# Optimizing the efficiency of command load inspection for the Advanced CCD Imaging Spectrometer (ACIS) on the Chandra X-ray Telescope

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## ABSTRACT

The Chandra X-ray Observatory (CXO), launched in July of 1999, contains two focal-plane imaging detectors and two gratings spectrometers. Keeping these instruments operating at an optimal performance level is the responsibility of the Chandra X-ray Center, located in Cambridge, MA. Each week a new set of command loads is generated to be uploaded to the spacecraft for use in the following week. The command loads contain all of the necessary instructions for the observatory to execute a week's worth of science observations and spacecraft maintenance activities. Ensuring that these loads do not compromise the performance of the observatory or its health and safety in any way is a complex procedure. It requires a coordinated review and subsequent approval of the loads from a team of scientists and engineers representing each instrument on the spacecraft. Reviewing the command loads can be quite a daunting task; but with the help of automated scripts and command load interpretation into "human-readable" form, we have been able to streamline the command load review process as well as improve our ability to identify errors in commanding. We present here a detailed review of those scripts utilized in the inspection of command loads for the ACIS instrument. This work was supported by NASA contract NAS8-39073.

**Keywords:** Chandra X-ray Observatory, ACIS, Chandra command loads

## 1. INTRODUCTION

The CXO recently celebrated its third anniversary on 23 July 2002. This spacecraft has been orbiting earth for over 1000 days, approaching a distance traveled of nearly 100 million miles and providing astronomers and astrophysicists with some of the most dramatic and detailed glimpses of the X-ray universe ever seen. The knowledge obtained from these images and data has propelled astronomy into the new millennium. The CXO however does not operate completely autonomously; there is a large team of scientists and engineers dedicated towards optimizing the scientific return of this telescope and ensuring its health and safety for the life of the mission.

The ACIS Operations team is one of those teams and is responsible for the Advanced CCD Imaging Spectrometer, one of the two main focal plane instruments and the instrument that is responsible for 90% of the observations. This team is comprised of four scientists who monitor the health and safety of the instrument, perform calibration analysis of the detector data, and review and approve the ACIS specific portion of the weekly command loads. The command loads are generally released on a weekly schedule and contain commanding for the following week of observing. The command loads contain many different files but the most important from the ACIS perspective is the time line report (TLR). The TLR is produced by the Flight Operations Team (FOT) OffLine System (OFLS) software and contains every command that will be sent to the observatory in the following week and the time of that command's execution. The TLR is the basis of our command load inspection. All scripts and filters depend on this file to find command execution times and to generate the human readable format of the command load. A typical week consists of a command load review in which an error or undesirable aspect of the load is noted and subsequently corrected in the next version of the load, which may be generated and reviewed in a matter of hours. The version scheme is based on letters, the first version of the load is the "A" version, and the second is the "B" and so on. The ACIS scientist on call for that week is responsible for reviewing that load to catch any possible errors, as well as for monitoring the radiation environment of the telescope. This scientist will utilize many scripts written by fellow team members that streamline this review process. As with most projects, the efficiency of the review process evolved over time.

# 2. A BRIEF HISTORY OF CXO COMMAND LOADS

## 2.1 Commanding during orbital activation period

Early in the mission, the daily routine of ACIS operations was anything but routine. The spacecraft was actually run in real time for the first few weeks of the mission, from 23 July to 14 August 1999. At this time, there was no need for load reviews because there were no loads. All commands were sent directly to the spacecraft and communication (COMM) with the telescope was maintained for a majority of the day. The command control room at the Operations Control Center (OCC) in Cambridge, MA was occupied 24 hours a day, 7 days a week. Once operations became slightly more routine, loads were developed on a day-to-day basis from mid-August to the end of September of that year. During this time, loads were generated roughly 2-4 days at a time. This required load reviews on a regular basis, many versions of loads and became extremely taxing on the scientific staff, as they were required to review loads at least once a day. By the end of September, loads moved to generation on a weekly schedule, which was more manageable for all parties involved. Once the issue of how often to generate loads for review was addressed, the new issue of what was the most effective way to review the loads surfaced.

## 2.2 Command load files

As mentioned before, the output of command load generation involves a number of files, all of which tell some part of what the spacecraft will be doing. The first load reviews were done completely by hand, reviewing one of these raw files. The file that was mainly reviewed at this time was the “DOT” file, which contains a two column list of commands with the time of their execution and a command ID number of the form XOBSIDNNNN, where X is either O, E, C, or A (O - OR, E - ER, C - communications pass, and A - action statements), OBSID is the obsid given to a request and NNNN is a running number starting from 0001. Please see the following sample of commanding from the DOT file:

```
ATS,OBSID,ID=0105200,TIME=1999:226:11:33:20.000                  O010520001
ATS,MANVR,Q1=0.30871896,Q2=0.70532291,Q3=-0.14826268,            O010520003
MANSTART=000:00:00:00.000,CHANGE_RATE='FALSE',HW='RWA',          O010520003
TIME=1999:226:11:33:20.000                                       O010520003

ACIS,WSVIDALLDN,TIME=1999:226:11:36:20.000                       O010520004

ACIS,WSPOW1EC3F,TIME=1999:226:11:36:38.000                       O010520005

ACIS,RS_0000001,TIME=1999:226:11:37:41.000                       O010520006

ACIS,RH_0000001,TIME=1999:226:11:37:45.000                       O010520007

ACIS,XTZ0000005,TIME=1999:226:11:38:08.000                       O010520008

ACIS,AA00000000,TIME=1999:226:12:19:40.000                       O010520009

ATS,OBSID,ID=0126400,TIME=1999:226:12:19:40.000                  O012640001
```

This example shows the commanding for a complete observation. One can see the initial maneuver to the object, the explicit ACIS commanding that sets up the video boards, dumps the system information and begins and ends the science run and the ensuing obsid update for the next science observation. Notice that this format depicts when certain commands will be executed, but only one at a time. For a command like an "ATS" which contains many subcommands, those subcommands are not depicted in the report. In addition to this, the timings in the DOT file may not correspond to the actual time that the command is sent to ACIS on the spacecraft. It was for this lack of detail in the commanding, which could miss many subtle errors in the load that the team decided to use the TLR to review loads.

The TLR provides more information and in greater detail regarding the commanding in the load. It provides the exact times that commands will be sent to ACIS; this file is the information that the spacecraft will interpret to carry out the load. It is also somewhat more easily read than the DOT file, but can still be rather complex. Please see the following example of TLR commanding:

| GMT (extended) | Orbit /DSN Event | Command Mnemonic | Crt | Command Description | Command Data (Hex) | Trace ID | OBC Clock | OBC ID | SCS\|Step |
|---|---|---|---|---|---|---|---|---|---|
| 1999:226:11:37:41.000 | | COSATDLY | | NA//NA//-2//0 | 971 4E53 | | 7425619 | A | 128\| 307 |
| 1999:226:11:37:41.000 | | RS_0000001 | | | D80 0003<br>000 3004<br>200 2100 | O010520006.060 | 7425619 | A | 128\| 308 |
| 1999:226:11:37:45.000 | | COSATDLY | | NA//NA//-2//0 | 971 4E62 | | 7425634 | A | 128\| 311 |
| 1999:226:11:37:45.000 | | RH_0000001 | | | D80 0003<br>000 3004<br>400 2300 | O010520007.061 | 7425634 | A | 128\| 312 |
| 1999:226:11:38:08.000 | | COSATDLY | | NA//NA//-2//0 | 971 4EBC | | 7425724 | A | 128\| 315 |
| 1999:226:11:38:08.000 | | XTZ0000005 | | | D80 0004 | O010520008.062 | 7425724 | A | 128\| 316 |

This example shows the beginning of a science run; the commands to dump the system information and the start science are all present here as well as their specific hexadecimal counterparts and the exact time of their execution. This file provides the reviewer with the information needed to do a complete and thorough load review.

## 3. THE LOAD REVIEW

### 3.1 What exactly are we looking for?

One may ask oneself, what exactly needs to be checked before a command load can be sent to the spacecraft? The ACIS team is responsible for performing a number of checks on the loads to be certain that the proper commanding is in place for a given ACIS observation. In addition to this, the team is also responsible for ensuring that no commanding endangers the health and safety of the instrument. One of the most important checks that the team makes in a load review is to ensure that ACIS is not in the focal plane during a perigee passage.

It was discovered early in the mission that leaving ACIS in the focal plane throughout perigee transit exposes the CCDs to low energy particles from radiation zone passage. This significantly increases charge transfer inefficiency (CTI) in the detector, and so it was decided that ACIS should never be commanded to be in the focal plane during perigee passage. The exact sequence that should appear in the load is a Science Instrument Module (SIM) translation to the High Resolution Camera (HRC) occurring right before a Radiation Monitor (RADMON) disable. RADMON is disabled because the radiation zones will always trip the sensors and cause a safe mode, which is not necessary when HRC is in the focal plane through perigee passage. The team also checks that RADMON is enabled after radiation zone exit.

For ACIS science observations the team checks that all of the necessary commanding is present in the load for a specific observation to take place as desired. This involves knowing what each observation calls for and ensuring that the correct parameters are loaded in ACIS. For example, for each science observation there is a video board power down (WSVIDALLDN), a dump system configuration command (RS_0000001) and a dump Huffman tables command (RH_0000001) as well as start and stop science commands (XTZ0000005 and AA00000000 respectively). Each of these specific commands needs to be present in the TLR in order for the observation to be carried out correctly. One can see that this can become quite tedious and lends itself to scripting.

### 3.2 Why the need for automation?

With the copious amount of information present in the TLR and the line after line format of the file, one can quite easily see that there is a large margin for human error in the manual review process. Keep in mind that the TLR contains commanding for all aspects of the CXO, not just ACIS, and to expect each reviewer to know exactly what every observation calls for in a given week to compare with the load is not reasonable. Necessity being the mother of invention, this prompted the ACIS team members to develop a suite of scripts to autonomously check the most critical load review elements, and greatly expedite the review process.

## 4. LOAD REVIEW SCRIPTS

A successful weekly command load from the ACIS perspective is, by definition, one that has passed each automated test and manual check outlined herein.

### 4.1 Script 1: *lr.pl*

The *lr.pl* script is a "wrapper" PERL script that speeds up the load review process. It gathers needed files from the OFLS, creates necessary directories and calls on other scripts that utilize those files while consolidating the actual files to be reviewed. The Flight Operations Team (FOT) first filters the TLR into the "backstop" file; it contains the same information in a different format. The backstop file is then bundled with other command files in a zipped tar file and placed in a directory that all the teams can access for a review. The backstop is the file that is interpreted by the load review scripts. To use *lr*, the user enters the date and version of the current load, the date of the previous week's load and a print option on the command line, similar to this:

```
$: /<path>/lr JUL0802A JUL0102 printer_name
```

The script has an error trap that serves as a useful reminder of how to run it. One simply runs the script on the command line with no arguments and sees the following output:

```
$: /<path>/lr
ERROR! AT LEAST TWO INPUTS REQUIRED!
USAGE: lr {present load} {preceding week} {print option}
```

#### 4.1.1 *lr.pl* script operation

This script performs the following operations:

- For the "A" version of the load, it creates the new directory structure: /<path>/<year>/<load date>/oflsa, for all other versions it only creates the next "oflsX" directory.
- It grabs the FOT backstop file; this file is actually a zipped tarball containing many files, most importantly the backstop file used for the load review.
- *lr* then unzips the tar file, finds the backstop file and extracts it from the tar file.
- The script then uses that backstop file together with the previous load to call another script:
  /<path>/acis-backstop.pl /<path>/<year>/<load date>/oflsa/<backstop-file>
  /<path>/<year>/<previous load date>/ofls/ACIS-History.txt
  The history file provides continuity between weeks and is generated by the *acis-backstop.pl* script.
- Once *acis-backstop.pl* has finished running, *lr* deletes the tar file (it is no longer needed) and sets up a symbolic link between the current version "oflsa" load and the final version "ofls." This is done with each new version of the loads to ensure that the latest version is linked to the final version.
- The user can specify to have the output of *acis-backstop.pl* printed to a pre-defined printer, in this case "printer_name" and the default is not to print.
- All the while the script prompts the user as to what is happening, similar to this:

```
unzipping: JUL0802A_backstop.tar.gz ...
New Directory: /<path>/<year>/JUL0802/oflsa
Backstop File Used: CR189_0900.backstop
History File Used:
```

```
/<path>/<year>/JUL0102/ofls/ACIS-History.txt
Running ACIS Load Review Script...
Script done.
ACIS-LoadReview.txt printed to <printer_name>.
```

One caveat of this script's operation is that it cannot be used in the event of a Target of Opportunity (TOO) or a spacecraft shutdown (normally an "SCS-107" event). In these instances, the continuity of history files is affected by the fact that the load was interrupted and the load products no longer reflect the true state of the spacecraft. During these interruptions, certain portions of the load review have to be done manually. However, an altered version of *lr* called *lr-break.pl*, will still create the necessary directories and download and extract the backstop file; the user has to run *acis-backstop.pl* manually, providing it a hand edited history file.

The *lr* script automates much of what was previously done by hand in setting up the *acis-backstop.pl* load review script. It saves a good deal of time, and helps avoid confusion and human error by uniformly formatting all directory structures. It does not however, actually review the load products. That is where *acis-backstop.pl* enters.

### 4.2 Script 2: *acis-backstop.pl*[1]

This PERL script performs a number of automated tests on the load products, produces 9 output files and calls a total of 3 other scripts in its execution. The ACIS team utilizes the output files to perform several other manual checks and to ensure that no commanding endangers the health and safety of ACIS. As seen above in the *lr.pl* script, to run *acis-backstop.pl* one presents the full path to the backstop file for a given week, as well as the full path of the ACIS history file produced from the preceding week's load review. This script also incorporates an error trap similar to that of *lr.pl* that reminds the user how to run the script:

```
$: /<path>/acis-backstop.pl
ERROR! TWO INPUTS REQUIRED!
USAGE: acis-backstop.pl  {current_week_path/*.backstop} {preceding_week_path/ACIS-History.txt}
```

#### 4.2.1 Output files

The *acis-backstop.pl* program produces several ASCII text files, notably ACIS-LoadReview.txt. This is the output product that the ACIS team explicitly reviews; this file contains information that is relevant to the ACIS team. Examples are ACIS commands and other peripheral commands such as radiation monitor disable/enable, gratings insertion/retraction, OBSID changes, telemetry (TLM) format changes, electron/proton radiation zone entries/exits, perigee/apogee events, SIM translations, SIM focus adjustments, and COMM passes. The file is time-ordered and any errors found by the automated tests are clearly marked. The *acis-backstop.pl* also retrieves the current observing parameters from the observation catalog (OCAT) for a given an OBSID. It executes the *acisparams.csh* script which checks first to see if PERL5LIB is set. If it is, it temporarily removes it, executes *acisparams.pl*, which is the PERL script that actually retrieves the OCAT info, and then resets the PERL5LIB link upon exit. *acis-backstop.pl* also calls another PERL script named *pblockreader.pl*. This PERL script is designed to take as input the parameter block specified in the command load and retrieve relevant details of the parameter block so that the ACIS reviewer can check for consistency with the specified OCAT parameters. The parameter block specifies the exact parameters contained in a science mode (SI mode) observation that will be issued to ACIS. This allows the ACIS team to catch observing errors in the load, in OCAT, or in the way Software Operations Team (SOT)/ACIS Command Generation Software (SACGS) determines the SI mode for each ACIS observation. Please refer to the following sample from the JUL0802 ACIS-LoadReview.txt file:

```
 2002:189:15:29:07.000    8657178  MP_OBSID     2987
===> ObsID change occurs 3.0 minutes after stop science.
LATEST OCAT INFO FOR OBSID 2987:
Target Name: PSS 0016+3209        SI Mode: TE_002A2
Instrument: ACIS-S          Grating: NONE   Type: GO
Exposure Time: 15           Remaining Exposure time: 15
```

```
Offset: Y: -0.33    Z:            Z-sim:
ACIS Exposure Mode: TE Event TM Format: F         Frame Time:
Standard Chips: Y
Chips Turned On: NNYYNYYYYN
Subarray Type: NONE      Start:      Rows:    Frame Time:
Duty Cycle: N     Number:            Tprimary:            Tsecondary:
Onchip Summing: N         Rows: 1 Columns: 1
Event Filter: N    Lower:   Range:
Window Filter: N Start Row:           Start Column:
Height:  Width:
Lower Energy:     Energy Range:     Sample Rate:
Bias:      Frequency:           After:
Dither:
2002:189:15:30:01.285      REAL-TIME COMM ENDS
 ==> COMM DURATION:  90.00 mins.
2002:189:15:48:29.771    8661716  ACISPKT     WSVIDALLDN
2002:189:15:48:47.771    8661786  ACISPKT     WSPOW1EC3F
 ==> WSPOW COMMAND LOADS: All Feps;  I2 I3 S1 S2 S3 S4
2002:189:15:49:50.771    8662032  ACISPKT     RS_0000001
2002:189:15:49:54.771    8662047  ACISPKT     RH_0000001
2002:189:15:50:17.771    8662137  ACISPKT     WT002A3034

ACIS PBLOCK LOADS:
   parameterBlockId          = 0x002a3034
   fepCcdSelect              =    2    7    5    6    3    8
   fepMode                   = 2 # FEP_TE_MODE_EV3x3
   bepPackingMode            = 0 # BEP_TE_MODE_FAINT
   recomputeBias             = 0
   trickleBias               = 1
   subarrayStartRow          = 0
   subarrayRowCount          = 1023
   primaryExposure           = 32
   secondaryExposure         = 0
   dutyCycle                 = 0
   lowerEventAmplitude       = 20
   eventAmplitudeRange       = 3750
   windowSlotIndex           = 65535

2002:189:15:50:21.771    8662153  ACISPKT     XTZ0000005
====> CHANDRA STATUS ARRAY=(ACIS-S,HETG-OUT,LETG-OUT,2987,OORMPEN,CSELFMT2)
2002:189:19:36:49.771    8715179  ACISPKT     AA00000000
 ==> ACIS integration time of 13.59 ks.
```

This example shows an entire science run. One can see the OBSID update, the information obtained from the OCAT, the actual commands issued and the ACIS parameter block. This provides the reviewer with two independent verifications that a load is being executed as desired by the observer and gives the reviewer the actual commands and their exact timing. The end of the ACIS-LoadReview.txt file contains a summary table of ACIS commands and a compilation of all errors that were found. Lastly, a "pass/fail" comment is noted if none of the automated tests failed, or if at least one test failed, respectively. Here is a sample of that table:

```
ACIS LOAD REVIEW SUMMARY
****************************
THERE ARE 17 REAL-TIME COMM PASSAGES IN THIS LOAD.
```

```
FREQUENCY OF ACIS COMMAND OCCURENCES TABLE:
------------------------------------------------------------------------------------------------------
 OBSIDs  WSVIDALLDNs  RS_0000001  RH_0000001  X[TC]Z0000005  AA00000000
------------------------------------------------------------------------------------------------------
  23            6              25            22            22              63

**NOTE: There are 3 perigee crossings in this load.

FREQUENCY OF OTG INSERTIONS/RETRACTIONS:
--------------------------------------------------------
LETG_INs  LETG_REs  HETG_INs  HETG_REs
--------------------------------------------------------
   0            0            2            3

>>>WARNING: THE NO. OF HETG INSERTIONS DOES NOT EQUAL THE NO. OF HETG RETRACTIONS.
------------------------------------------------------------------------------------------------------------------------------------
AT LEAST ONE INSTANCE OF THE FOLLOWING TYPES OF WARNINGS OR ERRORS WERE ENCOUNTERED:

o. RadMon was disabled but the gratings have not been retracted yet.
o. Either Radmon is DISABLED at least 15 ks before electron 1 entry.
   -OR- Radmon was NOT disabled before electron 1 entry.
o. The number of HETG insertions do NOT equal the number of HETG retractions.
-----------------------------------------------------------------------------------------------
ANY LOAD ERRORS??????????
ACIS BACKSTOP REVIEW: One or more ACIS REVIEW tests **FAILED**
```

Two other files this script produces are ACIS-Observations.txt and ACIS-History.txt. The latter simply outputs the Chandra "status array" at the end of the load. That is to say, the state of the instruments at the end of the load. This file takes the form:

```
---------------------------------------------------
ACIS LOAD HISTORY:
OBSERVATIONS FOR REVIEW BY CXC ACIS PERSONNEL
Created By Shanil N. Virani (svirani@cfa)
---------------------------------------------------
USING /data/acis0/LoadReviews/2002/JUL0802/oflsc/CR189_0902.backstop
PREVIOUS LOAD HISTORY FROM: /data/acis0/LoadReviews/2002/JUL0102/ofls/ACIS-History.txt
2002:196:00:14:50.316 ====> CHANDRA STATUS ARRAY AT LOAD END = (ACIS-S,HETG-OUT,LETG-OUT,3071,OORMPEN,CSELFMT2)
```

If this version of a load is approved, then this file becomes the input for the following week's load review. This file becomes very important in the event of a spacecraft shutdown. It needs to be edited by hand to reflect the actual status of the instruments so that the recovery load review will have correct continuity. ACIS-Observations.txt simply tabulates all ACIS science observations (i.e., not CTI measurements nor ACIS next-in-line (NIL) ERs) with the corresponding OBSID, start science command, stop science command, and total integration time written to the file. It is important to note that the computed integration time is the script's best guess at the time on target; meaning it is the time from the last command whether that is an ACIS start science command or a SIM translation or focus movement or a gratings insertion, etc. to the ACIS stop science. This integration time is also written to ACIS-Observations.txt. The script does not "know" when a maneuver ends. Therefore, if the bias computation is completed by the time the maneuver ends, the integration time computed by the script is the actual time on target. If the bias is not complete, then the ACIS reviewer has to account for the remaining bias time in computing the total integration time so that the observation gets as much time on target as is allocated in OCAT. A future enhancement is under development at this time to avoid this complication in the integration time.

To summarize, the following scripts are called by *acis-backstop.pl*:

1. acisparams.csh
2. acisparams.pl
3. pblockreader.pl

The output files it produces are:

1. ACIS-LoadReview.txt - Reviewed by ACIS Operations Team
2. ACIS-Observations.txt - Currently not used
3. ACIS-History.txt - To be used in the next load
4. ACIS-FPHIST.dat - Used in ACIS orbital fluence monitor
5. ACIS-GRATHIST.dat - Used in ACIS orbital fluence monitor
6. ACIS-ATS-FIDSEL.txt - For use by SOT and mission planning (MP)
7. ACIS-OBSHIST.txt - Used in ACIS Real-Time Engineering Web Page
8. ACIS-TLMHIST.txt - Used in ACIS Real-Time Engineering Web Page
9. ACIS-TSCHIST.txt - Used in ACIS Real-Time Engineering Web Page

The last five files in the above list are the ACIS focal plane history files. These files are extremely important as they provide the ACIS team with information that allows the calculation of radiation fluence per orbit. They provide a concise, detailed history of important ACIS parameters that are used in the production of the ACIS Real-Time engineering web page. These files are all basically the same format, an ASCII tab separated file, containing times and relevant mode changes. Each file contains the history of that particular load and once the load is approved for upload these files are appended to global history files that contain the history since the beginning of the mission. For example, ACIS-FPHIST.dat contains the time of focal plane instrument changes during the load:

```
$: more ACIS-FPHIST.dat
2002:194:06:48:56.858    ACIS-S     2529
2002:194:14:58:48.799    ACIS-S     3718
2002:195:03:52:34.494     HRC-S     2928
2002:195:20:06:14.494    ACIS-S    61127
2002:196:00:14:50.316    ACIS-S     3071
```

When the load is approved, these files will be added to a running list of the same parameters since the beginning of the mission. The FP instrument and the gratings history are important in calculating the total radiation fluence that ACIS receives for a given orbit. If ACIS is not in the focal plane, or the gratings are inserted then the fluence is reduced and these files allow the team to factor that change into the fluence calculation.

### 4.2.2 Automated tests

The automated tests that the *acis-backstop.pl* code performs can be broadly categorized into the 3 groups listed below. Under each group is a brief description of the test performed. If a particular test fails a comment to that effect is printed immediately at that time location in the output file.

1. automatic SIM and radiation zone tests

- check that there are ORBITAL EVENTS in the load (apogee/perigee, predicted radiation belt entry and exit times)
- ensure that there is a 10 kilo second (ks) pad time on entry to the rad zone (defined as pad = <time of radiation belt entry> - <time of RADMON disable>)
- ensure that no SIM translation occurs during the entry leg pad time.

- ensure that the RADMON disable command is issued at least 10 ks before entry into the radiation belt but no earlier than 15 ks
- ensure that no SIM translation occurs during the radiation zone transit
- ensure that no SIM translation occurs during the exit leg pad time
- ensure that there is no SIM translation during an ACIS science run
- ensure that the RADMON enable command is issued at least 10 ks after exit from the radiation belt but no later than 15 ks
- ensure that there is a 10 ks pad time on exit form the radiation zone (defined as pad = <time of RADMON enable> - <time of radiation zone exit>)
- Coupled with 2 of the above tests, the script ensures that the RADMON disable occurs before radiation zone entry and that RADMON enable occurs after radiation zone exit.

2. Automatic ACIS tests

- ensure an OBSID change occurs at least 3 minutes after a stop science
- check that there are at least as many occurrences of OBSID changes as there are ACIS start science commands
- check that there is at least one WSVIDALLDN for every start science
- check that there is at least one RS_0000001 for every start science
- check that there is at least one RH_0000001 for every start science
- check that there is at least one ACIS stop science command for every ACIS start science command
- check to see if the instrument is in format (FMT) 2 if ACIS is in the focal plane. (the observatory runs in format 2 when ACIS is in the FP and format 1 when HRC is in the FP)
- check to see that we are in FMT 2 when doing a CTI measurement
- check to see that we are in the HRC-S position prior to radiation belt entry

3. Gratings tests

- ensure that there is a low energy transmission grating (LETG) retraction for every LETG insertion
- ensure that there is a high energy transmission grating (HETG) retraction for every HETG insertion
- check to make sure the gratings are removed prior to perigee transit

### 4.2.3 Manual tests

The manual checks that are performed are primarily related to ACIS commanding for science observations. For a given OBSID, we check that:

- the SI mode in OCAT is consistent with the SI mode in the load
- the ACIS observing parameters stipulated in the OCAT are consistent with that of the parameter block being used in the observation
  This consists of checking:
  - that the chips selected in OCAT are the ones being selected in the parameter block
  - that any sub-array defined in OCAT (start row, number of rows, alternating exposures, frame time) is consistent with the parameter block
  - that the ACIS exposure mode and event telemetry format OCAT entries are consistent with the parameter block
  - that the ACIS CCD “power-on" (ie, WSPOW****) is appropriate for the chip selection specified in OCAT
  - that if a z-sim offset is specified, that it is specified in the load
  - that the command load translates the SIM to the appropriate instrument (ACIS-I or ACIS-S) for that observation
  - that for every ACIS observation there is “power-down" of all the video boards, a dump of the system configuration and Huffman tables, prior to the ACIS start science command
  - that the appropriate gratings are inserted (or retracted) for that observation

- that the correct window block is used if one is specified
- that any unique observing parameters such as on-chip summing, an event filter range, changes to dither, or forced bias, are also defined in the parameter block that is used in the command load
- that the integration time is consistent with the integration time remaining according to OCAT

- the commanding for an ACIS diagnostic measurement is correct and as requested
- prior to perigee, that all video boards are powered down, and the system configuration and Huffman tables are dumped
- for HRC observations greater than 5 ks in duration, that ACIS is obtaining useful calibration data
- there is no significant "dead time" between stop of science observations and onset of calibration measurements on ingress and similarly egress of perigee
- that an OBSID change occurs prior to the start of the next science run
- ensure that the automatic tests have been done correctly

The ACIS operations team will approve a load upon successful completion of these tests.

## 5. CLOSING REMARKS

Over the course of the past 3 years, the load review process has evolved significantly. Scripting has greatly simplified the entire review and has made it possible for the ACIS operations team to be more thorough and complete in their inspection of the loads. The scripts described above enhance our abilities to smoothly operate one of NASA's "Great Observatories," and ensure that all science observations are carried out in the most effective and efficient way possible. With the continued coordination and determination of the staff at the Chandra X-ray Center, the observatory will continue to provide researchers with some of the most stunning and useful scientific data for years to come.

## REFERENCES

1. S. N. Virani, "Performing the ACIS Load Review: *acis-backstop.pl*," Internal CXC Memo, February 2001.