by the “Bias Selection” parameter of the Timed Exposure Parameter Block. The chosen algorithm may be tuned using the “Bias Parameters” of the same block.

3.2.2.3.8 Threshold Determination

The Front End Processor software shall compute the output node-specific threshold register values according to the following formula:

Threshold Register Value = Threshold Set Point + (Overclock Level - Initial Overclock) (EQ 5)

The Front End Processor software shall set the threshold registers with the computed values prior to each exposure.

3.2.2.3.9 Pixel Threshold Processing

The Front End Processor contains a Pixel Threshold BitMap. This bit map indicates which pixels in the acquired CCD image have pulse heights greater than their respective output - node threshold registers plus their respective pixel bias map values. The bit corresponding to a pixel is set if:

Pixel Pulse Height > Pixel Bias Map Value + Threshold Register Value (EQ 6)

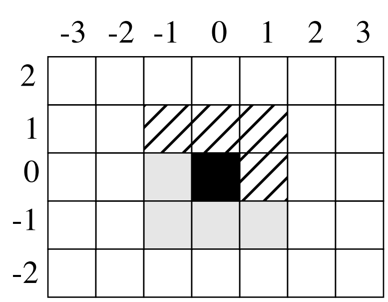
When the "Front End Selection Algorithm" field of the Timed Exposure Parameter Block indicates the Event-finding mode, the Front End Processor software shall scan this bitmap for each exposure. Any pixel marked as above its threshold shall be counted in an "above threshold" counter, and be tested as an event. This counter is telemetered with the event data. Refer to Section 3.2.2.3.10 for the requirements the Event-finding mode requirements.

The threshold map is ignored for all Front End Modes except "Event-finding Mode."

3.2.2.3.10 Front End Event-finding Mode

When the "Front End Selection Algorithm" field of the Timed Exposure Parameter Block indicates the Event-finding mode, the Front End processor selects events from candidates indicated by the hardware Pixel Threshold Map. If a pixel is indicated in this map, the Front End software compares the corrected pulse height (see Section 3.2.2.3.14 on page 65) of the pixel to the 8 surrounding pixels, as shown in Figure 21. In order to meet the criteria for an event, the center pixel (black square) must have a corrected pulse height greater than or equal to the previous row and the pixel immediately preceding it within its row (shaded squares), and must have a corrected pulse height greater than the pixels in the subsequent row, and the pixel immediately after it in its row (hatched squares).

FIGURE 21. 3x3 Event-finding Mode Pixel Diagram



If the pixels meet the criteria, the Front End processor forwards the 3x3 group of pixels to the Back End processor for further selection and processing.

Each Front End processor must be capable of testing at least 1000 candidate events per second. When put together, all 6 of the Front End processors must be capable of handling a total of at least 750 actual events per second.

3.2.2.3.11 Front End Raw Mode

When the “Front End Selection Algorithm” field of the Timed Exposure Parameter Block indicates “Raw Mode”, the Front End processor merely passes raw pixel data to the Back End Processor as it is poured into the Front End’s image buffer.

3.2.2.3.12 Front End Histogram Mode

When the “Front End Selection Algorithm” field of the Timed Exposure Parameter Block indicates “Histogram Mode”, the Front End processor forms one histogram for each active CCD output node (i.e. If “Output Register Clocking Mode” is Full-Mode or Diagnostic-Mode, four histograms are produced. In AC-Mode or BD-Mode, only two histograms are produced).

Each histogram contains 4096 bins, one bin for each raw pixel pulse height, where each bin is 32-bits wide. As raw pixel data is poured into the Front End’s image buffer, the Front End processor reads each acquired raw-pixel pulse height and increments the location indexed by pulse height value. It proceeds to do this for a user-selectable number of exposures (as specified in the “Histogram Parameters” field). Once the desired number of exposures have been processed, or if a “Stop Timed Exposure” command is received, the Front End processor stops processing, and forwards the histogram data to the Back End processor to be telemetered.

For each exposure added to the histogram, the Front End Processor shall compute the overclock values for the exposure, and maintain the minimum, maximum, mean and variance of the computed overclock values. Once the histograms are complete, the Front End processor shall forward the computed minimum, maximum, mean and variance values to the Back End processor, which includes the information in the telemetry stream.

NOTE: If the “Exposure Duty Cycle” is not zero, then only exposures whose integration time is defined by “Secondary Exposure Time” are accumulated into the histograms (see Table 11).

The Front End Processors shall be able to process all pixels from every other 2.65 second exposure. It is a goal to be able to keep up with each 2.65 second exposure.

3.2.2.3.13 Bad Pixel and Column Map Content and Application

The Back End Processor shall contain a list or bitmap of bad pixels and columns from each CCD. This Bad Pixel and Column Map is edited using maintenance commands from the ground (see Section 3.2.7 on page 99). The Bad Pixel and Column Map entries provide the information described in Table 14 and Table 15.

TABLE 14. Bad Pixel Entry Information

Req	Item	Description
14-1	CCD Id	The Bad Pixel Map must contain enough information to identify the CCD to which the bad pixel entry applies.
14-2	Pixel Row and Column Id	The Bad Pixel Map must contain enough information to identify which pixel in the CCD is bad.

TABLE 15. Bad Column Entry Information

Req	Item	Description
15-1	CCD Id	The Bad Column Map must contain enough information to identify the CCD to which the bad column applies.
15-2	Column Id	The Bad Column Map must contain enough information to identify which column in the CCD is bad.

When the “Front End Selection Algorithm” field of the Timed Exposure Parameter Block indicates the Event-finding mode, and the “Ignore Bad Pixel Map Flag” is de-asserted, the software shall test any events generated by the Front End to ensure that the center pixel of the 3x3 event is not listed in the Bad Pixel and Column Map. If the center pixel is in the list, no further processing on the event takes place. If the center of the event is not in the list, software accepts the event for further selection and processing.

Bad pixels or pixels belonging to a bad column which surround the center pixel of an event shall be treated as having a pulse-height of 0.

The Bad Pixel and Column maps are ignored for all Front End Modes except “Event-finding Mode.”

3.2.2.3.14 Pulse Height Bias Correction and Event Amplitude

To obtain the corrected pulse height of a pixel, the ACIS Science Instrument Software subtracts the corresponding output node overclock level, computed pixel bias value (i.e. the stored bias map value minus the global initial overclock) from its raw pulse height

Corrected Pixel PH = raw pixel ph - pixel bias map value - (overclock - initial overclock)   (EQ 7)

The amplitude of an event is the sum of the corrected pulse heights of the appropriate pixels in the group. The pixels whose pulse heights are to be included are shown in Figure 22, and are as follows:

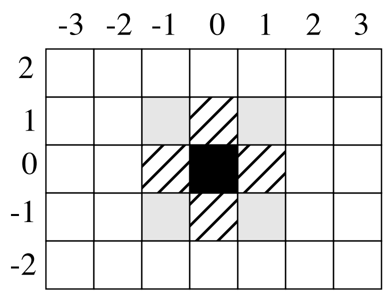
- Center Pixel (black square)
- Edge Pixels above Split Threshold (hatched squares)

These pixels are located to the top, bottom, left and right of the center pixel whose bias-corrected pulse height exceed the split threshold specified by the “Split Threshold Set Point” (see Table 11, “Timed Exposure Parameter Block Content,” on page 53).

- Corner Pixels (shaded squares) above Split Threshold and adjacent to included Edge Pixel(s)

  These pixels are located diagonally from the Center Pixel and have a corrected pulse height greater than the Split Threshold. These pixels must also be adjacent to one or more Edge Pixels whose pulse height(s) are above the Split Threshold.

FIGURE 22. Event Amplitude Pixel Diagram



3.2.2.3.15 Event Selection by Event Amplitude

When the “Front End Selection Algorithm” field of the Timed Exposure Parameter Block indicates the Event-finding mode, the Back End Processor shall compute the overall amplitude of 3x3 events received from the Front End, and compare the result with the “Event Amplitude Lower Bound and Range” specified in the Timed Exposure Parameter Block. If the value is less than the lower bound, or greater than or equal to the upper bound (lower bound plus range), the software shall increment a telemetered event amplitude rejection counter and discard the event. If the value is within range, the software shall accept the event for further selection and processing.

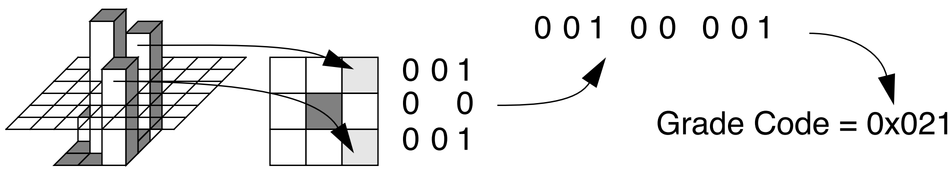
Event Amplitude selection only applies when the “Front End Selection Algorithm” field indicates “Event-finding Mode.”

3.2.2.3.16 Event Grade Computation

When needed for event selection or telemetry, the Back End software shall compute the “grade” of a 3x3 pixel event. To accomplish this, the software compares the corrected pulse heights of the 8 outer edge pixels of the event to the “Split Threshold” specified in the Timed Exposure Parameter Block. Each pixel corresponds to a “bit” in the grade code. If a pixel’s pulse height is greater than or equal to the threshold, the corresponding bit is marked as a ‘1’. If a pixel’s pulse height is less than the threshold, the bit is marked as a ‘0’. Since there are 8 pixels on the edge of a 3x3 event, this leads to an 8 bit grade code. There are 256 possible “grades” for a 3x3 event. The actual pixel position to grade code bit assignments will be defined in the design.

Figure 23 illustrates an example 3x3 event, with pixel pulse heights drawn as vertical bars, and the split threshold drawn as a grid. The pixels whose pulse height is above the threshold are shown to the right as lightly shaded areas. The since the center pixel does not contribute to the grade, it is shown using a darker shade. The diagram then shows the mapping of the pixels to grading bits, and from grading bits to the resulting Grade Code.

FIGURE 23. 3x3 Event Grading Illustration



3.2.2.3.17 Event Selection by Grade

When the "Front End Selection Algorithm" field of the Timed Exposure Parameter Block indicates the Event-finding mode, and the "Grading Selection Bitmap" does not indicate that all possible grades are to be accepted, the Back End software shall compute the grade of an event and compare the computed code to the list of desired grades. If the computed grade is not in the list, the grade discard counter is advanced and the event is ignored. If the event's grade is in the list, the event is accepted for further selection and processing.

Grade-based event selection only applies when the "Front End Selection Algorithm" field indicates "Event-finding Mode," and when the "Grading Selection Bitmap" indicates that only a subset of grades are to be processed (i.e. if all grades are accepted, no grade-based selection operation is performed).

3.2.2.3.18 2-D Window Event Processing

The Back End software shall use 2-D windows to select events and pixels to report. If an event's center pixel, or an individual pixel's position is within the bounds of a 2-D window, it is selected according to the window. For a given event or pixel, each window in the window list is checked in the order they are presented in the list. If the event/pixel position is within the boundaries of the window, the event/pixel is processed by the window. If the position is outside the bounds of the window, the next window is checked. This continues until the list is exhausted.

If no window list is specified, or if the event/pixel does not intersect with any of the configured windows, the event/pixel is, by default, accepted for processing. This behavior can be thought of as acting as a default window which encompasses the entire CCD and whose property is to accept all events/pixels.

The possible selection modes for the windows are as follows:

- Event/Pixel Sampling

The “Sample Cycle” argument (see Table 12, “2-Dimensional Window Information,” on page 57) reduces the telemetered event rate by specifying the number of events to discard before processing another event. When processing event data, a value of “0” corresponds to a clipping feature, causing the software to count and discard all events which fall within the bounds of the window. A value of “1” corresponds to accepting every event that belongs to the window. A value of “2” means to accept every other event, “3” to accept every third, and so on. When processing raw pixel data, a value of “0” causes the pixels intersecting the window to be dropped, and any other value causes the intersecting pixels to be telemetered.

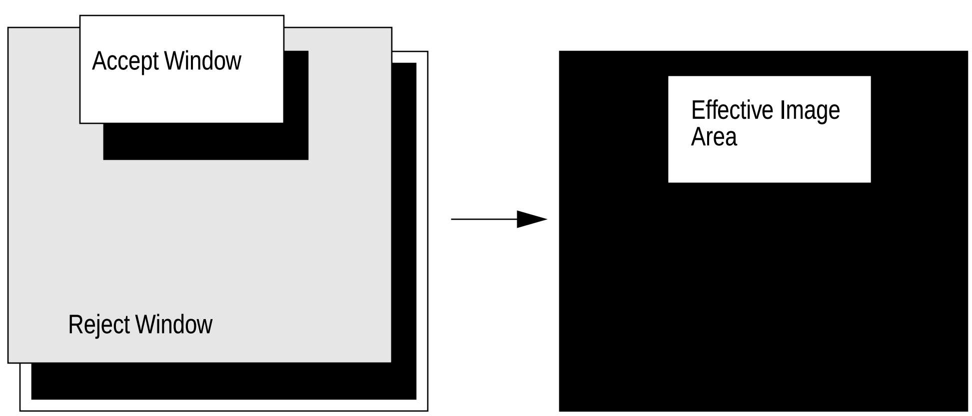
NOTE: The skip count extends across exposures, so it is possible to have some exposures with all of their events discarded.

- Localized Event Amplitude Filtering

  This window feature provides spatially selective filtering of events based on the event’s corrected amplitude. This feature provides useful background rejection when coupled with transmission gratings. This feature works as described by Section 3.2.2.3.15 on page 66 except that it applies window-specific event amplitude ranges. This feature only applies to event data and is not used when processing raw pixels.

For example, to accept only events which occur within a small region of a CCD, two windows are needed, as shown in Figure 24. The first window (white square) in the list specifies the region to accept, and has a processing mode which accepts all events. The second window (shaded square) encompasses the entire CCD, and has a processing mode which rejects all events. Events whose position intersects the smaller first window are accepted by the window. All remaining events will intersect only the second window, and are rejected.

FIGURE 24. Example Clipping Technique



Another example to perform the inverse of the previously described operation, as shown in Figure 25. Here, we want to reject events in the smaller window, and accept all other events. This scenario only requires a single window. This window identifies the region from which to reject events. Events which intersect this window are then rejected. All other events will be handled by the default CCD window, whose scope is the entire CCD, and whose property is to accept all events.

FIGURE 25. Example Inverse Clipping Technique

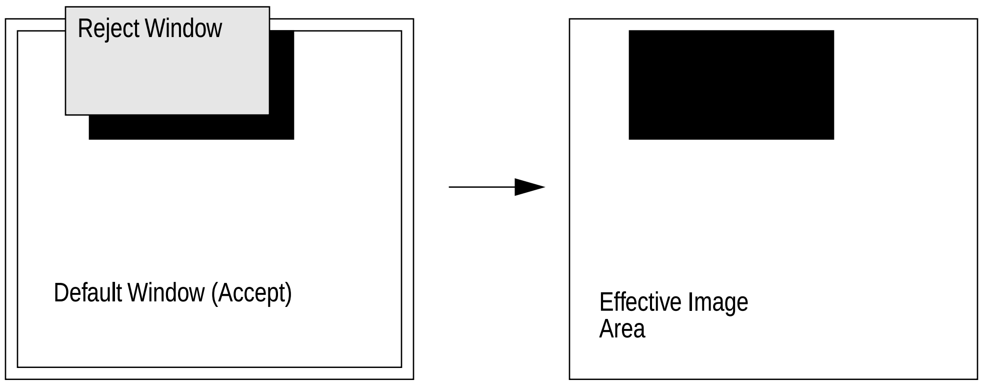
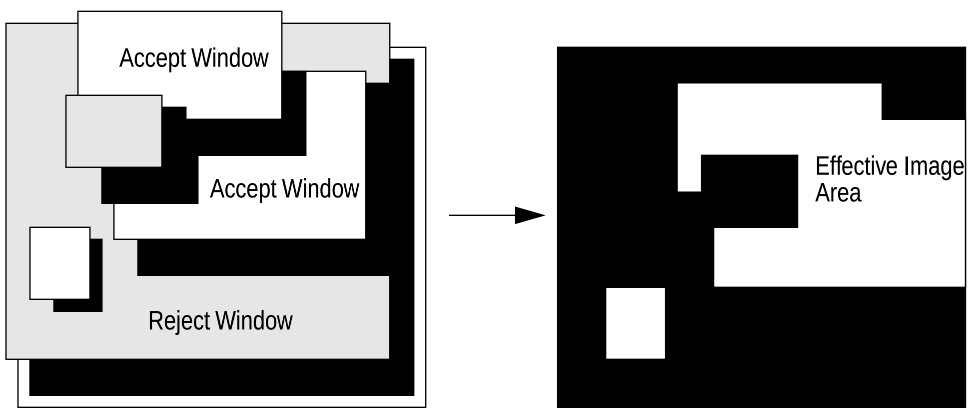


Figure 26 illustrates an fictitious layout which uses several windows.

FIGURE 26. Multiple Windows



3.2.2.3.19 Raw Mode Telemetry

The Back End software produces raw pixel telemetry when the “Front End Selection Algorithm” field of the Timed Exposure Parameter Block indicates a “Raw” mode. In this mode, contiguous regions of pixels are bit-packed into telemetry packets and telemetered as a set. For each CCD readout, zero or more Raw Mode Data Telemetry packets are produced, followed by one Raw Mode Exposure Record packet.

Table 20 describes the content of the CCD data telemetry when in this mode and Table 17 describes the exposure record telemetry.

TABLE 16. Raw Mode Data Telemetry Content

Req	Field	Description
16-1	Packet Synch	This field marks the start of the ACIS packet within the telemetry stream.
16-2	Packet Word Length	This field indicates the number of 32-bit words in the packet.
16-3	Format Tag	This field indicates the type of data contained in the telemetry packet, in this case a Timed Exposure Raw Mode data packet.
16-4	Packet Sequence Number	This field is used to sequentially number all ACIS telemetry packets.
16-5	CCD/FEP Identifiers	These identify which CCD and FEP produced the raw pixel data.
16-6	Data Packet Number	Since data from different CCDs can be interleaved, and also mixed with other kinds of packets, this field sequentially numbers the data packet for a given CCD exposure.
16-7	Compression Selection Flag and Table Selection	These fields indicate whether or not the raw data has been compress, and if so, by which compression table.
16-8	Pixel Position	This specifies the row and column of the first pixel in the packet in a collection of raw pixel data.
16-9	Packed or compressed collection of raw 12-bit CCD pixel and overclock data	This consists of an array of window-selected raw CCD pixel data. Pixels filtered out by the window processing are dropped. This forces the ground to use knowledge of the chosen 2-D windows to reconstruct the image. The packed pixels are output row by row, starting from the first row clocked out of the CCD, with the overclock data for a given row sent immediately after the pixel data for the row. Overclock pixels are always sent, even if the row is completely filtered out by the 2-D windows. Unused bits at the end of the telemetry packet (needed to fill out to the nearest 32-bit word boundary) will be zero.

TABLE 17. Raw Mode Exposure Record Telemetry

Req	Field	Description
17-1	Packet Synch	This field marks the start of the ACIS packet within the telemetry stream.
17-2	Packet Word Length	This field indicates the number of 32-bit words in the packet.
17-3	Format Tag	This field indicates the type of data contained in the telemetry packet, in this case, a Timed Exposure Raw Mode Exposure Record packet.
17-4	Packet Sequence Number	This field contains the packet sequence number.
17-5	Science Run Start Time	This identifies the start time of the science run using the ACIS timestamp latched by the hardware at the start of the run.
17-6	Timed Exposure Parameter Block Identifier	This item is a copy of the Timed Exposure Parameter Block Identifier used to configure the current run.

TABLE 17. Raw Mode Exposure Record Telemetry (Continued)

Req	Field	Description
17-7	Window Block Identifier	This item is a copy of the Window List Parameter Block Identifier used to configure the current run. If no Window List was specified, this field will be 0xffffffff.
17-8	CCD/FEP Identifiers	These identify which CCD and FEP produced the exposure.
17-9	FEP Timestamp	This is the value of the FEP time-stamp counter when the exposure arrived from the CCD.
17-10	Exposure Number	This uniquely identifies the clocked exposure during the run. This field must allow the ground to uniquely identify over 2.6 million exposures during a single run (0.1 second exposures for 72 hours).
17-11	Pixel Count	This specifies the total # of pixels sent for the exposure from the CCD.

3.2.2.3.20 Histogram Telemetry

The Back End software produces “Histogram Mode” telemetry when the Front End Processor is in “Histogram Mode,” as indicated by the “Front End Selection Algorithm.”

Table 18 describes the content of the CCD data telemetry and Table 19 describes the exposure record telemetry when in this mode. Zero or more data packets, followed by one Histogram Record packet are sent for each active CCD.

TABLE 18. Histogram Data Content

Req	Field	Description
18-1	Packet Synch	This field marks the start of the ACIS packet within the telemetry stream.
18-2	Packet Word Length	This field indicates the number of 32-bit words in the packet.
18-3	Format Tag	This field indicates the type of data contained in the telemetry packet, in this case a Timed Exposure Histogram data packet.
18-4	Packet Sequence Number	This field contains the packet sequence number.
18-5	CCD/FEP Identifiers	These identify which CCD and FEP produced the histogram.
18-6	Data Packet Number	Since data from different CCDs can be interleaved, and also mixed with other kinds of packets, this field sequentially numbers the data packet for a given CCD exposure.
18-7	Output Node Identifier	This identifies from which output node the histogram was formed.
18-8	Starting Bin Number	This item is the index of the first histogram bin contained within the packet.
18-9	Array of histogram counts	This consists of an array of adjacent histogram bins. Each bin contains a count of the number of pixels from the specified output node whose pulse height corresponded to the bin index.

TABLE 19. Histogram Record Content

Req	Field	Description
19-1	Packet Synch	This field marks the start of the ACIS packet within the telemetry stream.
19-2	Packet Word Length	This field indicates the number of 32-bit words in the packet.
19-3	Format Tag	This field indicates the type of data contained in the telemetry packet, in this case a Timed Exposure Histogram Record packet.
19-4	Packet Sequence Number	This field contains the packet sequence number.
19-5	Science Run Start Time	This identifies the start time of the science run using the ACIS time-stamp latched by the hardware at the start of the run.
19-6	Timed Exposure Parameter Block Identifier	This item is a copy of the Timed Exposure Parameter Block Identifier used to configure the current run.
19-7	CCD/FEP Identifiers	These identify which CCD and FEP produced the histogram.
19-8	First Exposure Number	This uniquely identifies the first exposure acquired into the histogram during the run. This field must allow the ground to uniquely identify over 130,000 exposures during a single run (2 second exposures for 72 hours).
19-9	Last Exposure Number	This uniquely identifies the last exposure acquired into the histogram during the run. This field must allow the ground to uniquely identify over 130,000 exposures during a single run (2 second exposures for 72 hours).
19-10	Output Node Identifier	This identifies from which output node the histogram was formed.
19-11	Number of Exposures Processed	This identifies the total number of exposures acquired in the histogram. Since one or more exposures may be dropped or ignored, this may be different than the "Exposure Number" listed above.
19-12	Overclock Values	These contain the minimum, maximum, mean and variance of the overclock values computed while the histogram was been formed.

3.2.2.3.21 Faint Mode Event Telemetry

The Back End software produces Faint Mode event telemetry when the "Event List Packing Code" field of the Timed Exposure Parameter Block indicates a "Faint" packing mode. This mode applies only when the Front End Processor is in "Event-finding mode," as indicated by the "Front End Selection Algorithm." In this mode, sets of distinct events are telemetered as 3x3 arrays of pixels. Table 20 illustrates the content of the Faint-Mode event list data packet, and Table 21 illustrates the content of an Exposure Record used with Faint-Mode.

TABLE 20. Faint Mode Exposure Event Data

Req	Field	Description
20-1	Packet Synch	This field marks the start of the ACIS packet within the telemetry stream.
20-2	Packet Word Length	This field indicates the number of 32-bit words in the packet.
20-3	Format Tag	This field indicates the type of data contained in the telemetry packet, in this case a Timed Exposure Faint-Mode data packet.
20-4	Packet Sequence Number	This field is used to sequentially number all ACIS telemetry packets.
20-5	CCD/FEP Identifiers	These identify which CCD and FEP produced the event
20-6	Data Packet Number	Since data from different CCDs can be interleaved, and also mixed with other kinds of packets, this field sequentially numbers the data packet for a given CCD exposure.
	The remainder of the packet contains zero or more of the following:	
20-7	Position Identifier	This identifies the row and column of the center pixel of the event
20-8	Uncorrected Pulse Heights.	These items are the measured (uncorrected) pulse heights of the 9 pixels of the event's 3x3 array.

TABLE 21. Faint Mode Exposure Record Content

Req	Field	Description
21-1	Packet Synch	This field marks the start of the ACIS packet within the telemetry stream.
21-2	Packet Word Length	This field indicates the number of 32-bit words in the packet.
21-3	Format Tag	This field indicates the type of data contained in the telemetry packet, in this case, a Faint-Mode Exposure Record packet.
21-4	Packet Sequence Number	This field is used to sequentially number all ACIS telemetry packets.
21-5	Science Run Start Time	This identifies the start time of the science run, as specified by the DEA latched ACIS time-stamp.
21-6	Timed Exposure Parameter Block Identifier	This item is a copy of the Timed Exposure Parameter Block Identifier used to configure the current run.
21-7	Window Block Identifier	This item is a copy of the Window List Parameter Block Identifier used to configure the current run. If no Window List was specified, this field will be 0xffffffff.

TABLE 21. Faint Mode Exposure Record Content (Continued)

Req	Field	Description
21-8	Bias Start Time	This identifies the start time of the most recently computed bias map, relative to when the DEA interface latched the ACIS time-stamp at the start of the bias computation.
21-9	Bias Parameter Block Identifier	This item is a copy of the Parameter Block Identifier used to configure the most recent bias map computation.
21-10	CCD/FEP Identifiers	These identify which CCD and FEP produced the exposure
21-11	FEP Timestamp	This is the value of the FEP time-stamp counter when the exposure arrived from the CCD.
21-12	Exposure Number	This uniquely identifies the clocked exposure during the run. This field must allow the ground to uniquely identify over 130,000 exposures during a single run (2 second exposures for 72 hours).
21-13	Number of Events Telemetered	This specifies the number of events being telemetered in the exposure. This field must accommodate at least 64K events.
21-14	Number of Pixels above threshold	These specify the total number of pixels from a CCD whose pulse heights were above their respective spatial thresholds during the exposure.
21-15	Number of Events Discarded by Amplitude	These specify the number of events which were discarded due to their amplitude. This field must accommodate the total number of pixels within the CCDs.
21-16	Number of Events Discarded by Grade	These specify the number of events which were discarded due to their “grade.”
21-17	Number of Events Discarded by Window	These specify the number of events which were discarded by the processing windows.
21-18	Overclock Levels	These identify the overclock levels used for the thresholding during the exposure which produced the events.
21-19	Bias Map Parity Hit Count	This specifies the total number of pixels disabled due to parity hits.

3.2.2.3.22 Faint-Bias Mode Telemetry

The Back End software produces Faint Bias Mode event telemetry when the “Event List Packing Code” field of the Timed Exposure Parameter Block indicates a “Faint-Bias” packing mode. This mode applies only when the Front End Processor is in “Event-finding mode,” as indicated by the “Front End Selection Algorithm.” In this mode, sets of distinct events are telemetered as 3x3 arrays of pixels along with the corresponding pixel bias values. Table 22 illustrates the content of the Faint-Bias Mode event list data packet, and Table 23 illustrates the content of a Faint-Bias Mode Exposure Record.

TABLE 22. Faint-Bias Mode Exposure Data Content

Req	Field	Description
22-1	Packet Synch	This field marks the start of the ACIS packet within the telemetry stream.
22-2	Packet Word Length	This field indicates the number of 32-bit words in the packet.
22-3	Format Tag	This field indicates the type of data contained in the telemetry packet, in this case a Timed Exposure Faint-Bias Mode data packet.
22-4	Packet Sequence Number	This field is used to sequentially number all ACIS telemetry packets.
22-5	CCD/FEP Identifiers	These identify which CCD and FEP produced the event
22-6	Data Packet Number	Since data from different CCDs can be interleaved, and also mixed with other kinds of packets, this field sequentially numbers the data packet for a given CCD exposure.
	The remainder of the packet contains zero or more of the following:	
22-7	Position Identifier	This identifies the row and column of the center pixel of the event
22-8	Uncorrected Pulse Heights	These items are the measured (uncorrected) pulse heights of the 9 pixels of the event's 3x3 array.
22-9	Pixel Bias Map Values	These are the computed pixel bias values associated with the event's 9 pixels.

TABLE 23. Faint-Bias Mode Exposure Record Content

Req	Field	Description
23-1	Packet Synch	This field marks the start of the ACIS packet within the telemetry stream.
23-2	Packet Word Length	This field indicates the number of 32-bit words in the packet.
23-3	Format Tag	This field indicates the type of data contained in the telemetry packet, in this case, a Faint-Bias Mode Exposure Record packet.
23-4	Packet Sequence Number	This field is used to sequentially number all ACIS telemetry packets.
23-5	Science Run Start Time	This identifies the start time of the science run, as specified by the DEA latched ACIS time-stamp.
23-6	Timed Exposure Parameter Block Identifier	This item is a copy of the Timed Exposure Parameter Block Identifier used to configure the current run.
23-7	Window Block Identifier	This item is a copy of the Window List Parameter Block Identifier used to configure the current run. If no Window List was specified, this field will be 0xffffffff.

TABLE 23. Faint-Bias Mode Exposure Record Content (Continued)

Req	Field	Description
23-8	Bias Start Time	This identifies the start time of the most recently computed bias map, relative to when the DEA interface latched the ACIS time-stamp at the start of the bias computation.
23-9	Bias Parameter Block Identifier	This item is a copy of the Parameter Block Identifier used to configure the most recent bias map computation.
23-10	CCD/FEP Identifiers	These identify which CCD and FEP produced the exposure
23-11	FEP Timestamp	This is the value of the FEP time-stamp counter when the exposure arrived from the CCD.
23-12	Exposure Number	This uniquely identifies the clocked exposure during the run. This field must allow the ground to uniquely identify over 130,000 exposures during a single run (2 second exposures for 72 hours).
23-13	Number of Events Telemetered	This specifies the number of events being telemetered in the exposure. This field must accommodate at least 64K events.
23-14	Number of Pixels above threshold	These specify the total number of pixels from a CCD whose pulse heights were above their respective spatial thresholds during the exposure.
23-15	Number of Events Discarded by Amplitude	These specifies the number of events which were discarded due to their amplitude. This field must accommodate the total number of pixels within the CCDs.
23-16	Number of Events Discarded by Grade	These specify the number of events which were discarded due to their “grade.”
23-17	Number of Events Discarded by Window	These specify the number of events which were discarded by the processing windows.
23-18	Overclock Levels	These identify the overclock levels used for the thresholding during the exposure which produced the events.
23-19	Bias Map Parity Hit Count	This specifies the total number of pixels disabled due to parity hits in the corresponding bias map location.
23-20	Initial Overclock	This is the initial overclock added to the pixel bias map values. (NOTE: This should have the same value for the length of the entire run).

3.2.2.3.23 Graded Event Telemetry

The Back End software produces Graded event telemetry when the “Event List Packing Code” field of the Timed Exposure Parameter Block indicates a “Graded” packing mode. This mode applies only when the Front End Processor is in “3x3 Mode,” as indicated by the “Front End Selection Algorithm.” In this mode, sets of distinct events are telemetered using reduced event amplitude information and event “Grade” (see Section 3.2.2.3.16 on page 66). The content of an Exposure Record in this mode is identical to that used by Faint

Mode Telemetry (see Table 21). The event data content, however, is different. Table 24 illustrates the content of the event lists telemetered when in this mode.

TABLE 24. Graded Event Telemetry Content

Req	Item	Description
24-1	Packet Synch	This field marks the start of the ACIS packet within the telemetry stream.
24-2	Packet Word Length	This field indicates the number of 32-bit words in the packet.
24-3	Format Tag	This field indicates the type of data contained in the telemetry packet, in this case a Timed Exposure Graded Event Mode data packet.
24-4	Packet Sequence Number	This field is used to sequentially number all ACIS telemetry packets.
24-5	CCD/FEP Identifiers	These identify which CCD and FEP produced the event
24-6	Data Packet Number	Since data from different CCDs can be interleaved, and also mixed with other kinds of packets, this field sequentially numbers the data packet for a given CCD exposure.
	The remainder of the packet contains zero or more of the following:	
24-7	Position Identifier	This identifies the row and column of the center pixel of the event
24-8	Event Amplitude	This identifies the amplitude of the event (see Section 3.2.2.3.14 on page 65).
24-9	Grade Code	This identifies the Grade Code of the event. The computation of an event's Grade Code is described by Section 3.2.2.3.16 on page 66.
24-10	Corner Pulse Height Mean	This is the mean, rounded to the nearest integer, of the corrected pulse-heights of those corner pixels in the 3x3 event array which are below their corresponding split threshold in two's complement.

3.2.2.3.24 Pixel Bias Map Telemetry

When configured to re-compute and telemeter the bias maps, the instrument software shall trickle the pixel bias maps from each of the active Front End Processors, into the telemetry stream. The algorithm used shall ensure a 10% minimum utilization of the telemetry stream. The algorithm is permitted to consume under-utilized telemetry. The pixel bias map values may be compressed in a number of rows using a compression scheme which utilizes patchable, pre-defined CCD-specific compression tables.

TABLE 25. Pixel Bias Map Telemetry Content

Req	Item	Description
25-1	Packet Synch	This field marks the start of the ACIS packet within the telemetry stream.
25-2	Packet Word Length	This field indicates the number of 32-bit words in the packet.
25-3	Format Tag	This field indicates the type of data contained in the telemetry packet, in this case a Timed Exposure Pixel Bias Map packet.

TABLE 25. Pixel Bias Map Telemetry Content (Continued)

Req	Item	Description
25-4	Packet Sequence Number	This field is used to sequentially number all ACIS telemetry packets.
25-5	Bias Start Time	This identifies the start time of the bias run, as specified by the DEA latched ACIS time-stamp.
25-6	Timed Exposure Parameter Block Identifier	This item is a copy of the Timed Exposure Parameter Block Identifier used to configure the current run.
25-7	CCD/FEP Identifiers	These identify which CCD and FEP produced the bias map
25-8	Bias Packet Number	Since bias data from different CCDs can be interleaved, and also mixed with other kinds of packets, this field sequentially numbers the data packet for a given CCD exposure.
25-9	Initial Overclock	This specifies the initial overclock value used to correct subsequent exposures for changes in average overclock.
25-10	Compression Selection Flag and Table Selection	These fields indicate whether or not the data has been compress, and if so, by which compression table.
25-11	Row Identifier	This specifies which row of the pixel bias map is being sent first within the packet. Since the rows are being sent in reverse order, subsequent rows in the packet are those consecutively closer to the Framestore.
25-12	Row Count	This specifies the number of rows being sent.
25-13	Pixels Per Row	This specifies the number of pixel bias values per row
	The remainder of the packet contains zero or more of the following:	
25-14	Compressed Bias Map Data	This is a bit-packed array of compressed Bias map data, starting from “Row Identifier” and encompassing “Row Count”. In order to send the bias map rows near the most likely focal point first, the rows are sent in reverse order, starting with those farthest from the Framestore. The column order is NOT reversed.

3.2.2.3.25 Pixel Bias Map Parity Error Telemetry

In the process of producing events during an exposure. the Front End Processors detect and forward pixel bias map parity errors to the Back End Processor. The Back End accumulates these errors into one or more parity error telemetry packets, and posts these packet to telemetry as they fill, or at the end of each exposure if a partially filled data packet remains. The content of these packets is illustrated in Table 26.

TABLE 26. Bias Map Parity Error Telemetry Content

Req	Item	Description
26-1	Packet Synch	This field marks the start of the ACIS packet within the telemetry stream.
26-2	Packet Word Length	This field indicates the number of 32-bit words in the packet.
26-3	Format Tag	This field indicates the type of data contained in the telemetry packet, in this case a Timed Exposure Parity Error data packet.
26-4	Packet Sequence Number	This field is used to sequentially number all ACIS telemetry packets.
26-5	CCD/FEP Identifiers	These identify which CCD and FEP produced the event
26-6	Data Packet Number	Since data from different CCDs can be interleaved, and also mixed with other kinds of packets, this field sequentially numbers the parity error packet for a given CCD exposure.
	The remainder of the packet contains zero or more of the following:	
26-7	Position Identifier	This identifies the row and column of the bias error.
26-8	Corrupted Value	This a copy of the corrupted pixel bias map value.

3.2.2.3.26 Diagnostic Features

The diagnostic extensions of this mode are described in more detail by Section 3.2.5 on page 97. The extensions specific to Timed Exposure Mode include:

- Telemeter Full-Frame CCD and Overclock Data

  This is accomplished by configuring the Timed Exposure Parameter Block to use Raw Front End Processing and Raw Back End telemetry processing.

- Telemeter System Noise Levels

  This is accomplished by running any of the described clocking and processing modes, only using the Diagnostic-Mode for the Serial Output Shift Registers. This will cause the output registers to clock inward, and prevent them from directly driving the output nodes. This allows the maintainer to quantify the effect of the clocking operations on the data received when performing real science operations.

3.2.3 Continuous Clocking Science Mode

3.2.3.1 Purpose

An observer uses Continuous Clocking Science Mode to acquire, process and telemeter high time-resolution, 1-dimensional images from the CCD array. An observer uses a Continuous Clocking Parameter Block to configure a Continuous Clocking Science Run, and "Start Continuous Clocking Run" and "Stop Continuous Clocking Run" commands to start and stop the run.

Continuous Clocking Science Mode provides data as a time-series of events which occurred along the columns of a CCD. An analogy is that of a strip-chart recorder, where each CCD column acts as a single pen.

3.2.3.2 Scenario

To execute a Continuous Clocking Science Run, an observer sends a "Start Continuous Clocking Run" command to ACIS. ACIS retrieves the parameter block referenced by the start command, dumps the parameter block(s), and proceeds to execute the science run, optionally computing and sending the CCD bias values, and then processing the event data in blocks of 512 rows. Although each block of 512 rows is processed as a unit, there is no additional time delay between row 511 of one block, and row 0 of the next. If telemetry stream or the processor become saturated, data is discarded in units of 512 rows until the condition subsides. The observer allows ACIS to acquire, process and telemeter CCD data for a period of time, after which the observer sends a "Stop Continuous Run" command to ACIS. ACIS then stops the run and telemeters a Science Run Report. Optionally, the observer may then decide to recompute the bias values and send a "Compute Continuous-Clocking Bias" command. ACIS will then re-compute and telemeter the bias values and then stop.

If the observer requires parameters not already provided by the ACIS parameter library, the observer must issue a "Load Continuous Clocking Parameter Block" command to load the desired parameters for the run. If the loaded parameter block requires custom event processing windows, the observer must also issue a "Load 1-D Window List" command to place the desired window settings into the instrument.

3.2.3.3 Functional Requirements

3.2.3.3.1 Continuous Clocking Parameter Block Contents

An observer configures Continuous Clocking Mode using a Continuous Clocking Mode Parameter Block. Table 27 describes the content of a Continuous Clocking Parameter Block.

TABLE 27. Continuous Clocking Parameter Block

Req	Item	Description
27-1	Parameter Block Identifier	This item is a ground-supplied identifier which is echoed by the instrument software in key portions of the science telemetry.
27-2	FEP CCD Selection	These items specify which CCD a given FEP should process. The items are indexed by FEP Id. Any given CCD may be specified more than once in the set, at the cost of reducing the total number of CCDs being used. CCDs or FEPs which are not powered on (see Section 3.2.7 on page 99) are ignored and will not be used for the run. If there are no powered CCD being processed by a powered FEP, the science run will be aborted.
27-3	Number of Rows to Sum	This specifies the number of rows to sum prior to clocking out the output registers, expressed in powers of 2. For example, 0 means don't perform any row summation, 1 means sum 2 rows, 2 means sum 4 rows, etc. This value can range from 0 to 9 (i.e. sum a maximum of 512 rows) (NOTE: Power constraints may further restrict the total number of rows that can be summed. Such restrictions, however, do not have to be built into the instrument software).
27-4	Number of Columns to Sum	This specifies the number of pixels to sum at the Output Node prior to each transfer to the DPA, expressed in powers of 2. For example, 0 means don't perform any column summation, 1 means sum 2 columns, 2 means sum 4 columns, etc. This value can range from 0 to 6 (i.e. sum a maximum of 64 columns to ensure that each quadrant contain at least 4 columns).
27-5	Output Register Clocking Mode	This item controls the clocking mode of all of the CCD's Serial Output Shift Registers. This item can specify either Full-Mode, AC-Mode, BD-Mode or Diagnostic-Mode. See Section 2.2.2 on page 20 for a description of these modes.
27-6	Number of Overclock Pairs	This item specifies the number of extra summed pixel pairs to clock out of the Serial Output Shift Registers. Continuous Clocking Mode uses these pixel sums to determine the bias introduced in the CCD's pixel pulse height by the analog electronics. This value can range from 0 to 15 pairs of pixels.
27-7	Video Chain Responses	This item controls the response of the Video Subsection in the Detector Electronics Assembly. This item selects 1 or 4 electrons per Analog-to-Digital Unit (ADU). These items are indexed by FEP Id. If a single CCD is specified by more than 1 FEP entry, then the last corresponding chain response entry is used for the listed CCD.

TABLE 27. Continuous Clocking Parameter Block (Continued)

Req	Item	Description
27-8	Reference to an explicit DEA Load	This is an optional item which allows a maintainer to by-pass the on-board SRAM/PRAM load builder, and load these areas directly. This reference points directly into BEP memory. If 0, then no explicit DEA load is to be used. If not 0, then the item points to the memory block which contains the load image to use. Post-launch DEA load images are uplinked into memory by the maintainer using the Write Memory function of the instrument (see Section 3.2.8.3.2 on page 108), or via a patch. This parameter is intended to be used by the maintainer of the instrument, and should be 0 during normal operations. The format of the referenced SRAM/PRAM load will be specified in the ACIS Instrument Software Detailed Design Specification (AS-BUILT), MIT 36-53200, and shall support different load contents for distinct DEA boards.
27-9	Front End Selection Algorithm	This item specifies whether or not the Front End Processor should supply all pixels to the Back End (Raw Mode), or only those whose center is above the current threshold and whose pulse height is greater than or equal to the (possibly summed) pixel to its left, and greater than the (possibly summed) pixel to its right (Event-finding Mode).
27-10	Threshold Set Points	These items control the minimum pulse-height above bias a pixel sum should have to be considered an event candidate. Each of these items applies to a specific CCD output node. These values can range from -4096 to 4095. These values are only used when the Front End Selection Algorithm is in Event-finding Mode. One set of four values is specified for each FEP.
27-11	Reference to Front End Processor Code	This value allows a maintainer to override the standard code and data loaded into the Front End Processor, and provide a special load for the Science Run. This reference points directly into BEP memory. If 0, then no explicit FEP load is to be used. If not 0, then the item points to the memory block which contains the load image to use. Post-launch FEP load images are uplinked into memory by the maintainer using the Write Memory function of the instrument (see Section 3.2.8.3.2 on page 108), or via a patch. This parameter is intended to be used by the maintainer of the instrument, and should be 0 during normal operations. The format of the referenced FEP Load image will be specified in the ACIS Instrument Software Detailed Design Specification (AS-BUILT), MIT 36-53200.
27-12	Event List Packing Code	This parameter is only used when the Front End Selection Algorithm is in “Event Finding Mode”. This value is not used when the Front End is processing raw pixels. This value selects the format to use when sending processed events. Currently, the following event-list formats are supported: Faint 1x3 and Graded 1x3.
27-13	Reference to a 1-D Window Collection	An observer uses this item to specify a set of 1-dimensional event selection and processing windows to use for the Science Run. If no windows are specified, Continuous Clocking Mode shall process all events from the CCDs using processing parameters specified in this block.

TABLE 27. Continuous Clocking Parameter Block (Continued)

Req	Item	Description
27-14	Split Threshold Set Points	These values are only used when the Front End Selection Algorithm is in “Event Finding Mode.” These values specify the threshold above which a neighboring pixel’s pulse height must be to be considered as part of an event. These values are used when grading events and computing the overall energy of an event. Each of these items applies to a specific CCD output node. These values can range from 0 to 4095, and each set is indexed by FEP Id.
27-15	Ignore Bad Column Map Flag	This value is only used when the Front End Selection Algorithm is in “Event Finding Mode.” This value controls whether or not to discard events on the basis of the CCDs list of bad columns.
27-16	Grading Selection Bit Map	These parameters are only used when the Front End Selection Algorithm is in “Event Finding Mode.” This set of values selects which event grades to accept. Accepted events whose grade is indicated in this list shall be telemetered.
27-17	Event Amplitude Lower Bound and Range	These parameters are only used when the Front End Selection Algorithm is in “Event Finding Mode”. These parameters select the minimum and maximum amplitudes of accepted events. Events whose total amplitude (see Section 3.2.3.3.12) is less than the lower bound value, or greater than or equal to the lower bound plus range are not telemetered. These field’s ranges are governed by the minimum and maximum corrected event amplitudes.
27-18	Re-compute Bias Flag	This item indicates if the software must re-compute the pixel bias values prior to starting data processing.
27-19	Bias Algorithm Mode	This parameter selects either a mean or fractile bias algorithm
27-20	Bias Rejection Criteria	If the mean bias algorithm is selected, this parameter specifies the sigma rejection criteria, used to prevent pixels containing X-ray or charged particle artifacts from affecting the estimate of the bias. If the fractile algorithm is selected, this parameter specifies the index of the sorted pixel array to use to determine the bias levels. This field can range from 0 to 4095.
27-21	Compression Flag	This indicates whether or not to compress raw pixel data values prior to being telemetered.
27-22	Compression Selection	If raw pixel data compression is enabled, this item specifies which compression table to use.
27-23	Initial Frames to Ignore	This field plus 1 specifies the number of whole exposure frames that the FEP is to ignore at the start of a bias calibration that uses this parameter block. If this value is zero, each FEP will start processing all data pixels and overclocks received after the second vsync code. Science data processing, however, always ignores the first two whole exposures.
27-24	Trickle Bias Flag	This item indicates if the software must telemeter the current bias map to telemetry after it has been computed.

3.2.3.3.2 1-D Window Lists

Events produced by Continuous Clocking of the CCDs have an originating column within the CCD's Image Array. Continuous Clocking Mode has the capability to select and process events based on this column position. This selection and processing is controlled using a 1-D Window Parameter Block. Table 28 illustrates the content within a single 1-D Window, and Table 29 illustrates the content of a list of 1-D Windows.

TABLE 28. 1-Dimension Window Information

Req	Item	Description
28-1	CCD Identifier	This selects the CCD to which the window applies.
28-2	Window Column	This specifies the position of the window in terms of the left most column within the CCD's Image Array. This position is independent of the summing column parameters in the Continuous Clocking Parameter Block.
28-3	Window Width	This specifies the number of columns (un-summed) in the window.
28-4	Sample Cycle	If processing event data, this specifies the sampling frequency of the window. If zero, no events are processed in the window. If one, then every event is processed, if 2, every other event is processed, if 3, every third, and so on. If processing raw pixel data, this specifies whether or not to send pixels who belong to the window. If zero, all pixels belonging to the window are discarded. If not zero, the pixels are telemetered.
28-5	Local Event Amplitude Range	When processing events, these items set the lower and upper amplitudes used to select candidate events. Events whose amplitude is outside this range would be rejected. When processing raw pixel data, this parameter is ignored.

TABLE 29. 1-Dimension Window List Parameter Block

Req	Item	Description
29-1	Parameter Block Identifier	This item is a ground-supplied identifier which is echoed by the instrument software in key portions of the science telemetry.
29-2	Window Count	This item identifies the number of 1-D Windows contained in the Window List. This value can range from 0 to 36. This field is not actually be loaded nor telemetered, but is calculated using the length of the enclosing command or telemetry packet.
29-3	Windows[Window Count]	This item is an array of 1-D windows. The content of these windows is described in Table 28. The number of windows in the array is determined by "Window Count."

3.2.3.3.3 Building of DEA PRAM and SRAM Loads

Due to the expected size of SRAM and PRAM loads (greater than 2Kbytes), the ACIS software shall be capable of building the SRAM and PRAM loads needed to perform a Continuous Clocking Mode, as described in Section 2.2.4 on page 23.

The following itemizes the inputs needed by the synthesizer:

- CCD Array and Selection
- Count of Rows to Sum
- Count of Columns to Sum
- Output Register Clocking Mode
- Number of Overclock Pixel Sums
- The video chain response selections for each CCD
- Optional DEA SRAM/PRAM load override

The result of the build shall consist of a series of DEA SRAM and PRAM load commands to the DEA Common Subsections. The CCD Array and Selections determine which Common Subsections need to be addressed.

The row sum parameter controls the number of Frame Store rows to clock into the output registers prior to clocking out the registers. This has the effect of summing the rows as they are clocked into the output register. A sum row count of 1 indicates that no row summing is to be performed.

The column sum parameter controls the number of pixels to clock out of the output registers and integrate at the output nodes. A column sum count of 1 indicates that no column summing is to be performed.

The Output Register Clocking Mode specifies how to clock out the output registers. The number of overclock pixel sums determines how many pixels to clock out of the output registers after each row of data has been completely clocked out.

The video chain response information controls how the pixel data is processed in the DEA's analog video processing section.

The optional DEA SRAM/PRAM load override instructs the synthesizer to ignore all of the previous parameters and to load the explicitly specified SRAM and PRAM commands.

3.2.3.3.4 Continuous CCD Clocking Requirements

In Continuous Clocking mode, ACIS shall program the DEA's PRAM and SRAM to clock the CCDs in the following fashion:

1. Clear the Image Array, Frame Store and Serial Output Shift Registers
2. Clock a set of rows through the Image Array and Frame Store into the output registers

This is accomplished by clocking the Image Array and Frame Store by the number of rows specified by "Number of Rows to Sum" in the Continuous Clocking Parameter Block.

3. Sum a set of columns into the Output Nodes

   This is accomplished by integrating a number of pixels at the output nodes as they are being clocked out of the output registers. The number of pixels to sum is determined by the "Number of Columns to Sum" contained in the Continuous Clocking Parameter Block.

4. Repeat step 3 until output registers are empty
5. Clock specified number of overclocks into the Overclock Buffer

   The number of overclocks to use is specified by the "Number of Overclock Pairs" in the Continuous Clocking Parameter Block.

6. Repeat from 2.

The time it takes to clock out one row from the Output Registers (steps 3-5) shall be no greater than 6.5ms. The goal is to clock out the rows as fast as the hardware allows.

3.2.3.3.5 Overclock Processing

The overclocking processing for Continuous Clocking Science Mode is almost identical to that for Timed Exposure Science Mode, except the number of clocks and exposures are specified via the Continuous Clocking Parameter Block. Refer to Section 3.2.2.3.6 on page 62 for a description of these requirements.

3.2.3.3.6 Pixel Bias Map Determination

The pixel-by-pixel bias map values are computed when configured by the parameter block, instructed by a "Compute Bias" command, or when the bias maps are invalid. Prior to processing events, the Front End Processor shall use one or more exposures to compute a output node-specific "Initial Overclock" values, and a pixel-by-pixel bias level and store the result in the Front End's Pixel Bias Map.

$$\text{Pixel Bias Map Value} = \text{Computed Pixel Bias} + \text{Initial Overclock} \qquad \text{(EQ 8)}$$

The algorithm to use to compute the bias is determined by the "Bias Algorithm Mode" parameter of the Continuous Clocking Parameter Block. The chosen algorithm may be tuned using the "Bias Rejection Criterea" of the same block.

3.2.3.3.7 Threshold Determination

The Front End Processor software shall compute the CCD threshold according to the following formula:

$$\text{Threshold Register Value} = \text{Threshold Set Point} + \text{Overclock Level} - \text{Initial Overclock} \qquad \text{(EQ 9)}$$

The Front End Processor software shall set the threshold registers with the computed values prior to each set of 512 rows.

3.2.3.3.8 Pixel Threshold Processing

The Front End Processor contains a Pixel Threshold BitMap. This bitmap indicates which pixels in the acquired CCD data have pulse heights greater their respective output -node threshold registers plus their respective pixel bias map values. The bit corresponding to a pixel is set if:

$$\text{Pixel Pulse Height} > \text{Pixel Bias Map Value} + \text{Threshold Register Value} \qquad \text{(EQ 10)}$$

When the "Front End Selection Algorithm" field of the Continuous Clocking Parameter Block indicates the Event-finding mode, the Front End Processor software shall scan this bitmap for each exposure. Any pixel marked as above its threshold shall be counted in an "above threshold" counter, and be tested as an event. Refer to Section 3.2.3.3.9 on page 87 for the Event-finding requirements.

The threshold map is ignored for all Front End Modes except "Event-finding Mode."

3.2.3.3.9 Front End Event-finding Mode

When the "Front End Selection Algorithm" field of the Continuous Clocking Parameter Block indicates the Event-finding mode, the Front End Processor selects events from candidates indicated by the hardware Pixel Threshold Map. If a pixel is indicated in this map, the Front End software compares the corrected pulse height of the pixel (see Section 3.2.3.3.12 on page 88) to each pixel on either side of the candidate. If the candidate's pulse height is greater than or equal to the pixel immediately preceding it in the row, and greater than the pixel immediately following it in the row, the Front End processor forwards the 3 pixels to the Back End processor for further selection and processing.

Each Front End shall be capable of testing at least 1000 candidate events per second, and the total number of events capable of being produced by all of the Front Ends shall be at least 750 events per second (assuming unbounded telemetry).

3.2.3.3.10 Front End Raw Mode

When the "Front End Selection Algorithm" field of the Continuous Clocking Parameter Block indicates "Raw Mode", the Front End processor merely passes raw pixel data to the Back End Processor as it is poured into the Front End's image buffer.

3.2.3.3.11 Bad Column Map Content and Application

The Back End Processor shall contain a list of bad columns from each CCD. This Bad Column Map is edited using maintenance commands from the ground (see Section 3.2.7 on page 99). The Bad Column Map entries provide the information described in Table 30.

TABLE 30. Bad Column Map Content

Req	Item	Description
30-1	CCD Id	The Bad Column Map must contain enough information to identify the CCD to which the bad column applies.
30-2	Column Id	The Bad Column Map must contain enough information to identify which column in the CCD is bad.

When the “Front End Selection Algorithm” field of the Continuous Clocking Parameter Block indicates the Event-finding mode, and the “Ignore Bad Column Map Flag” is de-asserted, the software shall test any events generated by the Front End to ensure that the center pixel of the 1x3 event is not listed in the Bad Column Map. If the center pixel is in the list, no further processing on the event takes place. If the center of the event is not in the list, the software accepts the event for further selection and processing.

Pixels belonging to a bad column which surround the center pixel of an event shall be treated as having a pulse-height of 0.

The Bad Column maps are ignored for all Front End Modes except “Event-finding Mode.”

3.2.3.3.12 Pulse Height Bias Correction and Event Amplitude

To obtain the corrected pulse height of a pixel, the ACIS Science Instrument Software subtracts the corresponding output node overclock level, computed bias value (i.e. the bias map value minus the global initial overclock) from each pixel in the 1x3 group, to obtain a bias corrected pulse height of each pixel.

Corrected Pixel PH = raw pixel ph - pixel bias value - (overclock - initial overclock) (EQ 11)

The ACIS software shall compute the corrected event amplitude of a 1x3 group of pixels by summing the corrected pulse heights of all 3 pixels which are greater than the “Split Threshold,” as specified in the Continuous Clocking Parameter Block (see Table 3.2.3.3.1).

3.2.3.3.13 Event Selection by Event Amplitude

When the “Front End Selection Algorithm” field of the Continuous Clocking Parameter block indicates an Event-finding mode, the Back End Processor shall compute the overall corrected amplitude of the 1x3 events received from the Front End, and compare the result with the “Event Amplitude Lower Bound and Range”, specified in the parameter block.

If the value is less than the lower bound, or greater than or equal to the lower bound plus the range, the software shall increment the “amplitude” event rejection counter, and discard the event. If the value is within range, the software shall accept the event for further selection and processing.

Event Amplitude selection only applies when the “Front End Selection Algorithm” field indicates “Event-finding Mode.”

3.2.3.3.14 Event Grade Computation

When required to do so, the Back End software shall compute the “grade” of a 1x3 pixel event. To accomplish this, the software compares the corrected pulse heights of the 2 outside pixels of the event to the “Split Threshold” specified in the Continuous Clocking Parameter Block. This threshold is dependent on the number of summed rows and columns and therefore does not need to be scaled.

Each outside pixel corresponds to a bit in the 2-bit grade code. If a pixel’s pulse height is above the “Split Threshold”, the corresponding bit is set to ‘1’. If below the threshold, the pixel’s bit is set to 0.

3.2.3.3.15 Event Selection by Grade

When the “Front End Selection Algorithm” field of the Continuous Clocking Parameter Block indicates an Event-finding mode, and the “Grading Selection Bitmap” does not indicate that all possible grades are to be accepted, the Back End software shall compute the grade of an event and compare the computed grade to the list of desired grades. If the computed grade is not in the list, the event is counted and discarded. If the event’s grade is in the list, the event is accepted for further selection and processing.

Grade-based event selection only applies when the “Front End Selection Algorithm” field indicates “Event-finding Mode,” and when the “Grading Selection Bitmap” indicates that only a subset of grades are to be processed (i.e. if all grades are accepted, no grade-based selection operation is performed).

3.2.3.3.16 1-D Window Event Processing

The Back End software shall use 1-D windows to select events and pixels to telemeter. If an event’s center pixel, or an individual pixel’s position is within the bounds of a 1-D window, it is processed according to the window’s selection code. For a given event or pixel, each window in the window list is checked in the order they are presented in the list. If the event/pixel column is within the bounds of the window, the event/pixel is processed by the window. The window boundaries are expressed independently of the number of summed columns. Therefore, the pixel position, relative to a window, is really a range of positions. If this range intersects the window, it is considered a match, and event is selected by the window. If the position is outside the bounds of the window, the next window is checked. This continues until either a match is found, or until the list is exhausted.

If no window list is specified, or if the list becomes exhausted with the event/pixel not being picked up by any of the windows, the event/pixel is, by default, accepted for processing.

The precise processing modes for the windows are the same as those described for Timed Exposure Mode (see Section 3.2.2.3.18 on page 67).

3.2.3.3.17 Raw Mode Telemetry

The Back End software produces raw event telemetry when the "Front End Selection Algorithm" field of the Timed Exposure Parameter Block indicates a "Raw" mode. In this mode, contiguous regions of 512 rows of pixels are telemetered as a set. For each 512 rows, a "Continuous Raw Mode Record" is formed and telemetered. Table 31 lists the elements telemetered for each pixel and Table 32 identifies the components of a Continuous Raw Mode Record.

TABLE 31. Continuous Raw Mode Data Telemetry

Req	Item	Description
31-1	Packet Synch	This field marks the start of the ACIS packet within the telemetry stream.
31-2	Packet Word Length	This field indicates the number of 32-bit words in the packet.
31-3	Format Tag	This field indicates the type of data contained in the telemetry packet, in this case a Continuous Clocking Raw Mode data packet.
31-4	Packet Sequence Number	This field is used to sequentially number all ACIS telemetry packets.
31-5	CCD/FEP Identifiers	These identify which CCD and FEP produced the raw pixel data.
31-6	Data Packet Number	Since data from different CCDs can be interleaved, and also mixed with other kinds of packets, this field sequentially numbers the data packet for a given CCD exposure.
31-7	Compression Selection Flag and Table Selection	These fields indicate whether or not the raw data has been compressed, and if so, by which compression table.
31-8	Pixel Position	This specifies the row and column of the first pixel in the packet, relative to the start of a 512 row block.
31-9	Packed or compressed collection of raw 12-bit CCD pixel and overclock data	This consists of an array of window-selected raw CCD pixel data. Pixels filtered out by the window processing are dropped. This forces the ground to use knowledge of the chosen 1-D windows to reconstruct the image. The packed pixels are output row by row, starting from the first row clocked out of the CCD, with the overclock data for a given row sent immediately after the pixel data for the row. Overclock pixels are always sent, even if the row is completely filtered out by the 1-D windows. Unused bits at the end of the telemetry packet (needed to fill out to the nearest 32-bit word boundary) will be zero.

TABLE 32. Continuous Raw Mode Record Content

Req	Item	Description
32-1	Packet Synch	This field marks the start of the ACIS packet within the telemetry stream.
32-2	Packet Word Length	This field indicates the number of 32-bit words in the packet.
32-3	Format Tag	This field indicates the type of data contained in the telemetry packet, in this case a Continuous Clocking Raw Mode Exposure Record packet.
32-4	Packet Sequence Number	This field is used to sequentially number all ACIS telemetry packets.
32-5	Science Run Start Time	This identifies the start time of the science run, relative to when the DEA interface latched the ACIS time-stamp at the start of the run.
32-6	Continuous Clocking Parameter Block Identifier	This item is a copy of the Continuous Clocking Parameter Block Identifier used to configure the current run.
32-7	Window Block Identifier	This item is a copy of the Window List Parameter Block Identifier used to configure the current run. If no Window List was specified, this field will be 0xffffffff.
32-8	FEP Timestamp	This is the value of the FEP time-stamp counter when the exposure arrived from the CCD.
32-9	Exposure Number	This uniquely identifies the group of events during the run. This field must allow the ground to uniquely identify over 259,200 sets of 512 rows (exposures) during a single run (1 second/exposure for 72 hours).
32-10	CCD/FEP Identifier	This identifies from which CCD and FEP the raw pixel data was taken.
32-11	Pixel Count	This specifies the total # of pixels being sent for the exposure from the CCD.

3.2.3.3.18 Faint Mode Event Telemetry

The Back End software produces Faint Mode event telemetry when the “Event Packing Code” field of the Continuous Clocking Parameter Block indicates “Faint” packing mode. This mode applies only when the Front End Processor is in “Event-finding mode.” In this mode, a series of distinct events are telemetered as 1x3 arrays of pixels. Table 33 illustrates the content of the Faint-Mode event lists, and Table 34 illustrates the content of a Continuous Faint Mode Record.

TABLE 33. Continuous Faint Mode Event Data

Req	Item	Description
33-1	Packet Synch	This field marks the start of the ACIS packet within the telemetry stream.
33-2	Packet Word Length	This field indicates the number of 32-bit words in the packet.
33-3	Format Tag	This field indicates the type of data contained in the telemetry packet, in this case a Continuous Clocking Faint-Mode Event data packet.
33-4	Packet Sequence Number	This field is used to sequentially number all ACIS telemetry packets.
33-5	CCD/FEP Identifiers	These identify which CCD and FEP produced the event
33-6	Data Packet Number	Since data from different CCDs can be interleaved, and also mixed with other kinds of packets, this field sequentially numbers the data packet for a given CCD exposure.
	The remainder of the packet contains zero or more of the following:	
33-7	Row Identifier	This identifies from which (possibly summed) row the event was acquired, relative to the 512 row block. This value can be used to obtain a high-resolution time-stamp of the event, knowing the row rate from the CCD.
33-8	Column Identifier	This identifies from which (possibly summed) column the event was acquired.
33-9	Uncorrected Pulse Heights	These items are the measured (uncorrected) pulse heights of the 3 pixels of the event’s 1x3 array.

TABLE 34. Continuous Faint Mode Record Content

Req	Item	Description
34-1	Packet Synch	This field marks the start of the ACIS packet within the telemetry stream.
34-2	Packet Word Length	This field indicates the number of 32-bit words in the packet.
34-3	Format Tag	This field indicates the type of data contained in the telemetry packet, in this case a Continuous Clocking Faint Mode Record
34-4	Packet Sequence Number	This field is used to sequentially number all ACIS telemetry packets.
34-5	Science Run Start Time	This identifies the start time of the science run, relative to when the DEA interface latched the ACIS time-stamp at the start of the run.
34-6	Continuous Clocking Parameter Block Identifier	This item is a copy of the Continuous Clocking Parameter Block Identifier used to configure the current run.
34-7	Window Block Identifier	This item is a copy of the Window List Parameter Block Identifier used to configure the current run. If no Window List was specified, this field will be 0xffffffff.

TABLE 34. Continuous Faint Mode Record Content (Continued)

Req	Item	Description
34-8	Bias Start Time	This identifies the start time of the most recently computed bias map, relative to when the DEA interface latched the ACIS time-stamp at the start of the bias computation.
34-9	Bias Parameter Block Identifier	This item is a copy of the Parameter Block Identifier used to configure the most recent bias map computation.
34-10	CCD/FEP Identifiers	These identify which CCD and FEP produced the exposure
34-11	FEP Timestamp	This is the value of the FEP time-stamp counter when the exposure arrived from the CCD.
34-12	Continuous Faint Mode Exposure Number	This uniquely identifies a stream of data within the run. This field must allow the ground to uniquely identify over 130,000 records during a single run (2 second exposures for 72 hours).
34-13	Number of Events	This specifies the number of events being telemetered as part of this event stream. This field must accommodate at least 64K events.
34-14	Number of Pixels above Threshold	This specifies the total number of (possibly summed) pixels whose pulse heights were above the threshold.
34-15	Number of Events Discarded by Amplitude	These specifies the number of events which were discarded due to their amplitude. This field must accommodate the total number of pixels within the CCDs.
34-16	Number of Events Discarded by Grade	These specify the number of events which were discarded due to their “grade.”
34-17	Number of Events Discarded by Window	These specify the number of events which were discarded by the processing windows.
34-18	Overclock Levels	These identify the overclock levels used for the thresholding during the exposure which produced the events.
34-19	Bias Map Parity Hit Count	This specifies the total number of pixels disabled due to parity hits in the corresponding bias map location.

3.2.3.3.19 Continuous Graded Mode Event Telemetry

The Back End software produces Graded event telemetry when the “Event Packing” Code” field of the Continuous Clocking Parameter Block indicates a “Graded” packing mode. This mode applies only when the Front End Processor is in “Event Finding Mode,” as indicated by the “Front End Selection Algorithm.” In this mode, sets of distinct events are telemetered using reduced event amplitude information and event “Grade” (see Section 3.2.3.3.14 on page 89). The content of a Continuous Graded Event Record in this mode is identical to that used by Continuous Faint Mode Telemetry (see

Section 3.2.3.3.18 on page 91). The event data content, however, is different. Table 35 illustrates the content of the event lists telemetered when in this mode.

TABLE 35. Continuous Graded Mode Event Data Telemetry

Req	Item	Description
35-1	Packet Synch	This field marks the start of the ACIS packet within the telemetry stream.
35-2	Packet Word Length	This field indicates the number of 32-bit words in the packet.
35-3	Format Tag	This field indicates the type of data contained in the telemetry packet, in this case a Continuous Clocking Graded Mode data packet.
35-4	Packet Sequence Number	This field is used to sequentially number all ACIS telemetry packets.
35-5	CCD/FEP Identifiers	These identify which CCD and FEP produced the event
35-6	Data Packet Number	Since data from different CCDs can be interleaved, and also mixed with other kinds of packets, this field sequentially numbers the data packet for a given CCD exposure.
	The remainder of the packet contains zero or more of the following:	
35-7	Row Identifier	This identifies from which (possibly summed) row the event was acquired. This value is used to obtain a high-resolution time-stamp of the event.
35-8	Column Identifier	This identifies from which (possibly summed) column the event was acquired.
35-9	Event Amplitude	This item is the corrected amplitude of the 1x3 event.
35-10	Grade Code	This identifies the Grade Code of the event. See Section 3.2.3.3.14 on page 89 for a description of how this is computed.

3.2.3.3.20 Pixel Bias Map Telemetry

When configured to re-compute and telemeter the bias maps, the instrument software shall trickle the pixel bias maps from each of the active Front End Processors, into the telemetry stream. The algorithm used shall ensure a 10% minimum utilization of the telemetry stream. The algorithm may consume under-utilized telemetry.

TABLE 36. Continuous Pixel Bias Map Telemetry Content

Req	Item	Description
36-1	Packet Synch	This field marks the start of the ACIS packet within the telemetry stream.
36-2	Packet Word Length	This field indicates the number of 32-bit words in the packet.
36-3	Format Tag	This field indicates the type of data contained in the telemetry packet, in this case a Continuous Clocking Bias Map packet.
36-4	Packet Sequence Number	This field is used to sequentially number all ACIS telemetry packets.
36-5	Bias Start Time	This identifies the start time of the bias run, as specified by the DEA latched ACIS time-stamp.

TABLE 36. Continuous Pixel Bias Map Telemetry Content (Continued)

Req	Item	Description
36-6	Continuous Clocking Parameter Block Identifier	This item is a copy of the Continuous Clocking Parameter Block Identifier used to configure the current run.
36-7	CCD/FEP Identifiers	These identify which CCD and FEP produced the bias map
36-8	Initial Overclock	This specifies the initial overclock value added to every pixel bias map value.
36-9	Pixels Per Row	This specifies the number of pixel bias values per row
36-10	Bias Map Data	This is a bit-packed array of the single row of bias map data. NOTE: Unlike Timed Exposure Mode, this data is not compressed.

3.2.3.3.21 Diagnostic Features

The diagnostic extensions of this mode are described in more detail by Section 3.2.5 on page 97. The extensions specific to Continuous Clocking Mode include:

- Telemeter Raw summed columns and pixels

  This is accomplished by configuring the Continuous Clocking Parameter Block to use Raw Front End Processing.

- Telemeter System Noise Levels

  This is accomplished by running any of the described clocking and processing modes, using Diagnostic-Mode for the output register clocking. This will cause the output registers to clock inward, and prevent them from directly driving the output nodes. This allows the maintainer to quantify the noise introduced by the clocking operations.

3.2.4 Spectroscopy Science Modes

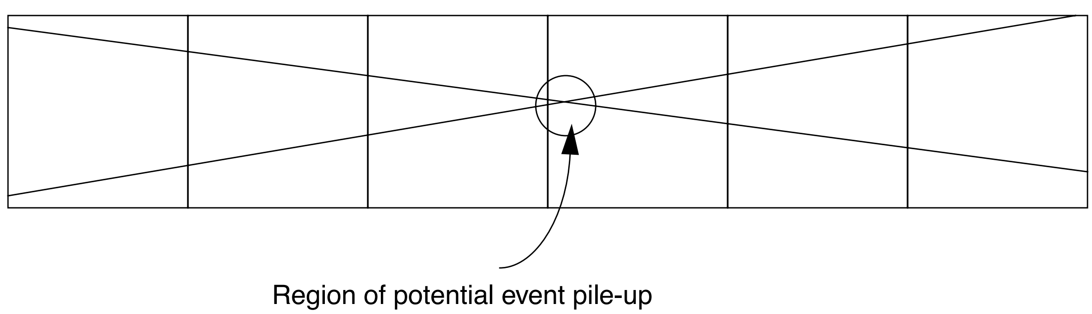
3.2.4.1 Purpose

An observer uses the spectroscopy set of CCDs in conjunction with the High Energy Transmission Gratings (HETG) to obtain very high resolution energy information from the observed source(s). When used with the HETG, an “X” is formed on the six spectroscopy CCDs. The distance from the center of the “X” reflects the energy of the detected X-rays. The central pixels of the “X” will receive many more events than the “arms” of the “X.” In order to use the pixels at the center of the “X” for relatively bright sources, the instrument must provide the capability of interleaving short exposure times with longer ones. ACIS provides this capability within the Timed Exposure Science Mode.

3.2.4.2 Scenario

An observer performs a Spectroscopy Science Mode by commanding the hardware (not described in this document) to move the gratings into place, and by configuring and running a Timed Exposure Science Mode, as described in Section 3.2.2.2 on page 48. The observer uses the Timed Exposure Parameter Block settings to select the Spectroscopy CCD Array, and uses the primary exposure times to acquire data from the “arms” of the “X”. The observer uses the secondary exposure time to provide data from the central pixels, minimizing event pile-up, and the duty-cycle parameter to control how often to acquire these short exposures. In all cases, all active CCDs are clocked in unison.

FIGURE 27. Representative HETG projection onto ACIS



3.2.4.3 Functional Requirements

Since Timed Exposure Science Mode covers the needs for Spectroscopy observations, refer to Timed Exposure Science Mode, Section 3.2.2 on page 48, for the functional requirements.

3.2.5 Diagnostic Modes

3.2.5.1 Purpose

The maintainer uses ACIS Diagnostic Modes to acquire information when trying to determine causes for abnormal conditions and determine side-effects within the instrument. When diagnosing problems, the maintainer may want to change the system as little as possible from the state it is in when a problem first arises. In order to support this type of operation, ACIS provides diagnostic options to each of its main science modes, allowing selective changes to the operation of the instrument. This allows the maintainer to perform the diagnostic operations while changing the setup as little as possible.

3.2.5.2 Scenario

A maintainer executes a diagnostic mode in the same fashion as any other Science Run, by sending the desired parameter block, starting the run, and stopping the run when sufficient telemetry has been generated.

3.2.5.3 Functional Requirements

3.2.5.3.1 Raw Modes

Each of the ACIS Science Modes support a “Raw Mode” option, which instructs ACIS to telemeter the raw, unprocessed pixel data produced by the CCDs. This mode produces large amounts of telemetry (1.5Mbytes - 9Mbytes), but allows the maintainer to bypass the event detection algorithms and see all of the pixel information.

By providing “Raw Mode” for all clocking options, the maintainer can effectively evaluate any un-intended coupling between the CCD clocking and the raw pixel data.

3.2.5.3.2 Reverse Clocking Modes

Each of the ACIS Science Modes support the ability to clock the CCD’s Serial Output Shift Registers in the reverse direction. This allows the maintainer to see the effects of the clocking on the analog systems.

3.2.5.3.3 Histogram Mode

Timed-Exposure Mode provides separate CCD video chain histograms of the pixel pulse-heights from the respective output-nodes. This provides the maintainer an overall picture of the output-node performance, while using little telemetry, relative to the Raw Modes.

3.2.6 Calibration Modes

3.2.6.1 Purpose

A maintainer uses calibration modes to determine the various operating parameters of the CCDs. Over time, radiation damage to the CCDs change their respective properties. The calibration modes provide a means to monitor and evaluate these changes.

3.2.6.2 Scenario

To perform calibration measurements, a maintainer configures and executes one of the existing science modes described in this document. The ground uses the standard telemetered science data to determine the desired calibration information.

3.2.6.3 Functional Requirements

3.2.6.3.1 CCD charge transfer efficiency

A maintainer measures the Charge Transfer Efficiency by exposing the ACIS detectors to the on-board calibration source, and collects and telemeters events using Timed Exposure Mode's Faint Event Telemetry formats (see Section 3.2.2.3.21 on page 72). The maintainer then determines the Charge Transfer Efficiency using ground-based data analysis.

Other techniques are possible if we implement an event amplitude histogram processing feature for Timed Exposure Science Mode (see Appendix E.2).

3.2.6.3.2 CCD dark current

A maintainer measures a CCD's Dark Current by comparing CCD output levels (above the overclock level) for Timed Exposure clocked data using different exposure times, and uses ground-based processing of the different Timed Exposure runs to determine the CCD's Dark Current levels.

3.2.6.3.3 Other Calibration Functions

A maintainer measures the Spectral Resolution, Energy to Pulse Height Gain, CCD Quantum Efficiency, and Background Event Rates as done for the CCD Charge Transfer Efficiency. Each type of function, however, requires different ground-based data analysis of the telemetered data.

3.2.7 Hardware Configuration

3.2.7.1 Purpose

The Detector Electronics Assembly on ACIS contains a set of hardware settings used to condition the CCD clocks, control the analog signal processing, and set the focal plane and housing temperatures. In addition, ACIS provides the capability to filter bad pixels and columns from generated CCD data. ACIS provides a set of commands a maintainer uses to manage these settings.

3.2.7.2 Scenario

Over the life of the instrument, the maintainer may issue commands to ACIS to modify its settings for various DEA clock voltages, processing levels, etc. As the CCDs degrade due to radiation damage, the maintainer may also add pixels and columns to the ACIS Bad Pixel and Column Maps.

The maintainer modifies one or more settings by issuing a "Change System Configuration Settings" command to ACIS. Upon receipt of this command, ACIS updates its configuration parameter block. If a Science Run is in progress when the command is executed, the changes are held until the end of the run, after which they are loaded into the hardware. If no run is in progress, ACIS immediately loads the changes into the hardware.

The maintainer adds items to the Bad Pixel and Column Maps using "Add" commands, and deletes the contents of the maps using the "Reset Map" commands. Upon receipt of these commands, ACIS modifies the appropriate map. Any changes to the Bad Pixel or Column Map will not take effect until the start of the next Science Run.

3.2.7.3 Functional Requirements

3.2.7.3.1 System Configuration Parameters

ACIS shall contain a single set of System Configuration Parameters. Table 37 lists the possible content of this parameter set. The final content depends on the design of the Detector Electronics Assembly, and will be defined in the AS-BUILT ACIS Software Detailed Design Specification, MIT 36-53200. Each individual parameter shall be identifiable using a 16-bit setting code. Each value shall take 16-bits or less to represent. The range of each value are specified by the DEA hardware specifications.

TABLE 37. System Configuration Parameter Set Content

Req	Item	Description
37-1	DEA CCD-Controller Power Selection	This items selects which CCD Controller boards within the DEA are powered on.
37-2	FEP Power Selection	This item selects which Front End Processors are powered on.
	The remaining parameters consist of DEA board settings. In order to reduce the volatility of the software to changes in the DEA hardware design, the DEA parameter settings are implemented by the software as an array of DEA register settings, leaving the final register function designations up to the DEA hardware specification.	
37-3	Image Section Phase Clocks High Levels	These items control the high level of the Image Section Phase Clocks. The ACIS software loads these levels into the Driver board's clock conditioning Digital-to-Analog converters. These are specified for each CCD.
37-4	Image Section Phase Clocks Low Levels	These items control the low level of the Image Section Phase Clocks. The ACIS software loads these levels into the Driver board's clock conditioning Digital-to-Analog converters. These are specified for each CCD.
37-5	Framestore Phase Clocks High Levels	These items control the high level of the Framestore Phase Clocks. The ACIS software loads these levels into the Driver board's clock conditioning Digital-to-Analog converters. These are specified for each CCD.
37-6	Framestore Phase Clocks Low Levels	These items control the low level of the Framestore Phase Clocks. The ACIS software loads these levels into the Driver board's clock conditioning Digital-to-Analog converters. These are specified for each CCD.
37-7	Serial Output Register Phase Clocks High Levels	These items control the high level of the Serial Output Shift Register Phase Clocks. The ACIS software loads these levels into the Driver board's clock conditioning Digital-to-Analog converters. These are specified for each CCD.
37-8	Serial Output Register Phase Clocks Low Levels	These items control the low level of the Serial Output Shift Register Phase Clocks. The ACIS software loads these levels into the Driver board's clock conditioning Digital-to-Analog converters. These are specified for each CCD.
37-9	Output Node Reset Gate High Levels	These items control the high level of the Output Node Reset Gate. The ACIS software loads these levels into the Driver board's clock conditioning Digital-to-Analog converters. These are specified for each CCD.
37-10	Output Node Reset Gate Low Levels	These items control the low level of the Output Node Reset Gate. The ACIS software loads these levels into the Driver board's clock conditioning Digital-to-Analog converters. These are specified for each CCD.
37-11	Output Node Reset Diodes	These items control the level applied to the Output Node's Reset Diode. These are specified for each CCD.
37-12	Output Node Drains	These items control the levels of each of the Output Node Drains. These are specified for each CCD and Output Node.

TABLE 37. System Configuration Parameter Set Content (Continued)

Req	Item	Description
37-13	Output Node Output Gates	These items control the level of the Output Node Output Gates. These are specified for each CCD.
37-14	Output Node Bias Offsets	These items control the bias level applied to the Output Nodes. These are specified for each CCD.
37-15	Scuppers	These items control the bias-level to the Scuppers. These are specified for each CCD.
37-16	Back-Junction Diodes	These items select the levels of the Back Junction Diodes. These are specified for each CCD.
37-17	Bakeout Mode Switch	This item controls whether or not bakeout mode is enabled.
37-18	Focal Plane Temperature Set Point (Coarse and Fine)	These items set the focal plane temperature.

3.2.7.3.2 Change System Configuration Settings

ACIS shall provide a command to change one or more system configuration settings. Table 38 illustrates the contents of a Change Settings Command.

TABLE 38. Change Settings Command Packet

Req	Item	Description	
38-1	Packet Length	Length of command packet in 16-bit words	
38-2	Packet Identifier	This is used to identify the command	
38-3	Command Opcode	Change_Settings_Command opcode	
38-4	Settings[Number of entries]	This is an array of setting entries. The number of entries is determined using the Packet Length. Each entry has the following format:	
38-5		Setting Identifier	This is a 16-bit identifier which uniquely identifies the item within the System Configuration Parameter Block
38-6		Setting Value	This the value to use for the specified item. A single setting value shall take no more than 16-bits to represent.

Upon receipt of this command, ACIS shall overwrite the System Configuration Parameter Block items as indicated by the entries in the command packet. If no Science Run is in progress, the new settings will be loaded into the hardware immediately. If a Science Run is in progress, the new settings will be loaded after the current run completes. If a setting enables power to a previously un-powered CCD-controller, the corresponding hardware settings are re-loaded into the powered board. If a setting enables power to a previously un-powered Front End Processor, software will power on the corresponding processor and will load and run the default FEP program.

3.2.7.3.3 Dump System Configuration Settings

ACIS shall provide a command which allows a maintainer to dump the current contents of the System Configuration Parameter Block. This requirement may be implemented using a Read Back End Memory Command (see Section 3.2.8.3.1 on page 106) or may be implemented using a customized command packet and telemetry representation.

3.2.7.3.4 Add Bad Pixel

ACIS shall provide a command to add a set of pixels to the Bad Pixel Map. Table 39 describes the Add Bad Pixel Command.

TABLE 39. Add Bad Pixel Command Packet

Req	Item	Description	
39-1	Packet Length	Length of command packet in 16-bit words	
39-2	Packet Identifier	This is used to identify the command	
39-3	Command Opcode	Add_Bad_Pixel_Command opcode	
39-4	Pixels[Number of entries]	This is an array of setting entries. The number of entries is determined using the Packet Length. Each entry has the following format:	
39-5		CCD Identifier	This specifies the CCD containing the bad pixel.
39-6		Row and Column Addresses	These values identify the row and column within the CCD which is bad, in CCD Coordinates. Summed image pixels which include the specified CCD pixel location are considered bad.

Upon receipt of this command, the ACIS software shall add the listed pixels to its Bad Pixel Map. No attempt is made to eliminate redundant entries.

3.2.7.3.5 Reset Bad Pixel Map

ACIS shall provide a command to delete the contents of the Bad Pixel Map. Table 40 describes the Reset Bad Pixel Map Command.

TABLE 40. Reset Bad Pixel Map Command Packet

Req	Item	Description
40-1	Packet Length	Length of command packet in 16-bit words
40-2	Sequence Number	This is used to identify the command
40-3	Command Opcode	Reset_Bad_Pixel_Map opcode

Upon receipt of this command, the ACIS software shall remove all pixels from its Bad Pixel Map.

3.2.7.3.6 Dump Bad Pixels

ACIS shall provide a command to dump the contents of its bad pixel map into the telemetry stream. This is accomplished via a “Dump Bad Pixels” command. This command will have the form as shown in Table 41.

TABLE 41. Dump Bad Pixels Command Packet

Req	Item	Description
41-1	Packet Length	Length of command packet in 16-bit words
41-2	Packet Identifier	This is used to identify the command
41-3	Command Opcode	Dump_Bad_Pixels_Command opcode

The one or more telemetry packets resulting from this command will contain the information described in Table 42. This requirement may be implemented using a Read Back End Memory Command (see Section 3.2.8.3.1 on page 106) or may be implemented using a customized telemetry representation.

TABLE 42. Dumped Bad Pixel Map Telemetry Content

Req	Item	Description	
42-1	Packet Synch	This field marks the start of the ACIS packet within the telemetry stream.	
42-2	Packet Word Length	This field indicates the number of 32-bit words in the packet.	
42-3	Format Tag	This field indicates the type of data contained in the telemetry packet, in this case a Timed Exposure Bad Pixel Map Dump packet.	
42-4	Packet Sequence Number	This field is used to sequentially number all ACIS telemetry packets.	
42-5	Command Packet Identifier	This is the Packet Identifier of the command causing the dump being performed. This allows the ground to associate the command and the resulting telemetry packets.	
42-6	Pixels[Number of entries]	This is an array of setting entries where each entry has the following format.	
42-7		CCD Identifier	This specifies the CCD containing the bad pixel.
42-8		Row and Column Addresses	These values identify the row and column within the CCD which is bad

Upon receipt of a Dump Bad Pixels Command, the ACIS Back End software shall form and send one or more telemetry packet containing the current list of bad pixels for all CCDs.

3.2.7.3.7 Add Bad Columns

ACIS maintains two bad column maps, one for Timed Exposure Mode, and one for Continuous Clocking Mode. ACIS shall provide a command to add a set of columns to either Bad Column Map. Table 43 describes a generic Add Bad Column Command.

TABLE 43. Add Bad Column Command Packet

Req	Item	Description	
43-1	Packet Length	Length of command packet in 16-bit words	
43-2	Packet Identifier	This is used to identify the command	
43-3	Command Opcode	Mode-specific Add_Bad_Column_Command opcode	
43-4	Columns[Number of entries]	This is an array of setting entries. The number of entries is determined using the Packet Length. Each entry has the following format:	
43-5		CCD Identifier	This specifies the CCD containing the bad column.
43-6		Column Address	This value identifies the bad column within the CCD. Summed image pixels which include the specified CCD column are considered bad.

Upon receipt of this command, the ACIS software shall add the listed columns to the Bad Column Map indicated by the opcode. No attempt is made to eliminate redundant entries.

3.2.7.3.8 Reset Bad Column Map

ACIS shall provide a command to remove all columns from a Bad Column Map. Table 44 describes a generic Reset Bad Column Command.

TABLE 44. Reset Bad Column Map Command Packet

Req	Item	Description
44-1	Packet Length	Length of command packet in 16-bit words
44-2	Packet Identifier	This is used to identify the command
44-3	Command Opcode	Mode-specific Reset_Bad_Column_Command opcode

Upon receipt of this command, the ACIS software shall remove all pixels from the Bad Column Map indicated by the opcode.

3.2.7.3.9 Dump Bad Columns

ACIS shall provide a command to dump the contents of a bad column map into the telemetry stream. This is accomplished via a “Dump Bad Columns” command. This command will have the form as shown in Table 41.

TABLE 45. Dump Bad Columns Command Packet

Req	Item	Description
45-1	Packet Length	Length of command packet in 16-bit words
45-2	Packet Identifier	This is used to identify the command
45-3	Command Opcode	Mode-specific Dump_Bad_Columns_Command opcode

The one or more telemetry packets resulting from this command will contain the information described in Table 42. This requirement may be implemented using a Read Back End Memory Command (see Section 3.2.8.3.1 on page 106) or may be implemented using a customized telemetry representation.

TABLE 46. Dumped Bad Column Map Telemetry Content

Req	Item	Description	
46-1	Packet Synch	This field marks the start of the ACIS packet within the telemetry stream.	
46-2	Packet Word Length	This field indicates the number of 32-bit words in the packet.	
46-3	Format Tag	This field indicates the type of data contained in the telemetry packet, in this case a Continuous Clocking Bad Column Map Dump packet.	
46-4	Packet Sequence Number	This field is used to sequentially number all ACIS telemetry packets.	
46-5	Command Packet Identifier	This is the Packet Identifier of the command causing the dump being performed. This allows the ground to associate the command and the resulting telemetry packets.	
46-6	Columns[Number of entries]	This is an array of setting entries where each entry has the following format:	
46-7		CCD Identifier	This specifies the CCD containing the bad column.
46-8		Column Address	This value identifies the column within the CCD which is bad

Upon receipt of a Dump Bad Columns Command, the ACIS Back End software shall form and send one or more telemetry packet containing the current list of bad columns for all CCDs.

3.2.8 Memory Commands

3.2.8.1 Purpose

A maintainer uses the ACIS memory commands to help debug and diagnose problems within ACIS during flight by giving them the access and control of the various ACIS processors' memory-mapped hardware.

These commands provide the ability to dump the contents of any memory-mapped region of either the Back End Processor or any of the Front End Processors. These commands also provide the ability to read and write directly into any of the DEA board's SRAM or PRAM.

These commands also provide the ability to overwrite any memory-mapped locations, and to call functions directly. Note that, in general, sending memory commands while processing science data will consume some processing and telemetry resources, and may temporarily result in science data loss while the memory command is being executed.

3.2.8.2 Scenario

A maintainer uses the memory commands in a variety of scenarios, however, the most common is to perform a memory dump of a region of the ACIS Back End Processor, such as the Instruction Cache RAM. To do this, the maintainer issues a single "Read Back End Memory" command to ACIS, specifying the start of Instruction Cache, and the length of the entire cache. Upon receipt of the command, ACIS will proceed to produce a series of Read Memory Telemetry Packets, each containing a copy of a contiguous piece of Instruction Cache RAM.

NOTE: Given the non-contiguous blocks in the Mongoose address space (such as Data Cache space vs. Instruction Cache space), a single "dump all memory" feature is not provided. Instead, the ground must issue a request for a specific region of RAM.

3.2.8.3 Functional Requirements

3.2.8.3.1 Read Back End Memory

ACIS shall provide the capability to dump the contents of the Back End Processor Memory into telemetry. This is accomplished via a "Read Memory" command. This command will have the form as shown in Table 47.

NOTE: Due to the nature of the Mongoose Processor's memory architecture, the addressed contiguous region must be either contained entirely within Instruction Cache, or entirely outside of the Instruction Cache.

TABLE 47. Read Back End Memory Command Packet

Req	Item	Description
47-1	Packet Length	Length of command packet in 16-bit words
47-2	Packet Identifier	This is used to identify the command
47-3	Command Opcode	Read_BEP_Memory_Command opcode
47-4	Virtual Address to Read From	32-bit Back End Processor virtual address to start reading from. This address must be long word aligned (i.e. evenly divisible by 4). If not, the instrument will reject the command.
47-5	Length to Read	The number of 32-bit words to read. This value can range from 1 to the maximum addressable memory location within the Back End Processor.

The telemetry packets resulting from this command will contain the information described in Table 48.

TABLE 48. Read Back End Memory Telemetry Content

Req	Item	Description
48-1	Packet Synch	This field marks the start of the ACIS packet within the telemetry stream.
48-2	Packet Word Length	This field indicates the number of 32-bit words in the packet.
48-3	Format Tag	This field indicates the type of data contained in the telemetry packet.
48-4	Packet Sequence Number	This field is used to sequentially number all ACIS telemetry packets.
48-5	Command Packet Identifier	This is the packet identifier of the command causing the dump being performed. This allows the ground to associate the command and the resulting telemetry packets.
48-6	BEP Tick Counter	This item contains the value of the internal timer-tick counter at the time the memory region was read.
48-7	Original Address to Read From	This is the original starting virtual address indicated by the command initiating the read.
48-8	Original Length to Read	This is the original word count specified by the command initiating the read.
48-9	Virtual Address Read From	This indicates the starting virtual address of the data being sent in this telemetry packet.
48-10	Number of words read	This indicates the number of 32-bit words being provided by this telemetry packet (NOTE: May be redundant with Packet Length).
48-11	Read Data	This is the read data as 32-bit words.

Upon receipt of a Read Back End Memory Command, the ACIS Back End software shall produce and send one or more telemetry packets containing the requested memory data from the Back End Processor. If memory-mapped devices were addressed by the command, the contents of their registers are read once, in sequence, as 32-bit words.

Since normal data reads from virtual addresses mapped to the Instruction Cache result in reads from the physical Data Cache RAM, the ACIS software shall recognize Instruction Cache addresses and provide the necessary code to read from the Instruction Cache RAM.

3.2.8.3.2 Write Back End Memory

ACIS shall provide the capability to write directly anywhere into the Back End memory and memory-mapped devices. When used inappropriately, this command may cause ACIS to crash, hang, or otherwise generate questionable science data, and must be used with caution. Under no circumstances, however, may this command cause damage to hardware, or prevent ACIS from recovering given appropriate (possibly time-consuming) corrective action (such as a load from uplink to fix memory and then reset).

NOTE: Due to the nature of the Mongoose Processor's memory architecture, the addressed contiguous region must be either contained entirely within Instruction Cache, or entirely outside of the Instruction Cache.

Table 49 illustrates this content of this command.

TABLE 49. Write Back End Memory Command Packet

Req	Item	Description
49-1	Packet Length	Length of command packet in 16-bit words
49-2	Packet Identifier	Used to identify the command
49-3	Command Opcode	Write_BEP_Memory_Command opcode
49-4	Virtual Address to Write To	32-bit Back End Processor Virtual Address to start writing to. This address must be long word aligned (i.e. evenly divisible by 4). If not, the instrument will reject the command.
49-5	Data to Write	The array of 32-bit data words to write. The number of 32-bit words to write is determined using the Packet Length.

Upon receipt of this command, ACIS shall copy the “Data” section of the command to the specified address. If memory-mapped devices are addressed by the command, the contents of their registers are written once, in sequence, as 32-bit words.

Since normal data writes to virtual addresses mapped to the Instruction Cache result in writes to the physical Data Cache RAM, the ACIS software shall recognize Instruction Cache addresses and provide the necessary code to write to the Instruction Cache RAM.

3.2.8.3.3 Execute Back End Memory

ACIS shall provide the capability to call code contained anywhere in the Back End memory. When used inappropriately, this command may cause ACIS to crash, hang, or otherwise generate questionable science data, and must be used with caution. Under no circumstances, however, may this command cause damage to hardware, or prevent ACIS from recovering given appropriate (possibly time-consuming) corrective action (such as a load from uplink to fix memory and then reset).

Table 50 illustrates this content of this command. The value returned by the called function is supplied in the telemetry stream. Table 51 illustrates the content of this telemetry.

TABLE 50. Execute Back End Memory Command Packet

Req	Item	Description
50-1	Packet Length	Length of command packet in 16-bit words
50-2	Packet Identifier	Used to identify the command
50-3	Command Opcode	Execute_BEP_Memory_Command opcode
50-4	Virtual Address to Execute	32-bit Back End Processor Virtual Address to call. This address must be long word aligned (i.e. evenly divisible by 4). If not, the instrument will reject the command.
50-5	Arguments	The array of arguments to pass. The number of arguments to pass is determined by the Packet Length. The maximum number of 32-bit arguments that can be passed is 20.

TABLE 51. Execute Back End Memory Telemetry Content

Req	Item	Description
51-1	Packet Synch	This field marks the start of the ACIS packet within the telemetry stream.
51-2	Packet Word Length	This field indicates the number of 32-bit words in the packet.
51-3	Format Tag	This field indicates the type of data contained in the telemetry packet.
51-4	Packet Sequence Number	This field is used to sequentially number all ACIS telemetry packets.
51-5	Command Packet Identifier	This identifies the executed command.
51-6	BEP Tick Counter	This items contains the value of the internal timer-tick counter at the time the function was called.
51-7	Original Address to Execute	This is address of the function that was called.
51-8	Return Value	This is the value returned by the called function.

Upon receipt of this command, ACIS shall push the argument list onto the stack and call the function located at the specified address. If the function returns, ACIS shall place the 32-bit returned value into the telemetry stream.

Since the Mongoose cannot execute code loaded into its Data Cache, the ACIS software shall trap attempts to execute from Virtual Addresses which map to the physical Data Cache RAM. Such attempts shall result in the command not being executed and in a run-time warning indicated in the software housekeeping telemetry.

3.2.8.3.4 Read Front End Memory

ACIS shall provide the capability to dump the entire contents of the Front End Processor Memory into telemetry. This is accomplished via a “Read FEP Memory” command. This command will have the form as shown in Table 52.

NOTE: Due to the nature of the Mongoose Processor’s memory architecture, the addressed contiguous region must be either contained entirely within Instruction Cache, or entirely outside of the Instruction Cache.

TABLE 52. Read Front End Memory Command Packet

Req	Item	Description
52-1	Packet Length	Length of command packet in 16-bit words
52-2	Packet Identifier	This is used to identify the command
52-3	Command Opcode	Read_FEP_Memory_Command opcode
52-4	Front End Processor Id	This identifies which Front End Processor to from which to acquire the memory contents.
52-5	Virtual Address to Read From	32-bit Front End Processor virtual address to start reading from. This address must be long word aligned (i.e. evenly divisible by 4). If not, the instrument will reject the command.
52-6	Length to Read	The number of 32-bit words to read.

The telemetry packets resulting from this command will contain the information described in Table 53

TABLE 53. Read Front End Memory Telemetry Content

Req	Item	Description
53-1	Packet Synch	This field marks the start of the ACIS packet within the telemetry stream.
53-2	Packet Word Length	This field indicates the number of 32-bit words in the packet.
53-3	Format Tag	This field indicates the type of data contained in the telemetry packet.
53-4	Packet Sequence Number	This field is used to sequentially number all ACIS telemetry packets.
53-5	Command Packet identifier	This is the packet identifier of the command causing the dump being performed. This allows the ground to associate the command and the resulting telemetry packets.
53-6	BEP Tick Counter	This items contains the value of the internal timer-tick counter at approximately the time (i.e. within a minute) of when the memory region was read.
53-7	Front End Processor Id	This identifies whose memory was read.
53-8	Original Address to Read From	This is the original starting virtual address indicated by the command initiating the read.
53-9	Original Length to Read	This is the original word count specified by the command initiating the read.

TABLE 53. Read Front End Memory Telemetry Content (Continued)

Req	Item	Description
53-10	Virtual Address Read From	This indicates the starting virtual address of the data being sent in this telemetry packet.
53-11	Number of words read	This indicates the number of 32-bit words being provided by this telemetry packet (NOTE: May be redundant with Packet Length).
53-12	Read Data	This is the read data as 32-bit words.

Upon receipt of a Read FEP Memory Command, the ACIS Back End software shall command the Front End to provide the data to the Back End, which then sends it using one or more telemetry packets. If memory-mapped devices were addressed by the command, the contents of their registers are read once, in sequence, as 32-bit words.

Since normal data reads from virtual addresses mapped to the Instruction Cache result in reads from the physical Data Cache RAM, the ACIS software shall recognize Instruction Cache addresses and provide the necessary code to read from the Instruction Cache RAM.

3.2.8.3.5 Write Front End Memory

ACIS shall provide the capability to write directly anywhere into the Front End Memory and Memory-mapped devices. When used inappropriately, this command may cause ACIS to crash, hang, or otherwise generate questionable science data, and must be used with caution. Under no circumstances, however, may this command cause damage to hardware, or prevent ACIS from recovering given appropriate (possibly time-consuming) corrective action.

NOTE: Due to the nature of the Mongoose Processor's memory architecture, the addressed contiguous region must be either contained entirely within Instruction Cache, or entirely outside of the Instruction Cache.

Table 54 illustrates this content of this command

TABLE 54. Write Front End Memory Command Packet

Req	Item	Description
54-1	Packet Length	Length of command packet in 16-bit words
54-2	Packet Identifier	Used to identify the command
54-3	Command Opcode	Write_FEP_Memory_Command opcode
54-4	Front End Processor Id	This identifies which Front End Processor to write to.
54-5	Virtual Address to Write To	32-bit Front End Processor Virtual Address to start writing to. This address must be long word aligned (i.e. evenly divisible by 4). If not, the instrument will reject the command.
54-6	Data to Write	The array of 32-bit data words to write. The number of 32-bit words to write is determined by the Packet Length.

Upon receipt of this command, the Back End shall command the addressed Front End Processor to copy the "Data" section of the command to the specified address. If FEP Memory-mapped devices are addressed by the command, the contents of their registers are written once, in sequence, as 32-bit words.

Since normal data writes to virtual addresses mapped to the Instruction Cache result in writes to the physical Data Cache RAM, the ACIS software shall recognize Instruction Cache addresses and provide the necessary code to write to the Instruction Cache RAM.

3.2.8.3.6 Execute Front End Memory

ACIS shall provide the capability to call code contained anywhere in the Front End Memory. When used inappropriately, this command may cause the Front End processor to crash, hang, or otherwise generate questionable science data, and must be used with caution. Under no circumstances, however, may this command cause damage to hardware, or prevent ACIS from recovering given appropriate (possibly time-consuming) corrective action.

Table 55 illustrates this content of this command. Table 56 illustrates the content of this telemetry.

TABLE 55. Execute Front End Memory Command Packet

Req	Item	Description
55-1	Packet Length	Length of command packet in 16-bit words
55-2	Packet Identifier	Used to identify the command
55-3	Command Opcode	Execute_FEP_Memory_Command opcode
55-4	Front End Processor Id	This identifies which Front End Processor to use for the command
55-5	Virtual Address to Execute	32-bit Front End Processor Virtual Address to call.This address must be long word aligned (i.e. evenly divisible by 4). If not, the instrument will reject the command.
55-6	Arguments	The array of 32-bit arguments to pass. The number of arguments to pass is determined from the Packet Length. The maximum number of 32-bit arguments that can be passed is 20.

TABLE 56. Execute Front End Memory Telemetry Content

Req	Item	Description
56-1	Packet Synch	This field marks the start of the ACIS packet within the telemetry stream.
56-2	Packet Word Length	This field indicates the number of 32-bit words in the packet.
56-3	Format Tag	This field indicates the type of data contained in the telemetry packet.
56-4	Packet Sequence Number	This field is used to sequentially number all ACIS telemetry packets.

TABLE 56. Execute Front End Memory Telemetry Content (Continued)

Req	Item	Description
56-5	Command Packet Identifier	This identifies the executed command.
56-6	BEP Tick Counter	This items contains the value of the internal timer-tick counter at approximately the time (i.e. within a minute) when the function was invoked.
56-7	Front End Processor Id	This identifies the FEP whose function was called.
56-8	Original Address to Execute	This is address of the function that was called.
56-9	Return Value	This is the value returned by the called function.

Upon receipt of this command, the ACIS Back End software shall issue a command to the addressed Front End processor, passing it the argument list. The Front End processor will then push the argument list onto its stack and call the function located at the specified address. If the function returns, the Front End processor shall send the 32-bit returned value (if any) back to the Back End software. The Back End then places the 32-bit returned value (if any) into the telemetry stream.

Since the Mongoose cannot execute code loaded into its Data Cache, the ACIS software shall trap attempts to execute from Virtual Addresses which map to the physical Data Cache RAM. Such attempts shall result in the command not being executed and in a run-time warning indicated via the software housekeeping telemetry stream.

3.2.8.3.7 Read SRAM

ACIS shall provide the capability to read the entire contents of SRAM on the selected DEA board. Due to hardware constraints, execution of this command will cause the DEA sequencer to stop. Table 57 illustrates the format of this command

TABLE 57. Read DEA Board Sequencer RAM Command Packet

Req	Item	Description
57-1	Packet Length	Length of command packet in 16-bit words
57-2	Packet Identifier	Used to identify the command
57-3	Command Opcode	Read_SRAM_Command opcode
57-4	DEA Board Id	This identifies which DEA board to use for the command
57-5	SRAM Index to read	16-bit index within the selected SRAM to read
57-6	Length to read	The number of 16-bit words to read from the SRAM.

The one or more telemetry packets resulting from this command will contain the information described in Table 58

TABLE 58. Read DEA Board Sequencer RAM Telemetry Content

Req	Item	Description
58-1	Packet Synch	This field marks the start of the ACIS packet within the telemetry stream.
58-2	Packet Word Length	This field indicates the number of 32-bit words in the packet.
58-3	Format Tag	This field indicates the type of data contained in the telemetry packet.
58-4	Packet Sequence Number	This field is used to sequentially number all ACIS telemetry packets.
58-5	Command Packet identifier	This is the packet identifier of the command causing the dump being performed. This allows the ground to associate the command and the resulting telemetry packets.
58-6	BEP Tick Counter	This items contains the value of the internal timer-tick counter at approximately the time (i.e. within a minute) of when the SRAM region was read.
58-7	DEA Board Id	This identifies whose SRAM was read.
58-8	Original Index to Read	This is the original index indicated by the command initiating the read.
58-9	Original Length to Read	This is the original count specified by the command initiating the read.
58-10	Index Read	This indicates the starting 16-bit SRAM index of the data being sent in this telemetry packet.
58-11	Number of words read	This indicates the number of 16-bit words being provided by this telemetry packet (NOTE: May be redundant with Packet Length).
58-12	Read Data	This is the read data as 16-bit words.

Upon receipt of this command, the ACIS Back End software shall issue DEA commands to read the SRAM from the selected DEA Board, and acquire and telemeter the responses.

3.2.8.3.8 Write SRAM

ACIS shall provide the capability to write the entire contents of SRAM on the selected DEA board. Due to hardware constraints, execution of this command will cause the DEA sequencer to stop. Table 59 illustrates this content of this command.

TABLE 59. Write DEA Board Sequencer RAM Command Packet

Req	Item	Description
59-1	Packet Length	Length of command packet in 16-bit words
59-2	Packet Identifier	Used to identify the command
59-3	Command Opcode	Write_SRAM_Command opcode

TABLE 59. Write DEA Board Sequencer RAM Command Packet (Continued)

Req	Item	Description
59-4	DEA Board Id	This identifies whose SRAM to overwrite
59-5	SRAM Index to write to	This specifies the starting 16-bit index within the selected SRAM to start writing to.
59-6	Data to Write	The array of 16-bit data to write. The number of words is determined by the Packet Length

Upon receipt of this command, ACIS shall issue DEA commands to load the addressed area of the selected DEA board's SRAM with the "data" section of the command.

3.2.8.3.9 Read PRAM

ACIS shall provide the capability to read the contents of PRAM on the selected DEA board. Due to hardware constraints, execution of this command will cause the DEA sequencer to stop. Table 60 illustrates the format of this command.

TABLE 60. Read DEA Board Program RAM Command Packet

Req	Item	Description
60-1	Packet Length	Length of command packet in 16-bit words
60-2	Packet Identifier	Used to identify the command
60-3	Command Opcode	Read_PRAM_Command opcode
60-4	DEA Board Id	This identifies which DEA board to use for the command
60-5	PRAM Index to read	16-bit index within the selected PRAM to read
60-6	Length to read	The number of 16-bit words to read from the PRAM.

The telemetry packets resulting from this command will contain the information described in Table 61.

TABLE 61. Read DEA Board Program RAM Telemetry Content

Req	Item	Description
61-1	Packet Synch	This field marks the start of the ACIS packet within the telemetry stream.
61-2	Packet Word Length	This field indicates the number of 32-bit words in the packet.
61-3	Format Tag	This field indicates the type of data contained in the telemetry packet.
61-4	Packet Sequence Number	This field is used to sequentially number all ACIS telemetry packets.
61-5	Command Packet identifier	This is the packet identifier of the command causing the dump being performed. This allows the ground to associate the command and the resulting telemetry packets.
61-6	BEP Tick Counter	This items contains the value of the internal timer-tick counter at approximately the time (i.e. within a minute) of when the PRAM region was read.
61-7	DEA Board Id	This identifies whose PRAM was read.

TABLE 61. Read DEA Board Program RAM Telemetry Content (Continued)

Req	Item	Description
61-8	Original Index to Read	This is the original index indicated by the command initiating the read.
61-9	Original Length to Read	This is the original count specified by the command initiating the read.
61-10	Address Read	This indicates the starting 16-bit PRAM address of the data being sent in this telemetry packet.
61-11	Number of words read	This indicates the number of 16-bit words being provided by this telemetry packet (NOTE: May be redundant with Packet Length).
61-12	Read Data	This is the read data as 16-bit words.

Upon receipt of this command, the ACIS Back End software shall issue DEA commands to read the PRAM from the selected DEA board, and acquire and telemeter the responses.

3.2.8.3.10 Write PRAM

ACIS shall provide the capability to write the contents of PRAM on the selected DEA board. Due to hardware constraints, execution of this command will cause the DEA sequencer to stop. Table 62 illustrates this content of this command

TABLE 62. Write DEA Board Program RAM Command Packet

Req	Item	Description
62-1	Packet Length	Length of command packet in 16-bit words
62-2	Packet Identifier	Used to identify the command
62-3	Command Opcode	Write_PRAM_Command opcode
62-4	DEA Board Id	This identifies whose PRAM to overwrite
62-5	PRAM Index to write to	This specifies the starting 16-bit index within the selected PRAM to start writing to.
62-6	Data to Write	The array of 16-bit data to write. The number of words to write is determined by the Packet Length

Upon receipt of this command, ACIS shall issue DEA commands to load the addressed area of the selected DEA board's PRAM with the "data" section of the command.

3.2.9 Software Housekeeping

3.2.9.1 Purpose

ACIS provides the maintainer with a measure of how the ACIS system is operating. This information includes the disposition of commands, statistics on various operating conditions, the current state of the instrument, and fatal error indications.

3.2.9.2 Scenario

In order to help a maintainer develop a history of the operation of ACIS, the ACIS Science Instrument Software maintains and telemeters software housekeeping information. Whenever an observer or maintainer sends a command to the ACIS Science Instrument Software, ACIS posts an echo of the command and its disposition to telemetry. This allows an maintainer to verify that all commands intended for ACIS software were received and interpreted.

In order to allow monitoring of the overall operation of ACIS without relying on its serial science telemetry, ACIS also provides active status information using the discrete telemetry signals, read by the hardware and placed into the Engineering portion of the telemetry stream (see Section 3.1.4.5 on page 36).

3.2.9.3 Functional Requirements

3.2.9.3.1 Command Indicators

ACIS shall provide command receipt and disposition indication in the telemetry stream. After processing each ACIS command, the software will form and post a telemetry packet which contains the Back End timer-tick value at the time the command was received, a result code indicating the disposition of the command, and a verbatim copy of the received command packet.

TABLE 63. Command Echo Telemetry Content

Req	Item	Description
63-1	Packet Synch	This field marks the start of the ACIS packet within the telemetry stream.
63-2	Packet Word Length	This field indicates the number of 32-bit words in the packet.

TABLE 63. Command Echo Telemetry Content (Continued)

Req	Item	Description
63-3	Format Tag	This field indicates the type of data contained in the telemetry packet.
63-4	Packet Sequence Number	This field is used to sequentially number all ACIS telemetry packets.
63-5	BEP Tick Counter	This item contains the value of the internal timer-tick counter at approximately the time at which the command packet was received by the software.
63-6	Command Result Code	This is the disposition code of the command. These codes shall be capable of representing the following types of conditions:
		Command executed successfully without warnings or errors
		Command was not executed (code must indicate reason)
		Command executed with warnings (code must indicate reason)
		Command executed with errors (code must indicate reason)
63-7	Copy of Command Packet	This is a copy of the command packet received by the ACIS software

3.2.9.3.2 Status Indicators

The ACIS software shall indicate its boot and running status using the 4 discrete telemetry signals provided by the ACIS hardware (see Section 3.1.4.5 on page 36).

During boot, these signals shall indicate the current mode of the boot and current state. If, ACIS hangs during the boot, the boot status shall provide an indication of the last action performed prior to the lockup.

While running after a commanded reset, the ACIS software shall cycle the signals between two or more values, indicating the current overall state of the software. If ACIS hangs, these signals will freeze into one state until the Watchdog Timer resets the system.

After a watchdog reset, ACIS shall cycle these signals between values which indicate that ACIS had locked up at some point, and was reset by the Watchdog Timer.

3.2.9.3.3 Run-time Statistics and Monitoring

ACIS shall maintain a set of system statistics representing various operating conditions, such as number of interrupts, numbers of context switches, etc. These statistics also contain the number of occurrences of various warning conditions, such as the number of dropped exposures. These statistics shall be represented as an array of counters. Periodically, ACIS shall telemeter and reset the contents of these statistic counters. Table 64 illustrates the content of a statistics packet.

TABLE 64. Software Housekeeping Telemetry Content

Req	Item	Description
64-1	Packet Synch	This field marks the start of the ACIS packet within the telemetry stream.
64-2	Packet Word Length	This field indicates the number of 32-bit words in the packet.
64-3	Format Tag	This field indicates the type of data contained in the telemetry packet.
64-4	Packet Sequence Number	This field is used to sequentially number all ACIS telemetry packets. Since this is the first packet which is sent after a reset, this field will be zero.
64-5	BEP Tick Counter	This items contains the value of the internal timer-tick counter at approximately the time (i.e. within a minute) when accumulation into the packet started.
	The remainder of the packet contains the set of software statistics reported since the previous housekeeping packet was sent, or since the Back End Processor was re-booted. Each statistic is reported using a statistic identifier, count of reports since the previous housekeepng packet, and the most recently reported value associated with the statistic (NOTE: For some statistics, this third item is always zero). The number of values and slot assignments are listed in the ACIS Software IP&CL Structures Definitions (MIT 36-53204.0204).	
64-6	Statistic Identifier	This identifies the item being reported in this entry.
64-7	Counter Value	This contains the number of times a particular statistic was reported since the last time a software housekeeping packet was sent, or since the instrument was reset if this is the first housekeeping packet.
64-8	Counter Argument	This contains the last reported statistic argument value.

3.2.9.3.4 Watchdog Maintenance

Both the ACIS Back End and Front End software shall periodically set their respective Watchdog Counters (see Figure 10, "Mongoose Component Overview," on page 30). The value written into the counter determines the time-out duration of the Watchdog Timer. In the event of a crash whereby the ACIS software hangs, the Watchdog Timers will reset the hung processor.

3.2.9.3.5 Startup Reporting

Upon reset, after the instrument software has been initialized and is running, the ACIS software shall post a startup telemetry packet, indicating the cause of the restart. Table 65 illustrates the content of this packet.

TABLE 65. Startup Telemetry Content

Req	Item	Description
65-1	Packet Synch	This field marks the start of the ACIS packet within the telemetry stream.
65-2	Packet Word Length	This field indicates the number of 32-bit words in the packet.
65-3	Format Tag	This field indicates the type of data contained in the telemetry packet.
65-4	Packet Sequence Number	This field is used to sequentially number all ACIS telemetry packets. Since this is the first packet which is sent after a reset, this field will be zero.
65-5	BEP Tick Counter	This items contains the value of the internal timer-tick counter at approximately the time (i.e. within a minute) when the packet is sent.
65-6	Reset Reason Code	This indicates the reason the instrument reset. This code specifies either a Commanded Reset, or a Watchdog Reset.
65-7	Startup Information	These items describe the state of the instrument at start-up, such as the version number of the software, the most recent fatal error message code and value, the states of the patch list, system configuration parameters, and stored parameter blocks.

3.2.9.3.6 Fatal Error Reporting and Recovery

If ACIS encounters a condition from which it cannot recover, it shall make a best attempt to flush the current telemetry packet being written to the RCTU, and then issue a telemetry message indicating that ACIS is about to reset. After sending this message, the software uses the Watchdog Timer to reset the instrument within at most 7 or 8 minutes (NOTE: The time-out will probably set to around 10 seconds to improve testability). Table 66 illustrates the content of this error message.

TABLE 66. Fatal Error Telemetry Content

Req	Item	Description
66-1	Packet Synch	This field marks the start of the ACIS packet within the telemetry stream.
66-2	Packet Word Length	This field indicates the number of 32-bit words in the packet.
66-3	Format Tag	This field indicates the type of data contained in the telemetry packet.
66-4	Packet Sequence Number	This field is used to sequentially number all ACIS telemetry packets.

TABLE 66. Fatal Error Telemetry Content (Continued)

Req	Item	Description
66-5	BEP Tick Counter	This items contains the value of the internal timer-tick counter at approximately the time (i.e. within a minute) when fatal condition was reported.
66-6	Fatal Error Code	This indicates the point at which the fatal error was detected.
66-7	Optional Argument	This item is provided to allow more information about the error to be telemetered. This meaning of this item depends on the Fatal Error Code.

3.2.10 DEA Housekeeping Runs

3.2.10.1 Purpose

A maintainer will wish to periodically monitor various Detector Electronics Assembly operating values. ACIS provides commands allowing the maintainer to select which values to monitor, and to start and stop the monitoring process. Some of these housekeeping values are coupled to specific CCDs. As a result, some flexibility is needed, in respect to which housekeeping values are to be sampled.

3.2.10.2 Scenario

ACIS DEA Housekeeping Runs can execute concurrently with and are similar in nature to Science Runs. To perform a DEA Housekeeping Run, the maintainer commands ACIS to accept a parameter block containing a list of DEA registers to sample, and then instructs ACIS to execute the run. ACIS first dumps the parameter block into the telemetry stream, and then proceeds to sample the specified items by issuing queries to the DEA and storing the responses. ACIS then telemeters the set of sampled values. The maintainer allows ACIS to continue its data acquisition for the desired period of time and then commands ACIS to terminate the run.

3.2.10.3 Functional Requirements

3.2.10.3.1 DEA Housekeeping Parameter Block

ACIS shall maintain one or more lists of DEA Housekeeping items to monitor. The maintainer installs this list by issuing a “Load DEA Housekeeping Parameter Block” command., and selects which list to use for a run via the “Slot Id” field of the list. Table 67 illustrates this command.

TABLE 67. Load DEA Housekeeping List Block Command Packet

Req	Field Name	Description
67-1	Packet Word Length	This indicates the total number of 16-bit words in the command packet.
67-2	Packet Identifier	This identifies the command packet.
67-3	Command Opcode	“Load DEA Housekeeping Parameter Block” command opcode. This instructs the ACIS software to store the List Data contained within the packet.
67-4	Slot Id	This identifies the block within ACIS.
67-5	Block CRC or Checksum	This is used to check the load.

TABLE 67. Load DEA Housekeeping List Block Command Packet (Continued)

Req	Field Name	Description
67-6	Parameter Block Identifier	This item is a ground-supplied identifier which is echoed by the instrument software in the DEA housekeeping telemetry.
67-7	Sampling Rate	This specifies the rate at which ACIS should sample and telemeter the acquired information. It is specified in terms of number of seconds between item samples. This parameter can range from 1 to 64 seconds.
67-8	DEA Item List	The remainder of the packet contains the list of DEA items to sample.

3.2.10.3.2 Start DEA Housekeeping Command

ACIS shall accept and process “Start DEA Housekeeping Run” commands. Table 68 describes the format of this command.

TABLE 68. Start DEA Housekeeping Run Command

Req	Field Name	Description
68-1	Packet Word Length	This indicates the total number of 16-bit words in the command packet
68-2	Packet Identifier	This identifies the command packet in a series.
68-3	Command Opcode	“Start DEA Housekeeping Run” command opcode. This instructs the ACIS software to retrieve the parameter block indicated by “Slot Id” below, and run the requested DEA Housekeeping operation. ACIS will continue to run the operation until commanded to stop.
68-4	Slot Id	This identifies the DEA Housekeeping Parameter block to use for the run. This block may have been loaded just prior to the Start Run command, or may be part of either the pre-loaded library, or one of the blocks provided at launch.

Upon receipt of this command, ACIS shall dump the contents of its parameter block into to the telemetry stream, and then start sampling and telemetering the items as specified by the parameter block.

3.2.10.3.3 Stop DEA Housekeeping Command

ACIS shall accept and process “Stop DEA Housekeeping Run” commands as described above. Table 69 describes the format for a generic “Stop DEA Housekeeping” command.

TABLE 69. Stop DEA Housekeeping Run Command

Req	Field Name	Description
69-1	Packet Word Length	This indicates the total number of 16-bit words in the command packet
69-2	Packet Identifier	This identifies the command packet in a series.
69-3	Command Opcode	“Stop DEA Housekeeping Run” command opcode. This instructs the ACIS software to stop the current run.

Upon receipt of this command, ACIS shall stop sampling and telemetering DEA Housekeeping information.

3.2.10.3.4 DEA Housekeeping Telemetry

During a DEA Housekeeping Run, the ACIS software shall report the acquired DEA register values. Table 70 illustrates the content of this telemetry.

TABLE 70. DEA Housekeeping Telemetry Content

Req	Item	Description	
70-1	Packet Synch	This field marks the start of the ACIS packet within the telemetry stream.	
70-2	Packet Word Length	This field indicates the number of 32-bit words in the packet.	
70-3	Format Tag	This field indicates the type of data contained in the telemetry packet.	
70-4	Packet Sequence Number	This field is used to sequentially number all ACIS telemetry packets.	
70-5	Command Packet Identifier	This is the packet identifier of the start command which initiated the current run.	
70-6	BEP Tick Counter	This items contains the value of the internal timer-tick counter at approximately the time (i.e. within a minute) when the data contained in the packet was started to be acquired.	
70-7	The remainder of the packet contains a list of DEA Housekeeping Entry pairs. The number of entries is determined using the packet length:		
70-8		Item Identifier	This value uniquely identifies the DEA Housekeeping item being sent
70-9		Item Value	This is the value of the acquired DEA Housekeeping item.

3.2.11 Post-launch Software Replacement

3.2.11.1 Purpose

In order to enhance the ACIS software, or work around problems discovered after delivery, ACIS shall maintain an on-board list of software changes. These changes are applied upon each warm ROM reboot. The changes are specified using the equivalent of a series of write memory commands which are executed upon start-up of the ACIS software. This form of a "write memory" command is known as a patch.

NOTE: A detailed description of the various BEP boot modes has been added to Appendix F -Boot Modes.

3.2.11.2 Scenario

To install a set of software changes, the maintainer issues a series of "Add Patch" commands to ACIS. ACIS then just records the patch in its internal patch list, to be applied upon the next commanded warm reboot from ROM. Once the maintainer is satisfied that all of the patches needed for the changes are installed, a command is issued to restart the ACIS software. After reloading its core image from ROM, the ACIS start-up code installs each of the patches specified in the patch list. Patches are not installed if the reset was caused by the watchdog timer.

To remove previously installed patches, the maintainer issues a series of "Remove Patch" commands to ACIS. ACIS then removes the specified patches from its list. Once the maintainer has removed the old changes, a command is issued to restart the ACIS software. After reloading its core image from ROM (effectively undoing the selected patches), the ACIS start-up code installs whatever patches are remaining.

In the event a badly conceived patch prevents the maintainer from removing the patch (such as a bad patch to the code which removes patches), the maintainer has the following options:

- Issue a cold commanded re-boot to remove all patches and reload all parameter blocks and bad pixel/column maps from ROM.
- Force a watchdog reset, and then issue a "Remove Patch" command
- Edit the patch list by hand using the "Write BEP Memory" commands (see Section 3.2.8.3.2 on page 108)
- Edit the patch list by hand using "Load From Command" feature (see Section 3.2.13 on page 129).

3.2.11.3 Functional Requirements

3.2.11.3.1 Add Patch Command

ACIS shall provide a command which allows the maintainer to add a change to the software. Table 71 illustrates this command.

TABLE 71. Add Patch Command Packet

Req	Field Name	Description
71-1	Packet Word Length	This indicates the total number of 16-bit words in the command packet
71-2	Packet Identifier	This identifies the command packet in a series.
71-3	Command Opcode	"Add Patch" command opcode. This instructs the ACIS software to add a patch to its list.
71-4	Patch Id	This identifies the patch within the patch list.
71-5	Virtual Address to Write To	32-bit Back End Processor Virtual Address to start writing to. This address must be long word aligned (i.e. evenly divisible by 4).
71-6	Data to Write	The array of 32-bit data values to write. The number of 32-bit words to write is determined by the Packet Length.

Upon receipt of an "Add Patch" command, ACIS shall store the patch information contained in the command. When the software restarts, the ACIS start-up software shall reload ROM to undo all previous patches, and then proceed to install all patches specified in the list.

Since normal data writes to virtual addresses mapped to the Instruction Cache result in writes to the physical Data Cache RAM, the ACIS software shall recognize Instruction Cache addresses and provide the necessary code to write to the Instruction Cache RAM.

NOTE: A method for indicating the patch revision at start-up is to include a patch which modifies the software version number sent in the start-up message (see Section 3.2.9.3.5).

3.2.11.3.2 Remove Patch Command

ACIS shall provide a command which allows the maintainer to remove a change from the software. Table 72 illustrates this command.

TABLE 72. Remove Patch Command Packet

Req	Field Name	Description
72-1	Packet Word Length	This indicates the total number of 16-bit words in the command packet
72-2	Packet Identifier	This identifies the command packet in a series.
72-3	Command Opcode	"Remove Patch" command opcode. This instructs the ACIS software to remove the patch specified by "Patch Id."
72-4	Patch Id	This identifies the patch within the patch list to remove

Upon receipt of a “Remove Patch” command, ACIS shall remove the specified patch from its internal list. The effect of the patch will not be eliminated until the ACIS software restarts.

3.2.11.3.3 Dump Patch list

ACIS shall provide a command to dump the contents of its patch list into the telemetry stream. This is accomplished via a “Dump Patch List” command. This command will have the form as shown in Table 73.

TABLE 73. Dump Patch List Command Packet

Req	Item	Description
73-1	Packet Length	Length of command packet in 16-bit words
73-2	Packet Identifier	This is used to identify the command
73-3	Command Opcode	Dump_Patch_List_Command opcode

The one or more telemetry packets resulting from this command will contain the information described in Table 74. This requirement may be implemented using a Read Back End Memory Command (see Section 3.2.8.3.1 on page 106) or may be implemented using a customized telemetry representation. If implemented using a Read Back End Memory, the organization of the telemetered patch list data will follow the internal orgnazation used by the instrument, and may require all telemetry packets to be interpretable.

TABLE 74. Dumped Patch List Telemetry Content

Req	Item	Description
74-1	Packet Synch	This field marks the start of the ACIS packet within the telemetry stream.
74-2	Packet Word Length	This field indicates the number of 32-bit words in the packet.
74-3	Format Tag	This field indicates the type of data contained in the telemetry packet, in this case a Patch List Dump packet.
74-4	Packet Sequence Number	This field is used to sequentially number all ACIS telemetry packets.
74-5	Command Packet Identifier	This is the Packet Identifier of the command causing the dump being performed. This allows the ground to associate the command and the resulting telemetry packets.
	The remainder of the packet shall contain a series of patch list entries. Each entry specifies the following:	
74-6	Patch Id	This identifies the patch.
74-7	Virtual Address to Write To	32-bit Back End Processor Virtual Address to start writing to. This address must be long word aligned (i.e. evenly divisible by 4).
74-8	Number of words to write	This is the number of words to write in the patch
74-9	Data to Write	The array of 32-bit data values to write.

Upon receipt of a Dump Patch List Command, the ACIS Back End software shall form and send one or more telemetry packet containing the contents of the current patch list.

3.2.12 Load from Read-Only-Memory

3.2.12.1 Purpose

ACIS requires the Load from Read-Only-Memory (ROM) feature as the main way to load and start the instrument software after being powered on, or after a hardware reset.

NOTE: A detailed description of the various BEP boot modes has been added to Appendix F -Boot Modes.

3.2.12.2 Scenario

After the Back End Processor hardware is powered on, or is reset, the processor proceeds to execute its Boot ROM. The Boot ROM then copies code and initialized data from the main bulk ROM into the Back End Processor's RAM and then transfers control to the loaded code.

3.2.12.3 Functional Requirements

3.2.12.3.1 Copy Code/Data from ROM into RAM

After a reset, the BEP Boot ROM shall initialize the processor registers and then shall copy code and initialized data from the instrument's bulk ROM into the BEP's RAM.

3.2.12.3.2 Execute Loaded Code

Once the code has been loaded from the bulk ROM into RAM, the BEP's Boot ROM shall transfer control to the start of the loaded code, which then performs some initial integrity checks, installs any patches, emits an initial start-up telemetry message (see Section 3.2.9.3.5) and starts the main software.

3.2.13 Load from Command

3.2.13.1 Purpose

ACIS provides the Load from Command feature to help the maintainer diagnose and work around problems which occur as a result of failures in the main software ROM, or to undo patches which prevent the ACIS software from successfully running to the point where a “Remove Patch” command can be executed. This feature serves as the maintainer’s “back-door” into ACIS.

NOTE: A detailed description of the various BEP boot modes has been added to Appendix F -Boot Modes.

3.2.13.2 Scenario

In the event of a hardware failure which allows ACIS to boot, but not execute its start-up-code loaded from the bulk ROM, the Boot ROM allows the maintainer to load code directly from the ACIS serial command channel, and execute the loaded code. To accomplish this, the maintainer issues a discrete command to set the ACIS “Boot Modifier” flag, followed by a second discrete command to reset ACIS. The ACIS Boot ROM then detects the assertion of the flag and proceeds to poll the uplink channel for a Start of Uplink Load command. The maintainer then sends a “Start Uplink Load Command”, followed by zero or more “Continue Uplink Load Commands.” Upon receipt of the “Start Uplink Load Command”, ACIS saves the total load length specified in the command, copies the code specified in the command to the desired location, and saves the execution address specified in the command. If the total load length exceeds the length of the command, ACIS waits for one or more “Continue Uplink Load” commands, and concatenates the contained information to the preceding loads. Once all of the code has been loaded, ACIS jumps to the execution address specified in the initial command. The ACIS software execution proceeds from there.

3.2.13.3 Functional Requirements

3.2.13.3.1 Start Uplink Load Command

When the ACIS software re-boots after a reset, it tests the Boot Modifier flag made available by the hardware. If the flag is asserted, ACIS shall poll the command channel for a Start Uplink Load Command. Table 75 illustrates this command.

TABLE 75. Start Uplink Load Command Packet

Req	Item	Description
75-1	Packet Length	Length of command packet in 16-bit words
75-2	Packet Identifier	Used to identify the command
75-3	Command Opcode	Uplink_Load_Command opcode

TABLE 75. Start Uplink Load Command Packet

Req	Item	Description
75-4	Virtual Address to Write To	32-bit Back End Processor Virtual Address to start writing to.
75-5	Total Length to Load	The total number of 32-bit words to write. If the length exceeds the number of words in the command packet, subsequent “Continue Uplink Load Commands” must be sent.
75-6	Virtual Address to start execution from	This specifies the virtual address to jump to after the load is complete.
75-7	Data to Write	The data to write.

Upon receipt of this command, ACIS copies the data to the specified contiguous locations.

If the total load length exceeds the data copied, ACIS polls the command interface for “Continue Uplink Load” commands. If another “Start Uplink Load Command” arrives before the load is complete, ACIS ignores the previous load and starts over. Previously loaded sections will remain until overwritten by a subsequent load.

If the “Start Uplink Load” command’s data satisfies the total load length, ACIS jumps to the execution address specified in the command.

3.2.13.3.2 Continue Uplink Load Command

The maintainer uses “Continue Uplink Load” commands when the desired load is larger than can be handled by single command packet. When ACIS receives a “Start Uplink Load” command which specifies a total load length larger than the data provided by the command, ACIS will poll the command interface for “Continue Uplink Load” commands. Table 76 illustrates this command.

TABLE 76. Continue Uplink Load Command Packet

Req	Item	Description
76-1	Packet Length	Length of command packet in 16-bit words
76-2	Packet Identifier	Used to identify the command
76-3	Command Opcode	Continue_Load_Command opcode
76-4	Data to write	The data to append to information copied from previous “Start Uplink Load” and possibly “Continue Uplink Load” commands.

Upon receipt of this command, ACIS appends the data to location last filled by the previous “Start Uplink Load” command, or possibly, “Continue Uplink Load” command. If the sum of the data copied after this command has been processed is less than the total load length specified in the “Start Uplink Load” command, ACIS will go back and poll the command interface for the next “Continue Uplink Load” command.

If the sum of the data copied after this command has been processed meets the total load length specified in the original “Start Uplink Load” command, ACIS shall jump to the location specified by the “Execution Address” in the original command.

3.2.14 Radiation Monitoring

3.2.14.1 Purpose

In order to extend the life of the CCDs and DEA Analog-to-Digital converters, ACIS monitors the state of the spacecraft controlled Radiation Flag, and can command the DEA to switch CCD biases on and off based on the flag's state.

3.2.14.2 Scenario

The Spacecraft contains a radiation monitor which is controlled by a ground configurable threshold set point. Whenever the measured radiation exceeds this threshold, the spacecraft tells ACIS that the monitor's threshold has been exceeded. When the radiation level subsides, the spacecraft will tell ACIS that the condition has subsided. This information appears to the ACIS software as a single radiation flag.

During periods of unexpectedly high radiation, the radiation monitor's level will trip, and the ACIS radiation monitor flag will be asserted. The software will then issue a command to the DEAs to disable power to the CCDs and terminate the active science run. Meanwhile, the ACIS software will continue to send any backlogged science data and bias information, and will produce DEA housekeeping data that indicates that the boards are powered off. When the radiation environment returns to acceptable levels, the flag will be de-asserted. ACIS will issue a command to the DEAs to allow power to be restored to the CCDs and command the DEA to re-calibrate its A/D converters.

If the radiation monitor is asserted while the instrument is booting and remains asserted until the instrument is completely initialized, the instrument shall act as described above. If the radiation monitor is asserted while the instrument is powered off, or does not remain asserted until the instrument has completed its initialization, the instrument will not react to the monitor.

3.2.14.3 Functional Requirements

3.2.14.3.1 Disable CCD Power

The ACIS software shall periodically sample the radiation monitor flag. When the flag is asserted, the ACIS software shall abort the current science run, flag the bias maps as invalid, and issue a command to the DEAs, disabling power to the CCDs. The most recent science run start and/or stop command which arrives while the flag is asserted shall be saved, along with its parameter block, as the desired state of the instrument once the radiation subsides. DEA Housekeeping will continue, however, but report that the DEA boards are off.

3.2.14.3.2 Re-enable CCD Power

When the radiation monitor flag is de-asserted, ACIS shall issue a command to the DEAs to re-enable power to the CCDs, re-load the DEA board settings, and re-calibrate its A/D converters. If a science run was in-progress when the monitor was originally asserted and a stop command has not yet been received, or if a subsequent start command was received while the monitor is active, the instrument shall start the desired science run, forcing a re-computation of the pixel-by-pixel bias maps.

3.3 Miscellaneous Requirements

3.3.1 Fault Detection and Isolation

Fault detection and isolation requirements specified by the ACIS Contract End Item are met by the Diagnostic, Memory, Housekeeping, and Patching features described in the "System Features" section of this document.

3.3.2 Self-Test

The instrument software shall perform self-test operations as an integral part of its normal activities. These include at least the following:

- Check the integrity of parameter blocks and the patch list after hardware resets.
- Check the integrity of parameter blocks just prior to use for a science run.
- Provide time-outs on command transmissions to the Detector Electronics Assembly, and provide time-outs on status responses from the assembly.
- Detect unexpected resets of the Front End Processors.
- Provide parity checks on the bias maps within the Front End Processors.

3.3.3 Redundancy Management and Hardware Re-configuration

Back End Processor redundancy requirements are not handled by the ACIS Science Instrument Software, but are instead covered by independently commandable, redundant Back End Processor hardware subsections.

Front End Processor redundancy requirements are covered by having multiple Front End Processors. By allowing commandable selection of CCDs, the software indirectly provides the capability to select which Front End Processors are in use (see Section 3.2.7.3.1). This also applies to the Detector Electronics Assembly subsections and CCDs.

3.3.4 Fault Management

There are no critical or semi-critical situations over which the ACIS Science Instrument Software has control. Therefore, the software has no requirements addressing these types of situations.

3.3.5 Watchdog Reset and Crash Recovery

If the instrument re-boots due to a fatal error or watchdog reset, the ACIS Science Instrument start-up software shall not install any patches. The software will idle, waiting for commands.

If a Front End processor resets due to a fatal error or watchdog reset, it will send no further science data to the Back End processor for the remainder of the science run.

3.3.6 Bad Parameter Block Corruption Handling

In the event that the instrument receives a parameter block whose computed integrity check code (CRC or Checksum) does not match the one contained within the block, the software will indicate the error in the Command Echo, but still overwrite the parameter block located at the identified slot.

If the instrument is then commanded to perform a run using a corrupted parameter block (either corrupted during transmission, or corrupted on-board), the software will indicate the condition in the command response, assume that the Imaging/Spectroscopy selection from the block is valid, and use the block to determine whether an Imaging or Spectroscopy run was desired, and then use one of the appropriate default parameter blocks for the run. The activated mode will run until a “Stop Run” command is received.

If the instrument attempts to use a default parameter block whose integrity check code is invalid, the instrument will indicate the condition in the command echo, and idle, waiting for commands.

3.3.7 Start or Bias Commands during a Run

In order to minimize data loss due to dropped commands, if a run has been started and another “Start Run” or “Recompute Bias” command is received, ACIS will indicate the condition in the command echo, proceed to shutdown the current run, and then start to execute the new request.

3.3.8 Timer Interrupt Response Time

In order to ensure the validity of the internal Back End Processor Tick counter (BEP Tick Counter) the handling time of the timer interrupt, plus all other interrupts with a higher priority, plus the longest period during which interrupts are disabled, shall be at least 20% shorter than the fastest timer tick responded to by the system.

3.4 Design Constraints

3.4.1 General

The ACIS Science Instrument Software design shall comply with the standards described and/or referenced by the ACIS Software Development Plan.

3.4.2 Memory Types

The ACIS hardware contains two types of memory; Single-Event Upset (SEU) Immune (current estimates are a couple of bit-flips per year), and bulk memory (current estimates are for 1-100 bit-flips per day). All processor code and stack shall be located in SEU Immune RAM. Any other data, which, if used after being corrupted, can cause the software to crash or corrupt SEU Immune RAM, shall either be located in SEU Immune RAM or be error-checked prior to its immediate use. If a corruption is detected, the software shall indicate the error, and either correct or work-around the corruption.

Given these design constraints, for each processor, the system can expect up to 2 SEU-induced resets per year, and 100 single-bit data corruptions per day.

3.5 Software System Attributes

3.5.1 Maintainability

The ACIS Science Instrument Software shall be designed and documented such that a knowledgeable party, other than MIT personnel, is capable of using and maintaining the instrument software after delivery of the ACIS instrument.

3.5.2 Transferability/Conversion

The ACIS Science Instrument Software is designed specifically for the ACIS hardware. No portability requirements exist, other than that needed to ease testing and provide flexibility to small hardware changes during system development.

In order to support third party (namely, the AXAF Science Center) maintenance of the ACIS software, all tools which directly affect the software delivered as part of the ACIS instrument, and all tools needed to maintain the instrument shall be transferrable to a third party.

4.0 Quality Assurance Requirements

The ACIS software will be developed using documented development, evaluation and acceptance standards. Information will be provided to management to determine how well these standards are being followed. Test results will adhere to validation standards. Refer to the ACIS Software Quality Assurance Plan for more details.

5.0 Test Requirements

The requirements identified in this document shall be validated as indicated in the Software Test Plan and Requirements Traceability Matrix.

Appendix A - Software Commands

TABLE 77. List of Software Commands

Req	Command Type	Command	Reference Page
77-1	Parameter Block Commands		page 40
77-2		Load Timed Exposure Parameter Block	page 53
77-3		Load Continuous Clocking Parameter Block	page 81
77-4		Load DEA Housekeeping Parameter Block	page 122
77-5		Load 2-D Window List	page 57
77-6		Load 1-D Window List	page 84
77-7			
77-8	Science Control Commands		page 40
77-9		Stop Science Run	page 44
77-10		Start Timed Exposure Run	page 48
77-11		Compute Timed Exposure Bias	page 48
77-12		Start Continuous Clocking Run	page 80
77-13		Compute Continuous Clocking Bias	page 80
77-14			
77-15	DEA Housekeeping Control Commands		page 122
77-16		Start DEA Housekeeping Run	page 123
77-17		Stop DEA Housekeeping Run	page 123
77-18			
77-19	Memory Commands		page 106
77-20		Read BEP Memory	page 107
77-21		Write BEP Memory	page 108
77-22		Execute BEP Memory	page 109
77-23		Read FEP Memory	page 110
77-24		Write FEP Memory	page 108
77-25		Execute FEP Memory	page 109
77-26		Read SRAM	page 109
77-27		Write SRAM	page 108
77-28		Read PRAM	page 109
77-29		Write PRAM	page 108
77-30	System Configuration Commands		page 99
77-31		Change System Configuration Setting	page 101
77-32		Add Bad Pixel	page 102
77-33		Reset Bad Pixel List	page 102

TABLE 77. List of Software Commands (Continued)

Req	Command Type	Command	Reference Page
77-34		Dump Bad Pixels	page 103
77-35		Add Bad Continuous Clocking Column	page 104
77-36		Reset Bad Continuous Clocking Column Map	page 104
77-37		Dump Bad Continuous Clocking Columns	page 103
77-38		Add Bad Timed Exposure Column	page 104
77-39		Reset Bad Timed Exposure Column Map	page 104
77-40		Dump Bad Timed Exposure Columns	page 103
77-41			
77-42	Uplink Boot Commands		page 129
77-43		Start Load from Uplink	page 129
77-44		Continue Load from Uplink	page 129
77-45			
77-46	Patch Commands		page 125
77-47		Add Patch	page 126
77-48		Remove Patch	page 126
77-49		Dump Patch List	page 127

Appendix B - Parameter and Configuration Blocks

TABLE 78. List of Configuration and Parameter Blocks

Req	Parameter Block	Reference Page
78-1	System Configuration Parameter Block	page 100
78-2	Timed Exposure Parameter Block	page 53
78-3	Continuous Clocking Parameter Block	page 81
78-4	2-D Window List	page 58
78-5	1-D Window List	page 84
78-6	DEA Housekeeping Parameter Block	page 122

Appendix C - Telemetry Items

TABLE 79. List of Telemetered Items

Req	Item	Reference Page
79-1	Science Frame Format	page 35
79-2	Serial Telemetry Packet Format	page 36
79-3	Science Data	page 46
79-4	Science Run Reports	page 47
79-5	Timed Exposure - Raw Mode Exposure Record	page 70
79-6	Timed Exposure - Raw Mode Pixel Data	page 73
79-7	Timed Exposure - Histogram Exposure Record	page 72
79-8	Timed Exposure - Histogram Data	page 71
79-9	Timed Exposure - Faint Mode Exposure Record	page 73
79-10	Timed Exposure - Faint Mode Event Data	page 73
79-11	Timed Exposure - Faint-Bias Mode Exposure Record	page 75
79-12	Timed Exposure - Faint-Bias Mode Event Data	page 75
79-13	Timed Exposure - Graded Mode Exposure Record	page 77
79-14	Timed Exposure - Graded Mode Event Data	page 77
79-15	Timed Exposure - Compressed CCD Pixel Bias Data	page 77
79-16	Continuous Clocking - Raw Mode Record	page 91
79-17	Continuous Clocking - Raw Mode Pixel Data	page 90
79-18	Continuous Clocking - Faint Mode Record	page 92
79-19	Continuous Clocking - Faint Mode Event Data	page 92
79-20	Continuous Clocking - Graded Mode Record	page 93
79-21	Continuous Clocking - Graded Mode Event Data	page 94
79-22	Continuous Clocking - CCD Pixel Bias Data	page 94
79-23	DEA Housekeeping	page 124
79-24	Dumped Bad Pixel Map	page 103
79-25	Dumped Bad Column Map	page 103
79-26	BEP Memory Dump	page 114
79-27	FEP Memory Dump	page 114
79-28	SRAM Memory Dump	page 114
79-29	PRAM Memory Dump	page 114
79-30	BEP Memory Execution Reply	page 109
79-31	FEP Memory Execution Reply	page 109
79-32	Command Echo	page 117
79-33	Software Statistics	page 118
79-34	Fatal Error Indications	page 120

Appendix D - ACIS Time to S/C Time Guidelines

This section provides a guide for producing algorithms which map the start times to observatory time and hence to UTC and TDB

Determining the Start Time of an Exposure (single exposure time)

The following describes the overall steps in determining the start time of a timed exposure (or of a particular image frame in continuous-clocking mode.) The method first computes the time in units of the BEP clock, and then relates that to observatory time through the synchronous science header timestamps.

1. Determine runStartTime, the starting time of the science run in BEP timer units. It is reported in the scienceReport packet that terminates the run, as well as in each individual exposure packet.
2. Add the DEA startup time, `startupTicks`.

   This is the initial delay, in BEP clock units, between the commanded start-of-run time and the start of the first CCD exposure period. It is a function based on the clocking parameters and method. This function will be provided as part of the AS-BUILT ACIS Software Detailed Design Specification, MIT 36-53200.
3. Inspect any pair of consecutive `fepTimestamp` values in exposure packets.

   If $\mathtt{fepTimestamp}_{i-1}$ is less than $\mathtt{fepTimestamp}_{i}$, exposure n starts at

   $$\mathtt{exposureStartTime}_n = \mathtt{runStartTime} + \mathtt{startupTicks} + n * (\mathtt{fepTimestamp}_i - \mathtt{fepTimestamp}_{i-1})$$

   expressed in BEP timer units. Otherwise, if the FEP time-stamp of exposure i is less than that of exposure i–1, the counter has wrapped, and the start time of exposure n is

   $$\mathtt{exposureStartTime}_n = \mathtt{runStartTime} + \mathtt{startupTicks} + n * (2^{25} + \mathtt{fepTimestamp}_i - \mathtt{fepTimestamp}_{i-1})$$
4. Now examine a pair of AXAF telemetry science frames generated during the run.

   The first 4 bytes of ACIS science data in frame number i contain the science header timestamp (`refTimei`). If $\mathtt{refTime}_{i+1}$ is greater than $\mathtt{refTime}_{i}$, the number of BEP clock ticks per 2.05 second science frame is

   $$\mathtt{ticksPerFrame} = \mathtt{refTime}_{i+1} - \mathtt{refTime}_i$$

   Otherwise, if $\mathtt{refTime}_{i+1}$ is less than $\mathtt{refTime}_{i}$,

   $$\mathtt{ticksPerFrame} = 2^{32} + \mathtt{refTime}_{i+1} - \mathtt{refTime}_i$$
5. Locate the science frame time-stamp nearest to $\mathtt{exposureStartTime}_n$.

   This should occur at the science frame numbered `nf`, where

   $$\mathtt{nf} = i + \mathtt{integer}((\mathtt{exposureStartTime}_n - \mathtt{refTime}_i)/\mathtt{ticksPerFrame})$$

   The frame i should be chosen close to the start of the run. If $\mathtt{refTime}_i$ is less than `runStartTime`, use

   $$\mathtt{nf} = i + \mathtt{integer}((\mathtt{exposureStartTimen} - \mathtt{refTimei} - 2^{32})/\mathtt{ticksPerFrame})$$

instead. Drift between the BEP clock and the observatory clock may be enough to cause an error in calculating `nf`, so a search should be made through nearby science frames for the one with the `refTime` value closest to exposure $\texttt{StartTime}_n$.

6. Extract or compute the Universal Time ($frameUT_{nf}$) corresponding to the start of the frame.

   This operation is determined by the contents of the spacecraft science frame. It was originally planned to store the spacecraft clock in the science header in each science telemetry frame. It is now proposed to compute UTC from the telemetry frame sequence number. The actual method chosen to relate the start of the telemetry frame to UTC is beyond the scope of this document.

7. Determine the precise observatory time of the start of exposure n:

   ```
   exposureUT_n = frameUT_nf + 2.05 *
                  (exposureStartTime_n - refTime_nf)/ticksPerFrame
   ```

   where 2.05 represents the time in seconds between successive science frame pulses (corresponding to 8 minor frames of 1025 bytes each at a rate of 32,000 bits per second; actual telemetry rates may differ.)

Determining the Start Time of an Exposure (two exposure times)

The following describes the overall steps in determining the start time of a particular exposure in Timed-Exposure Mode when two exposure times are used:

1. Compute `runStartTime` + `startupTicks`, as above.
2. Inspect several consecutive exposure records and compute three repetition intervals.

   ```
   int1 = fepTimestamp_i - fepTimestamp_i-1
   int2 = fepTimestamp_i+1 - fepTimestamp_i
   int3 = fepTimestamp_i+2 - fepTimestamp_i+1
   ```

   where exposure number i is evenly divisible by (`dutyCycle`+1). If a rate is negative, add 2^{25}.

3. Compute the exposure starting time in BEP timer units.

   ```
   primaryCount = integer((dutyCycle + n) / (dutyCycle + 1))
   cycleCount = integer(n / (dutyCycle + 1))
   ```

4. Compute the exposure starting time in BEP timer units.

   ```
   exposureStartTime_n = runStartTime + startupTicks +
                 (n - primaryCount - cycleCount) * int1 +
                 primaryCount * int2 + cycleCount * int3 +
                 (cycleCount - primaryCount) * (E_2 - E_1)
   ```

   where E_1 and E_2 are, respectively, the commanded `primaryExposureTime` and `secondaryExposureTime` from the timed exposure parameter block, converted to BEP clock units:

   ```
   E1 = 100,000 * (primaryExposure / 10)
   E2 = 100,000 * (secondaryExposure / 10)
   ```

5. Follow steps 4–7 of the preceding section totranslate $\texttt{exposureStartTime}_n$ to UT.

Appendix E - Additional Goals

This section specifies additional instrument software features which have been requested, but are not part of the core system requirements. These features may or may not delivered as part of the final instrument software release, depending on the availability of development and testing resources.

E.1 Timed Exposure 5x5 Event Telemetry

NOTE: In order to improve the spectral resolution of Back-Side illuminated CCDs, Faint 5x5 Mode has been added to the ACIS Flight Software. However, due to the extremely low event rate supported by Faint-with-Bias 5x5 Mode, the Faint-with-Bias variation has not been added.

This is a variant of Timed Exposure Faint Mode and Faint-with-Bias Mode. All event selection is performed in the same fashion as when the “Front End Selection Algorithm” is in “Event-finding Mode,” except that the Front End’s include the additional 16 pixels surrounding a detected 3x3 event when transferring the event to the Back End Processor. The Back End grades and filters the events as if they were 3x3 events, but includes the additional 16 pixels in the telemetry stream.

Addition of this feature modifies the existing requirements in the following ways:

1. Table 11: Add one new value to “Front End Selection Algorithm”, “Event-finding 5x5” to cause the Front End to send the additional pixels with each event.
2. Table 11: Add two new values to “Event List Packing Code”, “Faint 5x5” and “Faint-with-Bias 5x5”. “Faint 5x5” produces Faint Mode telemetry with the additional 25 pixels packed into the telemetry data packets. “Faint-with-Bias 5x5” adds the corresponding 25 pixel bias values to the data packets.
3. Section 3.2.2.3.10: Indicate that when the FEP is in “Event-finding 5x5” mode, it is required to transfer the 16 surrounding pixel and bias values to the Back End processor with each detected event.

In addition to these changes, the following two subsections are added to Section 3.2.2.

E.1.1 Faint 5x5 Mode Event Telemetry

The Back End software produces Faint Mode 5x5 event telemetry when the “Event List Packing Code” field of the Timed Exposure Parameter Block indicates a “Faint 5x5” packing mode. This mode applies only when the Front End Processor is in “Event-finding 5x5” mode as indicated by the “Front End Selection Algorithm.” In this mode, sets of distinct events are telemetered as 5x5 arrays of pixels. Table 80 illustrates the content of the Faint-

Mode 5x5 event list data packet. This mode uses the same Exposure Record format used by Faint-Mode (see Section 3.2.2.3.21).

TABLE 80. Faint 5x5 Mode Exposure Event Data

Req	Field	Description
80-1	Packet Synch	This field marks the start of the ACIS packet within the telemetry stream.
80-2	Packet Word Length	This field indicates the number of 32-bit words in the packet.
80-3	Format Tag	This field indicates the type of data contained in the telemetry packet, in this case a Timed Exposure Faint-Mode data packet.
80-4	Packet Sequence Number	This field is used to sequentially number all ACIS telemetry packets.
80-5	CCD/FEP Identifiers	These identify which CCD and FEP produced the event
80-6	Data Packet Number	Since data from different CCDs can be interleaved, and also mixed with other kinds of packets, this field sequentially numbers the data packet for a given CCD exposure.
	The remainder of the packet contains zero or more of the following:	
80-7	Position Identifier	This identifies the row and column of the center pixel of the event
80-8	Uncorrected Pulse Heights.	If not zero, these items are the measured (uncorrected) pulse heights of the 25 pixels of the event’s 5x5 array.

E.1.2 Faint-with-Bias 5x5 Mode Event Telemetry

The Back End software produces Faint Bias 5x5 Mode event telemetry when the “Event List Packing Code” field of the Timed Exposure Parameter Block indicates a “Faint-Bias 5x5” packing mode. This mode applies only when the Front End Processor is in “Event-finding 5x5” mode as indicated by the “Front End Selection Algorithm.” In this mode, sets of distinct events are telemetered as 5x5 arrays of pixels along with the corresponding pixel bias values. Table 81 illustrates the content of the Faint-Bias Mode event list data packet. The exposure record format used by this mode is identical to that used by Faint-with-Bias Mode (see Section 3.2.2.3.22).

TABLE 81. Faint-Bias 5x5 Mode Exposure Data Content

Req	Field	Description
81-1	Packet Synch	This field marks the start of the ACIS packet within the telemetry stream.
81-2	Packet Word Length	This field indicates the number of 32-bit words in the packet.
81-3	Format Tag	This field indicates the type of data contained in the telemetry packet, in this case a Timed Exposure Faint-Bias Mode data packet.
81-4	Packet Sequence Number	This field is used to sequentially number all ACIS telemetry packets.
81-5	CCD/FEP Identifiers	These identify which CCD and FEP produced the event

TABLE 81. Faint-Bias 5x5 Mode Exposure Data Content (Continued)

Req	Field	Description
81-6	Data Packet Number	Since data from different CCDs can be interleaved, and also mixed with other kinds of packets, this field sequentially numbers the data packet for a given CCD exposure.
	The remainder of the packet contains zero or more of the following:	
81-7	Position Identifier	This identifies the row and column of the center pixel of the event
81-8	Uncorrected Pulse Heights	These items are the measured (uncorrected) pulse heights of the 25 pixels of the event's 5x5 array.
81-9	Pixel Bias Map Values	These are the computed pixel bias values associated with the event's 25 pixels.

E.2 Timed Exposure Event Amplitude Histograms

This is a distinct processing mode. It uses the standard Front End "Event-finding" mode to produce events with each exposure, and filters the events on the Back End Processor. Rather than telemetering the events, however, the Back End Processor builds histograms of the event amplitudes. There is one histogram for each CCD output node, and each histogram contains at least 4097 amplitude bins. A bin is advanced by 1 whenever an event whose amplitude matches the bin number is accepted. Each bin must be capable of counting at least 64K events. Bins 0 through 4095 correspond to events whose amplitudes correspond to the respective bin number. Bin 4096 corresponds to all accepted events whose amplitude is greater than 4095.

Addition of this feature modifies the existing requirements in the following ways:

1. Table 11: Add a new value to "Event List Packing Code", "Event Amplitude Histogram, which causes the Back End Processor to produce histograms of event amplitudes, rather than telemetering the events themselves.
2. Table 11: Modify the name and description of the "Raw Histogram Exposure Count" to allow it to specify the number of exposures to be accumulated into the event amplitude histograms.

In addition to these changes, the following subsection is added to Section 3.2.2.

E.2.1 Event Amplitude Histogram Telemetry

The Back End software produces "Event Amplitude Histogram Mode" telemetry when the Front End Processor is in "Event-finding Mode," as indicated by the "Front End Selection Algorithm" and the "Event List Packing Code" indicates "Event Amplitude Histogram" mode.

When in this mode, the Back End Processor will filter events received from the Front End Processor. The amplitude of each accepted event is then accumulated into a CCD output-node specific histogram. Once the desired number of exposures has been processed, the Back End will telemeter the generated histograms, and then proceed to process the next collection of exposures. Table 82 illustrates the data packet telemetry content for this mode and Table 83 illustrates the content of an Exposure Record used with Event Amplitude Histogram mode.

TABLE 82. Event Amplitude Histogram Data

Req	Field	Description
82-1	Packet Synch	This field marks the start of the ACIS packet within the telemetry stream.
82-2	Packet Word Length	This field indicates the number of 32-bit words in the packet.
82-3	Format Tag	This field indicates the type of data contained in the telemetry packet, in this case a Timed Exposure Histogram data packet.
82-4	Packet Sequence Number	This field contains the packet sequence number.
82-5	CCD/FEP Identifiers	These identify which CCD and FEP produced the histogram.
82-6	Data Packet Number	Since data from different CCDs can be interleaved, and also mixed with other kinds of packets, this field sequentially numbers the data packet for a given set of CCD histograms.
82-7	Output Node Identifier	This identifies from which output node the histogram was formed.
82-8	Starting Bin Number	This item is the index of the first histogram bin contained within the packet.
82-9	Array of histogram counts	This consists of an array of adjacent histogram bins. Each bin contains a count of the number of accepted events from the specified output node whose amplitude corresponded to the bin index.

TABLE 83. Event Amplitude Histogram Record Content

Req	Field	Description
83-1	Packet Synch	This field marks the start of the ACIS packet within the telemetry stream.
83-2	Packet Word Length	This field indicates the number of 32-bit words in the packet.
83-3	Format Tag	This field indicates the type of data contained in the telemetry packet, in this case a Timed Exposure Event Amplitude Histogram Record packet.
83-4	Packet Sequence Number	This field contains the packet sequence number.
83-5	Science Run Start Time	This identifies the start time of the science run using the ACIS time-stamp latched by the hardware at the start of the run.
83-6	Timed Exposure Parameter Block Identifier	This item is a copy of the Timed Exposure Parameter Block Identifier used to configure the current run.

TABLE 83. Event Amplitude Histogram Record Content (Continued)

Req	Field	Description
83-7	Window Block Identifier	This item is a copy of the Window List Parameter Block Identifier used to configure the current run. If no Window List was specified, this field will be zero.
83-8	Bias Start Time	This identifies the start time of the most recently computed bias map, relative to when the DEA interface latched the ACIS time-stamp at the start of the bias computation.
83-9	Bias Parameter Block Identifier	This item is a copy of the Parameter Block Identifier used to configure the most recent bias map computation.
83-10	CCD/FEP Identifiers	These identify which CCD and FEP produced the histogram.
83-11	Output Node Identifier	This identifies from which output node the histogram was formed.
83-12	First Exposure Number	This uniquely identifies the first exposure acquired into the histogram during the run.
83-13	Last Exposure Number	This uniquely identifies the last exposure acquired into the histogram during the run.
83-14	Number of Exposures Processed	This identifies the total number of exposures acquired in the histogram. Since one or more exposures may be dropped or ignored, this may be different than the "Exposure Number" listed above.
83-15	Number of Pixels above threshold	These specify the total number of pixels from a CCD whose pulse heights were above their respective spatial thresholds during the exposure.
83-16	Number of Events Discarded by Amplitude	These specify the number of events which were discarded due to their amplitude. This field must accommodate the total number of pixels within the CCDs.
83-17	Number of Events Discarded by Grade	These specify the number of events which were discarded due to their "grade."
83-18	Number of Events Discarded by Window	These specify the number of events which were discarded by the processing windows.
83-19	Bias Map Parity Hit Count	This specifies the total number of pixels disabled due to parity hits.

E.3 Timed Exposure Fiducial Pixel Telemetry

This feature allows the maintainer to monitor specific pixels in the CCD on every exposure when the Front End Processor is in "Event-finding Mode", regardless of whether an event is detected in the pixel or not. The list of fiducial pixels are maintained in the Bad Pixel Map (see Section 3.2.2.3.13, Section 3.2.7.3.4 and Section 3.2.7.3.5). Entries are added using the "Add Bad Pixel" command, and are discarded whenever the bad pixel map is reset. The system will support a maximum of 128 fiducial entries per CCD. The set of fiducial pixels is produced by the Front End Processor for each exposure and forwarded to the Back End Processor. The Back End then compresses and telemeters the set.

Addition of this feature modifies the existing requirements in the following ways:

1. Table 11: Add a field to the table, indicating if a FEP should produce fiducial pixels for this run or not.
2. Table 14: Add a field indicating whether the entry is a Bad Pixel or a Fiducial Pixel.
3. Section 3.2.2.3.10: Add description indicating that the Front End must locate and forward fiducial pixels to the Back End Processor on each exposure.
4. Section 3.2.7.3.4: Add field to indicate whether an entry is a bad pixel or a fiducial pixel.

In addition to these changes, the following subsection is added to Section 3.2.2.

E.3.1 Fiducial Pixel Telemetry

Whenever the Front End Processor is in “Event-finding Mode”, it forwards zero or more pairs of fiducial pixel entries to the Back End Processor. On each exposure, the Back End Processor then compresses the set of fiducial pixel data and telemeters the set, using the raw data compression table selection. NOTE: If a fiducial is dropped (for whatever reason), it is represented using the value 4095 prior to compression. Table 84 illustrates the content of a fiducial pixel data telemetry packet.

TABLE 84. Fiducial Pixel Data Telemetry Content

Req	Field	Description
84-1	Packet Synch	This field marks the start of the ACIS packet within the telemetry stream.
84-2	Packet Word Length	This field indicates the number of 32-bit words in the packet.
84-3	Format Tag	This field indicates the type of data contained in the telemetry packet, in this case a Timed Exposure Parity Error data packet.
84-4	Packet Sequence Number	This field is used to sequentially number all ACIS telemetry packets.
84-5	Science Run Start Time	This identifies the start time of the science run using the ACIS time-stamp latched by the hardware at the start of the run.
84-6	Timed Exposure Parameter Block Identifier	This item is a copy of the Timed Exposure Parameter Block Identifier used to configure the current run.
84-7	CCD/FEP Identifiers	These identify which CCD and FEP produced the event
84-8	Exposure Number	Since data from different CCDs can be interleaved, and also mixed with other kinds of packets, this field sequentially numbers the fiducial packet for a given CCD exposure.
84-9	Fiducial Count	This specifies the total # of fiducial pixels sent for the exposure from the CCD.
84-10	Compression Selection Flag and Table Selection	These fields indicate whether or not the raw data has been compressed, and if so, by which compression table.
84-11	Packed or compressed collection of raw 12-bit CCD fiducial pixel pairs	This consists of an array of possibly compressed fiducial pixel data.

Appendix F - Boot Modes

This section refines the description of the various Boot-Modes and actions provided by the flight instrument. This section is taken from the Beta Flight Software Release Notes and explains the various ways in which the Back End Processor is initialized at startup.

The following only describes the various ways in which the Back End Processor software is loaded from EEPROM (see Section 3.2.13 for a description of loading the BEP from the uplink channel).

E.4 Boot Summary

The following is a summary of the flags and actions used to load and start the ACIS Flight Software. The '*' and '+' characters listed in the actions refer to notes after the table:

TABLE 85. Boot Action Summary

action	commanded reset	watchdog reset	bootmodifier	warmboot
power-on	off	off	off	off
cold-boot	on	off	off	off
cold-watchdog	off	on	off	off
uplink	on	off	on	off
uplink	off	on	on	off
warm-boot	on	off	off	on
watchdog-boot	off	on	off	on
uplink	on	off	on	on
uplink	off	on	on	on
uplink+	on	on	on	on
cold-watchdog+	on	on	off	off
uplink+	on	on	on	off
watchdog-boot+	on	on	off	on
uplink*	off	off	on	off
power-on*	off	off	off	on
uplink*	off	off	on	on

+: Appendix C of the Rev. C of the hardware specification (MIT 36-02104) indicates that a commanded reset clears the watchdog status bit, and that a watchdog reset clears the commanded reset status bit. Table 4 in Section 2.1.2.3.6.2, however, indicates the software must explicitly clear these bits. The described action is that taken by the Flight Software in the unlikely event both the commanded and watchdog reset status bits are on when the system is initialized.

*: Appendix C of the Rev. C hardware specification indicates that the bootmodifier and warmboot flags are zeroed by the hardware on a power-on reset (i.e. commanded reset and watchdog reset are 0). The described action is that taken by the Flight Software in the unlikely event both the commanded and watchdog reset status bits are off and either the bootmodifier or warmboot flags are on when the system is initialized.

E.5 Boot from Uplink (uplink)

This type of boot is caused by asserting the BEP's "bootmodifier" and resetting the BEP. This type of boot is also described in Section 3.2.13.

Once the BEP is reset, the BEP's loader, running from EEPROM, will poll the uplink FIFO for a "Start Upload" command packet. Once the packet is received, the BEP extracts the load address, total number of words in the load, and the execution address from the packet. It will then copy the remainder of the command packet into the specified address. If more data is required, the BEP waits for one or more "Continue Upload" command packets, and appends their contents to the previously copied image in BEP RAM. The BEP will continue this until the total number of words have been loaded, or until aborted by another "Start Upload" command is received. Once the entire image has been loaded into RAM, the BEP jumps to the code located at the indicated execution address.

Further interpretation of the boot control flags (other than the bootmodifier flag) is up to the program loaded from the uplink channel.

E.6 Power-On Boot (power-on)

This type of boot is caused by power-cycling the BEP. A power-on of the BEP causes the hardware to de-assert the BEP's "bootmodifier" and "warmboot" status bits. The hardware indicates a power-on reset to the BEP by de-asserting both the "watchdog-reset" and "commanded-reset" status bits.

A power-on boot performs the following actions:

1. The loader executing from EEPROM copies code and data from EEPROM into I-cache and D-cache RAM, and jumps to the loaded code. The loaded code in RAM then performs the remaining actions.
2. Reset the patchlist (eliminate all patches from the list)
3. Copy the default tables from EEPROM into I-cache, overwriting any previously stored tables. These tables include:
    - I-cache table layout format (can only be modified by patch)
    - System Configuration Settings
    - Huffman Compression Tables
    - Timed Exposure Parameter Blocks
    - Continuous Clocking Parameter Blocks
    - 2-D Window List Parameter Blocks
    - 1-D Window List Parameter Blocks
    - DEA Housekeeping Parameter Blocks
    - Timed Exposure Bad Column List

- Continuous Clocking Bad Column List
- Bad Pixel List

4. Issue startup message and continue with the startup procedure

5. Once loaded and running, the instrument will idle, waiting for commands

E.7 Cold Boot (cold-boot)

This type of boot occurs when the BEP is commanded to reset (as opposed to powered-on-reset or watchdog-reset), and its “bootmodifier” and “warmboot” status bits are in a deasserted state.

The operator can clear the “bootmodifier” status bit by issuing a hardware serial digital command (see the DPA Hardware Functional Description and Requirements). Using the “buildCmds” program (MIT 36-60302.01), the operator can generate a command to de-assert the bit by typing:

‘set bootmodifier off’

The operator can clear the “warmboot” status bit by issuing a hardware serial digital command (see the DPA Hardware Functional Description and Requirements). Using “buildCmds”, the operator can generate a command to de-assert the bit by typing:

‘set warmboot off’

To issue a commanded reset, the operator must first assert the BEP’s reset line and then release the BEP’s reset line. Using “buildCmds”, type:

‘halt bep’

followed by:

‘run bep’

The actions taken by the BEP for a cold boot are identical to that taken by a Power-On Boot (see the description above).

E.8 Warm Boot (warm-boot)

This type of boot occurs when the BEP is commanded to reset (as opposed to powered-on-reset or watchdog-reset), and its “bootmodifier” bit is deasserted but its “warmboot” status bit is asserted.

The operator can use “buildCmds” to assert the “warmboot” status bit by typing the following:

‘set warmboot on’

The operator can then issue a commanded reset as described above for a Cold Boot.

The actions taken by the BEP for a warm boot are as follows:

1. Copy code and data from EEPROM into I-cache and D-cache RAM
2. Apply the patches in the patchlist to the copied code and data.
3. Issue startup message and continue with the startup procedure
4. Once loaded and running, the instrument will wait for commands

Note that any table changes made prior to the reset will persist.

E.9 Cold Watchdog Resets (cold-watchdog)

This type of boot occurs when the BEP has been unexpectedly reset by its watchdog timer, and the “warmboot” flag is deasserted. The hardware indicates this type of reset to the BEP software by setting the “watchdog reset” status bit, while the “warmboot” status bit is in a deasserted state.

The actions taken by the BEP for a cold watchdog boot are identical to that taken for a power-on boot or a cold boot.

E.10 Warm Watchdog Resets (watchdog-boot)

This type of boot occurs when the BEP has been unexpectedly reset by its watchdog timer, and the “warmboot” flag is asserted. The hardware indicates this type of reset to the BEP software by setting the “watchdog reset” status bit, while the “warmboot” status bit is in an asserted state.

The actions taken by the BEP for a warm watchdog boot are as follows:

1. Copy code and data from EEPROM into I-cache and D-cache RAM (undoing patches applied during previous resets)
2. Issue startup message and continue with the startup procedure
3. Once loaded and running, the instrument will wait for commands

Note that after a warm watchdog reset, the patchlist is not destroyed, it is just not applied to the code and data reloaded from EEPROM. A subsequent commanded reset will cause the patches to be re-applied. Also, note that changes made to the tables prior to the reset will remain intact.