# AIA/SDO FITS Keywords for Scientific Usage and Data Processing at Levels 0.1, 0.3, 0.5, 1.0q, 1.0, and 1.5

(A document in progress)

Keyword Nomenclature:
(Telemetry keywords are ***bold italic***; derived keywords are **bold**; & potential keywords are *italic*)
{# = Integer (~ 0-999); @ = Optional single character A-Z; & = Alpha-numeric}

| | |
|---|---|
| *LL@#* | Lower Left corner pixel for row (X) / column (Y) for Region of Interest (ROI) # on CCD |
| *NAXIS@#* | Dimension (in pixels) along row (X) / column (Y) for ROI # on CCD |
| A@&&&&&& | Originating from telemetry data (@: H = HDR, F = FDB, I = ISP) |

(Note: The definitions of the output data levels included below have been extracted in part from the Stanford SDO DRMS and SUMS computer database, as well as from Phil Scherrer's JSOC Keywords Notes and Processing Plan for Level-0.)

## 1. Level-0.1

### 1.1 Basic Image Information for Level-0.1 (and Above)

Definition of Level-0.1 (Note: The intended use of this level is for JSOC-OPS quick-look viewing in near-real time.)

1. Image Header
   Metadata for Level-0, consisting of keywords derived directly from the image camera header data and those stored in a ground database containing the image characteristics, such as image size, date of observation, telescope, instrument, etc., plus that generated from the associated image status packet (ISP), including the status of mechanisms, the camera itself, the image stabilization system (ISS), and the guide telescope (GT). (See latest image status packet list)
2. Image Data
   Decompressed raw data recompressed using non-lossy compression, such as gzip (see http://www.gzip.org/) or rice.

(Note: At Level-0.1 there will be a different series of header and image data for each camera (telescope) and possibly three series for ROIs, differentiated by the number of ROI.)

From science data packet image header (HDR) information (definition in Doc. AIA02019):

***AHAPID*** = Packet APID (11b; from HDR)
***AHTCS*** = Packet Time Code Seconds (32b; from HDR)
***AHTCSS*** = Packet Time Code Sub Seconds (32b; from HDR)
***AHTLFSN*** = Camera/Frame Serial Number (32b; from HDR)
***AHT1RN*** = Target 1 Row Number (7b; from HDR) for the lower-left pixel of ROI1 (to the nearest 32$^{nd}$ row or column)
***AHT1CN*** = Target 1 Column Number (7b; from HDR) for the lower-left pixel of ROI1

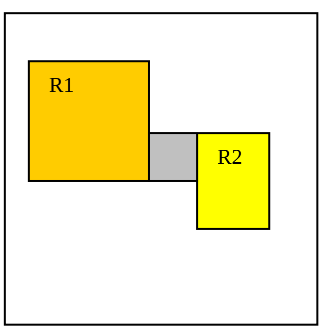
***AHT2RN*** = Target 2 Row Number (7b; from HDR) for the lower-left pixel of ROI2
***AHT2CN*** = Target 2 Column Number (7b; from HDR) for the lower-left pixel of ROI2
***AHFDBID*** = Frame Definition Block ID (8b; from HDR)
***AHTAPC*** = TAP Code (4b; from HDR)
***AHBITID*** = Bit Select ID (4b; from HDR)
***AHCPIDN*** = Compression parameter *n* (4b; from HDR)
***AHCPIDK*** = Compression parameter *k* (4b; from HDR)
***AHLUTID*** = Lookup Table ID (8b; from HDR)

The 2 highest order bits in the 32b Frame Serial Number field will be used to specify the AIA camera (telescope) number, **CAMERA** , associated with the data image, such that
***AHTLFSN*** = **AHTELID** (2b; telescope # -1) + **AHFSN** [Frame Serial Number (the least significant 30b)], where
**AHTELID =** [0, 1, 2, 3] = **CAMERA** – 1, or **CAMERA** = **AHTELID** + 1 = [1, 2, 3, 4].

From Frame Definition Block (FDB) (generated and stored in database on the ground [GDB]):

**AFDBID** = Frame Definition Block ID (8b; from GDB)
**AFDBSM** = SummingMode (4b; from GDB) for summing: 1x1, 2x2, 4x4 (= 0, 1, 2)
**AFDBNW** = NumWindows (4b; from GDB) for number of ROI windows (= 0, 1, 2)
**AFNR1** = NumRows1 (16b; TBD from GDB and crop tables) for height of region 1 in pixels
**AFNC1** = NumCols1 (16b; TBD from GDB and crop tables) for width of region 1 in pixels
**AFNR2** = NumRows2 (16b; TBD from GDB and crop tables) for height of region 2 in pixels
**AFNC2** = NumCols2 (16b; TBD from GDB and crop tables) for width of region 2 in pixels

Using the basic keywords above for the lower-left pixel of the 2 target regions of interest (ROI) and for the widths and heights of the regions, together with the following figure from the AIA Sequence Control Document (#AIA02019), where the lower-left corner pixel (LLC) is the origin with columns designated along the horizontal axis and rows along the vertical axis, the derived keywords below can be determined for each of the Region(s) of Interest (ROIs), 1, 2, and 3, in between, if the first two ROIs are overlapping in rows but not columns, as shown. It is assumed in the ROI figure below that nominal solar north direction is at the top of the figure. (This will be validated, or rotations will be made so solar north is up, in Level-0.3 when the ancillary data for instrument pointing and spacecraft pointing, roll, location, and velocity become available.)




LLC

Derived Keywords:

**NUMWIN** = **AFDBNW + '**TBD' [number of window ROIs:
= 0 for full (4kx4k) CCD ('TBD' = 0);
= 1 for 1 ROI ('TBD' = 0);
= 2 for 2 ROIs ('TBD' = 0);
= 3 for extra region when first 2 regions have overlapping rows but not columns ('TBD' = 1), as in the figure]
**ROI_LLX1** = ***AHT1CN*** * 32 [region 1 (R1) at center of lower left corner pixel, X variable]
**ROI_LLY1** = ***AHT1RN*** * 32 [R1 at center of lower left corner pixel, Y variable]
**ROI_LLX2** = ***AHT2CN*** * 32 [R2 at center of lower left corner pixel, X variable]
**ROI_LLY2** = ***AHT2RN*** * 32 [R2 at center of lower left corner pixel, Y variable]
**ROI_LLX3** = **ROI_LLX1** + **AFNC1** [gray region (R3) at center of lower left corner, X variable]
**ROI_LLY3** = **ROI_LLY1** [R3 at center of lower left corner, Y variable]
**NAXISX1** = **AFNC1** [R1 number of pixels along X axis]
**NAXISY1** = **AFNR1** [R1 number of pixels along Y axis]
**NAXISX2** = **AFNC2** [R2 number of pixels along X axis]
**NAXISY2** = **AFNR2** [R2 number of pixels along Y axis]
**NAXISX3** = **ROI_LLX2 – ROI_LLX1 – AFNC1** [R3 number of pixels along X axis]
**NAXISY3** = **ROI_LLY2 – ROI_LLY1** + **AFNR2** [R3 number of pixels along Y axis]
**NAXIS** = 2, 2, 1, 1 [corresponds to number of axes of images for **NUMWIN** = 0, 1, 2, 3, respectively, to not confuse simple FITS file readers.]
**NAXIS1** = 4096, **NAXISX1,** total number of pixels in area**,** total number of pixels in area
**NAXIS2** = 4096, **NAXISX2,** 0, 0
[the first 2 values of **NAXIS#** correspond, respectively, to the axis length for **NUMWIN** = 0, 1 and the last 2 values correspond to the total number of pixels in ROIs for **NAXIS1** and to zero by definition for **NAXIS2** to not confuse simple FITS file readers for **NUMWIN** = 2, 3.]

Quality/Sanity Check of FDB ID:

Does ***AHFDBID*** **= AFDBID ?**

Reconstructing the acquired image requires, in addition, the appropriate use of ***AHCPIDN***, ***AHCPIDK***, ***AHTAPC, AHBITID, AHLUTID***, **and AFDBSM.** The image observation time can be determined (TBD) from ***AHTCS*** and ***AHTCSS***.

## 1.2 Additional Information for Level-0.1 from Image Status Packet (ISP)

### 1.2.1 Instrument, Mechanisms, & Observable Information

***AIISSMD*** = *A8284* = AIA_IMG_ISS_MODE (1b; from ISP), ISS on/off
***AISQTELN*** = *AIA_SEQ_TEL_NUM* (2b; in ISP), from which again the camera (telescope) number that took this image, **CAMERA**, can be sanity checked
***AISQFSN*** = *AIA_SEQ_FRAME_SN* (30b; in ISP), from which the frame serial number of this image, ***AHFSN***, can be sanity checked (independent of the camera number)
***AIASEN*** = *A82BF* = AIA_IMG_AS_ENCODER (16b; from ISP), aperture selection encoder reading
***AIFWEN*** = *A8292* = AIA_IMG_FW_ENCODER (8b; from ISP), filter wheel selector encoder reading (0-255) for this image
***WAVELNTH*** = AIA_IMG_WAVELENGTH (8b; from ISP), wavelength of this observation: 2 each for camera (telescope) 1, 2, 4 and 4 for camera 3 (as a float in nm (Phil)):

| | |
|---|---|
| = 33.5, 13.1 | for camera 1 |
| = 19.3, 21.1 | for camera 2 |
| = 17.1, 160.0, 170.0, 450.0 | for camera 3 |
| = 9.4, 30.4 | for camera 4 |

***AIFILTYP*** = AIA_IMG_FILTER_TYPE (1b; from ISP), filter type, thick or thin (used for 131 A image only)
***AIMGTYP*** = AIA_IMG_IMAGE_TYPE (8b; from ISP), dark or light “shutter type”, and maybe cal in open filter of UV light curve (?)
***AIIOFSTY*** = AIA_IMG_ISS_OFFSET_Y (16b; from ISP), ISS offset, y-axis
***AIIOFSTX*** = AIA_IMG_ISS_OFFSET_X (16b; from ISP), ISS offset, x-axis
***AIGTSVY*** = AIA_IMG_GT_SIGNAL_VAL_Y (16b; from ISP), Guide Telescope (GT) signal value in y direction
***AIGTSVX*** = AIA_IMG_GT_SIGNAL_VAL_X (16b; from ISP), Guide Telescope (GT) signal value in x direction
***AIAECTI*** = *A82CA* = AIA_IMG_AEC_TABLE_ID (16b; from ISP), Automatic Exposure Control (AEC) tables used with this image
***AIAECENF*** = AIA_IMG_AEC_ENA_FLAG (1b; from ISP), AEC enable flag for this image
***AIAECTYP*** = AIA_IMG_AEC_TYPE (2b; from ISP), AEC table for current wavelength (4 tables per wavelength)
***AIAECDLY*** = AIA_IMG_AEC_DELAY (16b; from ISP), time since image used for AEC
***AIAECMOD*** = AIA_IMG_AEC_MODE (1b; from ISP), mode of AEC (on/off)
***AIFOENFL*** = AIA_IMG_FOCUS_ENA_FLAG (1b; from ISP), flag to indicate if focus table used or not
***AIFTSWTH*** = AIA_IMG_FLT_TYPE_SW_TH (16b; from ISP), filter switch threshold for 131A wavelength (exposure)

Exposure Information:

***AIMGSHEN*** = *A8296* = AIA_IMG_SH_ENCODER (8b; from ISP), shutter selector encoder reading (0-255) for this image

***AIMGOTS*** = *A8285* = AIA_IMG_OBT_TIME_SH_SEC (32b; from ISP), seconds time tag read from OBC shutter time tag register for the shutter operation making this image
***AIMGOTSS*** = *A8286* = AIA_IMG_OBT_TIME_SH_SS (16b; from ISP), subseconds time tag read from OBC shutter time tag register for the shutter operation making this image
***AIMGSHCE*** = *A8213* = AIA_IMG_SH_CMDED_EXPOSURE (16b; from ISP), commanded exposure for this image
***AIMSHOBC*** = *A853E* = AIA_IMG_SH_OPEN_BOT_CENTR (24b; from ISP), shutter timer register value for this position of this image
***AIMSHOBE*** = *A853F* = AIA_IMG_SH_OPEN_BOT_EDGE (24b; from ISP), (same as above)
***AIMSHOTC*** = *A8540* = AIA_IMG_SH_OPEN_TOP_CENTR (24b; from ISP), (same as above)
***AIMSHOTE*** = *A8541* = AIA_IMG_SH_OPEN_TOP_EDGE (24b; from ISP), (same as above)
***AIMSHCBC*** = *A8214* = AIA_IMG_SH_CLOSE_BOT_CENTR (24b; from ISP), (same as above)
***AIMSHCBE*** = *A8291* = AIA_IMG_SH_CLOSE_BOT_EDGE (24b; from ISP), (same as above)
***AIMSHCTC*** = *A853C* = AIA_IMG_SH_CLOSE_TOP_CENTR (24b; from ISP), (same as above)
***AIMSHCTE*** = *A853D* = AIA_IMG_SH_CLOSE_TOP_EDGE (24b; from ISP), (same as above)

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**EXPTIME** Exposure time in seconds (see Appendix 1: AIA Camera Exposure Time Calculation)

## 1.2.2 Time Information

***ATCS027*** = APID027_TIMECODE_SECONDS (32b; from ISP), APID027 timecode in seconds
***ATCSS027*** = APID027_TIMECODE_SUBSECS (32b; from ISP), APID027 timecode in subseconds

Another Quality/Sanity Check can be performed for the observation time

State Information

***AIFCPS*** = *A8225* = AIA_IMG_FC_POSITION (16b; from ISP), currently loaded target value for this mechanism
***AIFDBID*** = *A8315* = AIA_IMG_FDB_ID (16b; from ISP), frame definition block id
***AIFTSID*** = AIA_IMG_FTS_ID (16b; from ISP), framelist timeline schedule (FTS) id for this image
***AIFRMLID*** = AIA_IMG_FRMLIST_ID (16b; from ISP), framelist id for this image
***AIFRLPOS*** = AIA_IMG_FRLIST_POS (8b; from ISP), position within framelist of this frame
***AICFGDL1*** = AIA_IMG_CFG_DELAY_1 (8b; from ISP), mechanism delay 1 for this image
***AICFGDL2*** = AIA_IMG_CFG_DELAY_2 (8b; from ISP), clean table delay for this image
***AICFGDL3*** = AIA_IMG_CFG_DELAY_3 (8b; from ISP), shutter operation delay for this image
***AICDGDL4*** = AIA_IMG_CFG_DELAY_4 (8b; from ISP), readout delay for this image
***AIHISMXB*** = AIA_IMG_HIST_MAX_BIN (16b; from ISP), bin number of maximum of standard histogram for previous image in this wavelength used for the current AEC
***AIHIS192*** = AIA_IMG_HISTC_BN_192 (16b; from ISP), cumulative histogram value at bin #192
***AIHIS348*** = AIA_IMG_HISTC_BN_348 (16b; from ISP), cumulative histogram value at bin #348
***AIHIS604*** = AIA_IMG_HISTC_BN_604 (16b; from ISP), cumulative histogram value at bin #604

***AIHIS860*** = AIA_IMG_HISTC_BN_860 (16b; from ISP), cumulative histogram value at bin #860
***AIHISFSN*** = AIA_IMG_HIST_FSN (32b; from ISP), The FSN of the image from which histogram data was obtained

Quality/Sanity Check of FDB ID: Does ***AIFDBID = AFDBID*** **?**

------------------(These keywords are to be populated when information available)

| | |
|---|---|
| **TELESCOP** = "SDO/AIA" | text, Name of source telescope package |
| **INSTRUME** = "AIA_i" | text, Name of instrument (within telescope package) where i = camera number = 1, 2, 3, or 4 |
| **SIMPLE** = "T" | Boolean, always T for True, if conforming FITS file |
| **BITPIX** = "16" (?) | integer, Bits/pixel: 16, 32, -32, or -64 (negative for floating point) (HMI uses as 16 in L0) |
| **DATE** | text, Date and time of file creation in format: yyyy.mm.ddThh:mm:ss[.sss] in UTC as text |
| **DATE-OBS** | Date and time when observation of this image started (uses DATE format) **(TBD)** |
| **MJD** | float, Date of observation as modified julian day |
| **TIME** | float, Time of observation in seconds within a day. MJD and TIME describe the same instant as DATE-OBS **(TBD)** |
| **ORIGIN** | text, Location where file was made, e.g., "SDO/JSOC-SDP" |

## 2. Other Keywords for Higher Levels (0.3, 0.5, 1.0q, 1.0, and 1.5)

(These keywords are to be populated separately for each instrument when information becomes available following the guidelines for the various levels below. See latest JSOC Keywords Notes for the full implementation of these keywords.)

Coordinate Information (including instrument & spacecraft pointing)

| | |
|---|---|
| *CD#_#@* | Dimensioned transformation matrix |
| **CDELT#@** | Pixel spacing along axis # |
| **CROTA#** | Coordinate rotation (note: PC or CD transformation matrix is preferred) |
| **CRPIX#@** | Reference pixel along axis # |
| **CRVAL#@** | Reference value along axis # |
| **CTYPE#@** | Type of coordinate axis # |

Some **CTYPE** axes:

| | |
|---|---|
| RAW | Image or array with no know coordinate mapping |
| SOLARX | Axis represents position East-West in arc-seconds, positive is to west from the solar disk center |
| SOLARY | Axis represents position North-South in arc-seconds from the solar disk center. **CUNIT1** and **CUNIT2** default to "arcsec" if not present. |
| HPLN-TAN | Helioprojective longitude, tangent projection (Same as SOLARX but CDELT1 must be in degrees). |

HPLT-TAN Helioprojective latitude, tangent projection (Same as SOLARY but CDELT2 must be in degrees).

**CUNIT#@** Units along axis #
*PC#_#@* Transformation matrix
**R-SUN** Radius of the Sun in m (float)
**DSUN_OBS** Distance from Sun's center to SDO in m (float)
**RSUN_REF** Radius of the Sun in m, depends on wavelength (float)
**X0** X-axis location of solar disk center in pixels (float)
**Y0** Y-axis location of solar disk center in pixels (float)
**SDO_ROLL** Position angle of solar pole wrt the SDO Z axis (float, degrees)
**IM_SCALE** Arc-sec per pixel default value for the particular instrument (float)
**XCEN** X co-ordinate of array center (float)
**YCEN** Y co-ordinate of array center (float)

where **a** = **CROTA2**

**XCEN = CRVAL1 + CDELT1*cos(a)*((NAXIS1+1)/2 – CRPIX1)**
**– CDELT2*sin(a)*((NAXIS2+1)/2 – CRPIX2)**
**YCEN = CRVAL2 + CDELT1*sin(a)*((NAXIS1+1)/2 – CRPIX1)**
**+ CDELT2*cos(a)*((NAXIS2+1)/2 – CRPIX2)**

Observation Planning Information

**OBJECT** Name of object
**OBJ_ID** Object identifier, e.g. active region number
**OBSERVER** Name of observer
**OBS_PROG** Name of the observing program
**SCI_OBJ** The science objective of the observation
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**EXTEND** FITS file may contain extensions
**COMMENT** ASCII comment (can be multiple)
**HISTORY** ASCII history record (can be multiple)
**FILENAME** Name of the data file
**LEVEL NUMBER** of image
**VERSION** of reformatter
**QUALITY** of data
**PIPELINE VERSION**

**TBD**: keywords for S/C information, orbit information, etc., when available and derived keywords, e.g., statistics, bad pixels, flat fielding, image center, etc.

Reformatter Information

***AIVNIMST*** *= A831A = AIA_VER_NUM_IMAGE_STATUS,* ISP version number
***ACSUM027*** *= APID027_CHECKSUM,* ISP checksum

(Note: Some of the above keywords can be updated based on values in the ISP, e.g., **CDELTi** may be set since darks and normal images can be differentiated.

More level definitions

Definition of Level-0.3 (Note: The intended use of this level is for quick-look higher-level data products in near-real time with a few minute lag from Level-0.1.)

1. Header
   Metadata for Level-0.1 plus that generated or updated from ancillary information about instrument pointing and roll, spacecraft location and velocity using flight dynamics predict data (FDS), the time of the observation with respect to the spacecraft or instrument clock, and known errors in such clocks, as well as information concerning the state of the instrument, etc., to provide the lowest level of scientifically-useful data for quick look and other applications.
2. Data
   Decompressed raw data recompressed using non-lossy compression, such as gzip or rice. (Same as that for Level-0.1)

(Note: Since FDS data will be available at this level, it should be possible to set **CTYPEi** to SOLARX and SOLARY, and add **CRPIXj, CRVALi, and CROTAj** estimates assuming the image is centered on the CCD.)

Definition of Level-0.5 (Note: This is a delayed but more complete version of Level-0.3, lagging real time by hours up to a day.)

1. Header
   Metadata for Level-0.3 plus that updated from the final versions of SDO HK roll information and FDS data.
2. Data
   Decompressed raw data recompressed using non-lossy compression, such as gzip or rice. (Same as that for Level-0.1)

Definition of Level-1.0q (Note: The intended use of this intermediate, temporary data series is to facilitate quick-look observable computations lagging real time by at most a few minutes.)

1. Header
   Metadata for Level-0.3 reduced to those scientific FITS keywords needed for analysis at Level-1 plus updating the image coordinate mapping keywords to meaningful and nearly correct values.
2. Data
   Decompressed raw data (level 0) calibrated by applying pixel corrections for exposure time, integer pixel shifts for alignment between telescopes, identifying bad pixels to be carried along with the image segment, as well as time-dependent, on-orbit calibrations, such as gain variations of 4 quadrants, and finally recompressed using non-lossy compression, such as gzip or rice.

(Note: At this level the following can be set: **CTYPEi, CRPIXj, CRVALi, CROTAj, R_SUN, X0, Y0, XCEN, and YCEN** to meaningful and nearly correct values.)

Definition of Level-1.0 (Note: This temporary level is generated on demand from Level-0.5 and is held for up to 60 days.)

1. Header
   Metadata for Level-0.5 reduced to those scientific FITS keywords needed for analysis at Level-1 plus updating the image coordinate mapping keywords to meaningful and nearly correct values.
   (Note that the data of this level are equivalent to the lowest level provided by TRACE, except for the reversible pixel and gain adjustments.)
2. Data
   Decompressed raw data (level 0) calibrated by applying pixel corrections for exposure time, integer pixel shifts for alignment between telescopes, identifying bad pixels to be carried along with the image segment, as well as time-dependent, on-orbit calibrations, such as gain variations of 4 quadrants, and finally recompressed using non-lossy compression, such as gzip or rice.

Definition of Level-1.5 (Note: The output from this level will be permanently stored.)

1. Header
   Metadata for Level-1.0 updated for the applied calibrations below (that have irreversibly modified the data).
2. Data
   Decompressed Level-1.0 data images that are de-spiked using the bad pixel map, adjusted for plate scale and sub-pixel registration, roll corrected, as well as applied vignette and optical correcting flat fields, and finally recompressed using non-lossy compression, such as gzip or rice.

## 3. Draft of a Sample Level 1.0 Header with Keywords

| | | | | Section of this document |
|---|---|---|---|---|
| SIMPLE | = | T | | 1.2.2 |
| BITPIX | = | 16 | | 1.2.2 |
| NAXIS | = | 2 | | 1.1 |
| NAXIS1 | = | 4096 | | 1.1 |
| NAXIS2 | = | 4096 | | 1.1 |
| BLANK | = | -32768 | | (definition) |
| DATE | = | ‘2008-01-08T18:57:38’ | | 1.2.2 |
| DATE-OBS | = | ‘2008-01-08T18:56:00’ | | 1.2.2 |
| MJD | = | 2454474 | | 1.2.2 |
| TIME | = | 24960.0 | | 1.2.2 |
| ORIGIN | = | ‘SDO/JSOC-SDP’ | | 1.2.2 |
| TELESCOP | = | ‘SDO/AIA’ | | 1.2.2 |
| INSTRUME | = | ‘AIA_i’ | | 1.2.2 |
| CAMERA | = | 3 | | 1.1, 1.2.1 |
| WAVELNTH | = | 17.1 | | 1.2.1 |
| OBJECT | = | ‘NAME OF OBSERVATION OBJECT’ | | 2.0 |
| OBJ_ID | = | ‘OBJECT IDENTIFIER’ | | 2.0 |
| OBSERVER | = | ‘NAME OF OBSERVER’ | | 2.0 |
| OBS_PROG | = | ‘NAME OF OBSERVING PROGRAM’ | | 2.0 |
| SCI_OBJ | = | ‘SCIENCE OBJECTIVE’ | | 2.0 |
| FSN | = | 75000 | | 1.1, 1.2.1 |
| ROI_LLX1 | = | 0 | | 1.1 |
| ROI_LLY1 | = | 0 | | 1.1 |
| ROI_LLX2 | = | 0 | | 1.1 |
| ROI_LLY2 | = | 0 | | 1.1 |
| ROI_LLX3 | = | 0 | | 1.1 |
| ROI_LLY3 | = | 0 | | 1.1 |
| NAXISX1 | = | 4096 | | 1.1 |
| NAXISY1 | = | 4096 | | 1.1 |
| NAXISX2 | = | 0 | | 1.1 |
| NAXISY2 | = | 0 | | 1.1 |
| NAXISX3 | = | 0 | | 1.1 |
| NAXISY3 | = | 0 | | 1.1 |
| FOVX1 | = | 1020 | “Field of View in CUNITi” | TBD |
| FOVY1 | = | 1020 | “Field of View in CUNITi” | TBD |
| FOVX2 | = | 0 | “Field of View in CUNITi” | TBD |
| FOVY2 | = | 0 | “Field of View in CUNITi” | TBD |
| FOVX3 | = | 0 | “Field of View in CUNITi” | TBD |
| FOVY3 | = | 0 | “Field of View in CUNITi” | TBD |
| CTYPE1 | = | ‘SOLARX’ | | 2.0 |
| CTYPE2 | = | ‘SOLARY’ | | 2.0 |

| | | | | |
|---|---|---|---|---|
| CROTA1 | = | 0.0 | | 2.0 |
| CROTA2 | = | 0.0 | | 2.0 |
| CDELT1 | = | 0.5 | | 2.0 |
| CDELT2 | = | 0.5 | | 2.0 |
| CRPIX1 | = | -357.291 | | 2.0 |
| CRPIX2 | = | 850.624 | | 2.0 |
| CRVAL1 | = | 0.0 | | 2.0 |
| CRVAL2 | = | 0.0 | | 2.0 |
| CUNIT1 | = | ‘ARCSEC’ | | 2.0 |
| CUNIT2 | = | ‘ARCSEC’ | | 2.0 |
| CRDER1 | = | ‘Estimate of random error in 1 as CUNITi’ | | 2.0 |
| CRDER2 | = | ‘Estimate of random error in 2 as CUNITi’ | | 2.0 |
| CSYSER1 | = | ‘Estimate of systematic error in 1 as CUNITi’ | | 2.0 |
| CSYSER2 | = | ‘Estimate of systematic error in 2 as CUNITi’ | | 2.0 |
| RSUN_REF | = | 696000000 | | 2.0 |
| X0 | = | 0.0 | | 2.0 |
| Y0 | = | 0.0 | | 2.0 |
| SDO_ROLL | = | 0.0 | | 2.0 |
| R_SUN | = | ‘Radius of the Sun’s image in pixels’ | | 2.0 |
| SAT_ROT | = | ‘Position angle of solar pole wrt the SDO Z axis’ | | 2.0 |
| INST_ROT | = | ‘Rotation of the camera from the SDO Z axis’ | | 2.0 |
| IM_SCALE | = | 0.5 | | 2.0 |
| XCEN | = | 434.895 | | 2.0 |
| YCEN | = | -169.062 | | 2.0 |
| SUM_MODE | = | 1 | | 1.0 |
| TEMP1 | = | 17.9 | “Temperature Reading” | TBD |
| TEMP2 | = | 25.2 | “Temperature Reading” | TBD |
| TEMP3 | = | -30.3 | “Temperature Reading” | TBD |
| TEMP4 | = | -60.5 | “Temperature Reading” | TBD |
| COMDEXPT | = | 5.0 | | 1.2.1 |
| EXPTIME | = | 5.0399 | | 1.2.1, TBD |
| FILT_TYP | = | 1 | | 1.2.1 |
| IMG_TYP | = | ‘LIGHT’ | | 1.2.1 |
| PERCENTD | = | 100.0 | | TBD |
| IMG_MIN | = | 81.0 | | TBD |
| IMG_MAX | = | 4100.0 | | TBD |
| IMG_AVG | = | 218.345670 | | TBD |
| IMG_DEV | = | 22.687300 | | TBD |
| DATAP01 | = | 722.00000 | | TBD |
| DATAP10 | = | 726.00000 | | TBD |
| DATAP25 | = | 730.00000 | | TBD |
| DATAP75 | = | 1094.0000 | | TBD |
| DATAP90 | = | 1368.0000 | | TBD |
| DATAP95 | = | 1662.0000 | | TBD |
| DATAP98 | = | 2282.0000 | | TBD |
| DATAP99 | = | 2826.0000 | | TBD |

| | | |
|---|---|---|
| EXTEND | = ‘FITS FILE EXTENDED? T or F | 2.0 |
| COMMENT | = ‘COMMENT’ | 2.0 |
| HISTORY | = ‘ASCII HISTORY RECORD, ONE OR MORE’ | 2.0 |
| FILENAME | = ‘NAME OF DATA FILE’ | 2.0 |
| LVL _NUM | = ‘LEVEL NUMBER’ | 2.0 |
| VERSION (of reformatter) | | 2.0 |
| QUALITY (of data) | | 2.0 |
| PIPELINE VERSION | | 2.0 |
| END | | |

Appendix 1: AIA Camera Exposure Time Calculation

Telemetry data required:

***AIMGSHCE*** = AIA_IMG_SH_CMDED_EXPOSURE
***AIMSHOBC*** = AIA_IMG_SH_OPEN_BOT_CENTR
***AIMSHOBE*** = AIA_IMG_SH_OPEN_BOT_EDGE
***AIMSHOTC*** = AIA_IMG_SH_OPEN_TOP_CENTR
***AIMSHOTE*** = AIA_IMG_SH_OPEN_TOP_EDGE
***AIMSHCBC*** = AIA_IMG_SH_CLOSE_BOT_CENTR
***AIMSHCBE*** = AIA_IMG_SH_CLOSE_BOT_EDGE
***AIMSHCTC*** = AIA_IMG_SH_CLOSE_TOP_CENTR
***AIMSHCTE*** = AIA_IMG_SH_CLOSE_TOP_EDGE

***AIMGSHCE*** is the commanded exposure (16 bits) starting from ~0.005 s (due to size of narrow shutter slit) in 0.004 s steps to 262.14 s [$(2^{16} -1) * 4*10^{-3} = 262140*10^{-3}$] (timings are from document AIA01259 rev H). The maximum exposure of the AIA shutter mechanism is ~268 s. The 24 bit shutter open and close time measurements have a resolution of 0.000004 s, starting at 0.000004 s up to ~67 s [$(2^{24} – 1) * 4*10^{-6} = 67108860*10^{-6}$]. The three possible rollovers of the shutter close timers from ~67 s up to ~262 s are accounted for, as shown below, by using the commanded exposure value.

The shutter opening time, when the shutter first opens, is determined by averaging the four open measurements. Before the shutter closing times can be averaged to determine when the shutter last closes, each measurement must be checked for rollovers. The value of the commanded exposure just before each of the three rollover steps is 67.108 s, 134.217 s, and 201.326 s, respectively. When ***AIMGSHCE*** is above any of these values it has rolled over 1, 2, or 3 times, respectively, and the number of rollovers multiplied by 67.108860 s needs to be added to the respective close time before averaging them.

The actual exposure is the difference of the closing time minus the opening time, except when ***AIMGSHCE*** is less than 0.072 s, in which case the shutter mechanism is in its narrow slit mode. In the latter mode the narrow slit opening (smaller by 0.35) is utilized for one or more passes. Current operational planning calls for the shutter exposure to be about 5 s per image for each camera.

One possible algorithm written (and checked) in IDL for calculating the exposure time, taking all of the above into account, is as follows:

```
; To calculate the exposure time:
                                                ; average opening times
OPENING_TIME = (AIMSHOBC + AIMSHOBE + AIMSHOTC + AIMSHOTE)/4.0
if (AIMGSHCE le 67.108)  then  begin            ; average closing times
  CLOSING_TIME = (AIMSHCBC + AIMSHCBE + AIMSHCTC + AIMSHCTE)/4.0
  if (AIMGSHCE lt 0.072)  then  begin           ; in narrow slit mode
     ACTUAL_EXPOSURE = (CLOSING_TIME - OPENING_TIME) * 0.35
  endif else begin                              ; else in wide slit mode
     ACTUAL_EXPOSURE = (CLOSING_TIME - OPENING_TIME)
  end
endif else begin
  CLOSING_TIME = 0.0                            ; calculate each closing time and average them
  close = double(fltarr(4))
  close(0) = AIMSHCBC
  close(1) = AIMSHCBE
  close(2) = AIMSHCTC
  close(3) = AIMSHCTE
  for i = 0,3 do begin
    if (AIMGSHCE gt 201.326)  then  begin             ;if rollovers
      close(i) = 67.108860 * 3 + close(i)
     end else if (AIMGSHCE gt 134.217)  then  begin
                 close(i) = 67.108860 * 2 + close(i)
                end else if (AIMGSHCE gt 67.108)  then  begin
                            close(i) = 67.108860 + close(i)
                           end
    CLOSING_TIME = CLOSING_TIME + close(i)
  endfor
  CLOSING_TIME = CLOSING_TIME/4.0
  ACTUAL_EXPOSURE = (CLOSING_TIME - OPENING_TIME)
end
end
```