# 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 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)
***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 following **TBD** 4 or 5 keywords were not defined in the flight software:

- ***AHT1RN*** = Target 1 Row Number (7b; from HDR) for the lower-left pixel of ROI1 (to the nearest 32nd 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)

It is now planned that these keywords will be in the crop table associated with each frame to be extracted from the de-crop table during the jsoc processing.

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].

The following can be obtained from Frame Definition Block (FDB) (generated and stored in the FDB database on the ground):

**AFDBID** = Frame Definition Block ID (8b; from FDB)
**AFDBSM** = SummingMode (4b; from FDB) for summing: 1x1, 2x2, 4x4 (= 0, 1, 2)
**AFDBNW** = NumWindows (4b; from FDB) for number of ROI windows (= 0, 1, 2)
**AFNR1** = NumRows1 (16b; from FDB and crop table) for height of region 1 in pixels
**AFNC1** = NumCols1 (16b; from FDB and crop table) for width of region 1 in pixels
**AFNR2** = NumRows2 (16b; from FDB and crop table) for height of region 2 in pixels
**AFNC2** = NumCols2 (16b; from FDB and crop table) 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 and 2. If 2 ROIs are indicated, they most likely will be strips across the CCD. (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.)

Derived Keywords:

**NUMWIN** = **AFDBNW** [number of window ROIs:
= 0 for full (4kx4k) CCD;
= 1 for 1 ROI;
= 2 for 2 ROIs]

- **ROI_LLX1** = ***AHT1CN*** * 32 (**TBD**) [region 1 (R1) at center of lower left corner pixel, X variable]
- **ROI_LLY1** = ***AHT1RN*** * 32 (**TBD**) [R1 at center of lower left corner pixel, Y variable]
- **ROI_LLX2** = ***AHT2CN*** * 32 (**TBD**) [R2 at center of lower left corner pixel, X variable]
- **ROI_LLY2** = ***AHT2RN*** * 32 (**TBD**) [R2 at center of lower left corner pixel, 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]
**NAXIS** = 2, 2, 1 [corresponds to number of axes of images for **NUMWIN** = 0, 1, 2, respectively, to not confuse simple FITS file readers.]
**NAXIS1** = 4096, **NAXISX1,** total number of pixels in area
**NAXIS2** = 4096, **NAXISX2,** 0
[the first 2 values of **NAXIS#** correspond, respectively, to the axis length for **NUMWIN** = 0, 1 and the last value corresponds 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.]

Reconstructing the acquired image requires, in addition, the appropriate use of ***AHCPIDN***, ***AHCPIDK***, ***AHTAPC, AHBITID, AHLUTID***, **and AFDBSM.** The image observation time, **T_OBS,** can be determined, as discussed in Appendix 1.

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

(See Appendix 2 for a recent list of the telemetry words in the Image Status Packet.)

### 1.2.1 Instrument, Mechanisms, & Observable Information

***AISTATE*** = *A8284* = AIA_IMG_ISS_MODE (1b; from ISP), ISS on/off
***ASQHDR*** = AIA_SEQ_HEADER (32b; from ISP), a combination of the camera number and the frame serial number, both of which have their own keywords below
***ASQTNUM*** = AIA_SEQ_TEL_NUM (2b; in ISP), from which the camera (telescope) number that took this image, **CAMERA** (= ***ASQTNUM*** + 1), can be sanity checked
***ASQFSN*** = 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** = ***AIAWVLEN*** = AIA_IMG_WAVELENGTH (8b; from ISP), wavelength of this observation, with 2 each for camera (telescope) 1, 2, 4 and 4 for camera 3 (as a float in nm (Phil)), and with mapping reference number of each wavelength in ( ):

= 33.5 (0), 13.1 (1) for camera 1
= 21.1 (2), 19.3 (3) for camera 2
= 160.0 (4), 170.0 (5), 450.0 (6), 17.1 (7) for camera 3
= 30.4 (8), 9.4 (9) 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 (0) or light (1) "shutter type"

***AIGT1SVY*** = AIA_IMG_GT1_SUNVECTOR_Y (16b; from ISP), Guide Telescope (GT) 1 Sun vector in y direction

***AIGT1SVZ*** = AIA_IMG_GT1_ SUNVECTOR _Z (16b; from ISP), Guide Telescope (GT) 1 Sun vector in z direction

***AIGT2SVY*** = AIA_IMG_GT2_SUNVECTOR_Y (16b; from ISP), Guide Telescope (GT) 2 Sun vector in y direction

***AIGT2SVZ*** = AIA_IMG_GT2_ SUNVECTOR _Z (16b; from ISP), Guide Telescope (GT) 2 Sun vector in z direction

***AIGT3SVY*** = AIA_IMG_GT3_SUNVECTOR_Y (16b; from ISP), Guide Telescope (GT) 3 Sun vector in y direction

***AIGT3SVZ*** = AIA_IMG_GT3_ SUNVECTOR _Z (16b; from ISP), Guide Telescope (GT) 3 Sun vector in z direction

***AIGT4SVY*** = AIA_IMG_GT4_SUNVECTOR_Y (16b; from ISP), Guide Telescope (GT) 4 Sun vector in y direction

***AIGT4SVZ*** = AIA_IMG_GT4_ SUNVECTOR _Z (16b; from ISP), Guide Telescope (GT) 4 Sun vector in z 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

***AECTYPE*** = AIA_IMG_AEC_TYPE (2b; from ISP), AEC table for current wavelength (4 tables per wavelength)

***AECDELAY*** = AIA_IMG_AEC_DELAY (16b; from ISP), time since image used for AEC

***AECMODE*** = 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 (19b; 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)

### 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

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

***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
***AIMGFSN*** = 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), clear 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 (24b; from ISP), cumulative histogram value at bin #192
***AIHIS348*** = AIA_IMG_HISTC_BN_348 (24b; from ISP), cumulative histogram value at bin #348
***AIHIS604*** = AIA_IMG_HISTC_BN_604 (24b; from ISP), cumulative histogram value at bin #604
***AIHIS860*** = AIA_IMG_HISTC_BN_860 (24b; from ISP), cumulative histogram value at bin #860

***AIAHFSN*** = AIA_IMG_HIST_FSN (32b; from ISP), the FSN of the image from which the histogram data was obtained
***AIAGP1*** = AIA_IMG_GP1 (32B; from ISP), general purpose register word 1
***AIAGP2*** = AIA_IMG_GP2 (32B; from ISP), general purpose register word 2
***AIAGP3*** = AIA_IMG_GP3 (32B; from ISP), general purpose register word 3
***AIAGP4*** = AIA_IMG_GP4 (32B; from ISP), general purpose register word 4
***AIAGP5*** = AIA_IMG_GP5 (32B; from ISP), general purpose register word 5
***AIAGP6*** = AIA_IMG_GP6 (32B; from ISP), general purpose register word 6
***AIAGP7*** = AIA_IMG_GP7 (32B; from ISP), general purpose register word 7
***AIAGP8*** = AIA_IMG_GP8 (32B; from ISP), general purpose register word 8
***AIAGP9*** = AIA_IMG_GP9 (32B; from ISP), general purpose register word 9
***AIAGP10*** = AIA_IMG_GP10 (32B; from ISP), general purpose register word 10

Reformatter Information

***AIVNIMST*** = *A831A* = AIA_VER_NUM_IMAGE_STATUS (16b; from ISP), ISP version number
***ACSUM027*** = APID027_CHECKSUM (16b; from ISP), ISP checksum (last of ISP telemetry words)

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

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

**ORIGIN** string, location where file was made, e.g., "SDO/JSOC-SDP"
**DATE** string, date and time of file creation in format: yyyy.mm.ddThh:mm:ss[.sss] in UTC
**DATE-OBS = T_OBS – (EXPTIME**/2.0**)** string, UTC, date when image observation started
**T_OBS** time**,** UTC**,** middle of the exposure time (shutter open start time + exposure time / 2.
**EXPTIME** floating point, calculated in double precision, exposure time in seconds
**EXPTM_SD** float, calculated in double precision, standard deviation of the exposure time

(see Appendix 1: AIA Camera Exposure Time Calculation for details on the 4 keywords above.)

**MJD** float, date of observation as modified julian day number.
**TIME** double, time of observation in seconds within a day. MJD and TIME describe the same instant as DATE-OBS
**TELESCOP** = "SDO/AIA" string, name of source telescope package
**INSTRUME** = "AIA_i" string, name of instrument (within telescope package) where i = camera number = 1, 2, 3, or 4
**CAMERA** = **AHTELID** + 1, int, camera number = 1, 2, 3, or 4 for AIA

**WAVELNTH** = ***AIAWVLEN***, wavelength of this observation, with 2 each for camera (telescope) 1, 2, 4 and 4 for camera 3 (as a float in nm (Phil)), and with mapping reference number of each wavelength in ( ): (these keywords and values repeated from above)

= 33.5 (0), 13.1 (1) for camera 1
= 21.1 (2), 19.3 (3) for camera 2
= 160.0 (4), 170.0 (5), 450.0 (6), 17.1 (7) for camera 3
= 30.4 (8), 9.4 (9) for camera 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) |
| **BLANK** = "-32768" | value signaling undefined integer data |
| **BSCALE** | multiplier for data values |
| **BZERO** | offset for data values |
| | |
| **TLMDSNAM** | string, "Telemety data series name with first packet of image" |
| **T_PACKET** | time, "FIRST_PACKET_TIME" for images |
| **IMGAPID** | int, "Image Application ID" |
| **BITSELID** = ***AHBITID*** | int, "Bit select ID, r" |
| **COMPID** = ***AHCPIDN, AHCPIDK*** | int, "Compression ID; n,k" |
| **TAPCODE** = ***AHTAPC*** | int, "Take A Picture code" |
| **DATAVALS** | int, "Actual number of data values in image" |
| **MISSVALS** | int, "Missing values: TOTVALS - DATAVALS" |
| **TOTVALS** | int, "Expected number of data values (pixels)" |
| **NERRORS** | int, "Number of decompression errors" |
| **NPACKETS** | int, "Number of packets in image" |
| **QUALLEV0** | int, "Quality word" |
| | |
| **DATAMIN** | double, "Minimum value from all pixels" |
| **DATAMAX** | double, "Maximum value from all pixels" |
| **DATAMEDN** | double, "Median value from all pixels" |
| **DATAMEAN** | double, "Mean value for all pixels" |
| **DATARMS** | double, "Rms deviation from the mean value of all pixels" |
| **DATASKEW** | double, "Skewness from the mean value of all pixels " |
| **DATAKURT** | double, "Kurtosis of all pixels" |

## 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.)

Image coordinate mapping keywords, FITS standard (including instrument & spacecraft pointing). Specifies mapping from array axes (j) to image axes (i).

**CTYPE*i*** Text, type of image coordinate axis ***i*** for other Cxxxx keywords

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). |

**CRPIX*j*** Reference pixel along array axis ***j***. First pixel is number 1 (not 0).

**CRVAL*i*** Physical value along image axis ***i*** at the center of the pixel.

**CDELT*i*** Pixel spacing per index value along image axis ***i***

**CUNIT*i*** Physical units for position on image axis ***i***

**CROTA*j*** Rotation needed for array axes to get to image axes. Unit is degrees and since all **CROTA*j***s are the same for cases where we will use this notation only the first axis need be specified. The direction is opposite to the traditional solar position angle.

**CRDER*i*** Estimate of random error in coordinate ***i*** expressed in **CUNIT*i***.

**CSYSER*i*** Estimate of systematic error in coordinate ***i*** expressed in **CUNIT*i***.

These Cxxxxx keywords may have multiple sets present. If so the sets beyond the first have a single letter suffix indicating the set. Additionally a WCSNAMEa keyword should be added to identify the set. E.g. if a single second set is present then the additional keywords will be: WCSNAMEA, CTYPE1A, CTRYP2A, CRPIX1A, CRPIX2A, CRVAL1A, CRVAL2A, etc.

**R_SUN** Radius of the Sun's image in pixels (float)

**DSUN_OBS** Distance from Sun's center to SDO in m (float)

**RSUN_REF** = '960.0' Radius of the Sun in arcsecs, (float)

**X0** X-axis location of solar disk center in pixels (float)

**Y0** Y-axis location of solar disk center in pixels (float)

**SAT_ROT** Position angle of solar pole wrt the SDO Z axis (float, degrees) (used as input to the **CROTA** calculation)

**INST_ROT** Rotation of the camera from the SDO Z axis (float, degrees) (**CROTA*j*** will be the sum **SAT_ROT** + **INST_ROT**)

**IM_SCALE** Arc-sec per CCD pixel default value for the particular instrument (float). This value will be used for the estimate of CDELT for AIA. Note that IM_SCALE does not change when the image is rebinned on the ground. It is a characteristic of the data as observed.

**X0** X-axis location of solar disk center in pixels, start 0.0 (float)

**Y0** Y-axis location of solar disk center in pixels, start 0.0 (float)

For AIA these quantities will be computed *from* the WCS keywords. X0 and Y0 are wrt the center of the lower left pixel. NOTE that X0 and Y0 are the locations of Sun center in the image array

and are NOT related to EW or NS positions on the Sun. They are then the point about which CROTAj can be applied such that a rotated image will have valid CRPIX and CRVAL keywords.

**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)**

(Note: These differ from the SolarSoft documentation and maybe the correct definitions, but need to be verified.)

**TEMPCCD** 'Temp. at CCD'
**TEMPCEB** 'Temp. at common electronics box'
**TEMPSMIR** 'Temp. at seconday mirror'
**TEMPPMIR** 'Temp. at primary mirror'

**PZTOFFS1** PZT offset
**PZTOFFS2** PZT offset
**PZTOFFS3** PZT offset

**HELIOCN1** Heliocentric coordinates (6) - Rock (TBD)
**HELIOCN2**
**HELIOCN3**
**HELIOCN4**
**HELIOCN5**
**HELIOCN6**
**GEOCEN1** Geocentric coordinates (6) - Rock (TBD)
**GEOCEN2**
**GEOCEN3**
**GEOCEN4**
**GEOCEN5**
**GEOCEN6**
**CARRINGT** Carrington keyword - Rock (TBD)

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, data, and/or metadata (?) |
| **QUALITY** | of data |
| **PIPELINE VERSION** | |
| | |
| **FLAT_FIELD** | Set when applied to image |
| **LEAP_SEC** | Current number of leap seconds to add to TIA |

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

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 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 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 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 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 rescale from floating point to 16-bit integers by taking the square root of each pixel, then multiplying by 512, and rounding to the nearest integer. (To get the floating point image back, divide each pixel by 512.0 and then square the value.)

## 3. Draft of Level 0 and 1 Headers with Sample Keywords

| Level 0 | Level 1 | Sample Keyword | Section |
|---|---|---|---|
| **SIMPLE** | = **SIMPLE** = | T | 1.2.3 |
| **BITPIX** | = **BITPIX** = | 16 | 1.2.3 |
| ***AHAPID*** | Packet APID | | 1.1 (Header) |
| ***AHTAPC*** | TAP Code | | 1.1 (Header) |
| ***AHBITID*** | Bit Select ID, r | | 1.1 (Header), 1.2.3 |
| ***AHCPIDN*** | Compression parameter *n* | | 1.1 (Header), 1.2.3 |
| ***AHCPIDK*** | Compression parameter *k* | | 1.1 (Header), 1.2.3 |
| ***AHLUTID*** | Lookup Table ID | | 1.1 (Header) |
| **TLMDSNAM** | "Telemety data series name with first packet of image" | | 1.2.3 |
| **T_PACKET** | "FIRST_PACKET_TIME" | | 1.2.3 |
| **IMGAPID** | "Image Application ID" | | 1.2.3 |
| ***AHBITID*** | "Bit select ID, r" | | 1.2.3 |
| **BITSELID** | = **BITSELID** | (derived from ***AHBITID***) | 1.2.3 |
| **COMPID** | | (derived from ***AHCPIDN, AHCPIDK***) | 1.2.3 |
| ***AHTAPC*** | "Take A Picture code" | | 1.2.3 |
| **TAPCODE** | | (derived from ***AHTAPC***) | 1.2.3 |
| **DATAVALS** | "Actual number of data values in image" | | 1.2.3 |
| **MISSVALS** | "Missing values: TOTVALS - DATAVALS" | | 1.2.3 |
| **TOTVALS** | "Expected number of data values (pixels)" | | 1.2.3 |
| **NERRORS** | "Number of decompression errors" | | 1.2.3 |
| **NPACKETS** | "Number of packets in image" | | 1.2.3 |
| **QUALLEV0** | "Quality word" | | 1.2.3 |
| | | (used to define ROI(s)) | |
| ***AHT1RN*** | Target 1 Row Number for the lower-left pixel of ROI1 | (TDB) | 1.1 (Header) |
| ***AHT1CN*** | Target 1 Column Number for the lower-left pixel of ROI1 | (TDB) | 1.1 (Header) |
| ***AHT2RN*** | Target 2 Row Number for the lower-left pixel of ROI1 | (TDB) | 1.1 (Header) |
| ***AHT2CN*** | Target 2 Column Number for the lower-left pixel of ROI1 | (TDB) | 1.1 (Header) |
| ***AHFDBID*** | Frame Definition Block ID | (TDB) | 1.1 (Header) |
| ***AIFDBID*** | Frame Definition Block ID | | 1.2.1 (ISP) |
| **AFDBID** | Frame Definition Block ID | | 1.1 (FDB) |
| **AFDBSM** | = **SUM_MODE** | | 1.1 (FDB) |
| **AFDBNW** | Number of ROIs | | 1.1 (FDB) |
| **NUMWIN** | | (derived from **AFDBNW**) | 1.1 (FDB) |
| **AFNR1** | NumRows1 for height of region 1 in pixels | | 1.1 (FDB) |
| **AFNC1** | NumCols1 for width of region 1 in pixels | | 1.1 (FDB) |
| **AFNR2** | NumRows2 for height of region 2 in pixels | | 1.1 (FDB) |
| **AFNC2** | NumCols2 for width of region 2 in pixels | | 1.1 (FDB) |
| **ROI_LLX1** | = **ROI_LLX1** = | 0 | 1.1 |
| **ROI_LLY1** | = **ROI_LLY1** = | 0 | 1.1 |
| **ROI_LLX2** | = **ROI_LLX2** = | 0 | 1.1 |
| **ROI_LLY2** | = **ROI_LLY2** = | 0 | 1.1 |

| | | | | | |
|---|---|---|---|---|---|
| **ROI_LLX3** | = **ROI_LLX3** | = | 0 | | 1.1 |
| **ROI_LLY3** | = **ROI_LLY3** | = | 0 | | 1.1 |
| **NAXIS** | = **NAXIS** | = | 2 | | 1.1 |
| **NAXIS1** | = **NAXIS1** | = | 4096 | | 1.1 |
| **NAXIS2** | = **NAXIS2** | = | 4096 | | 1.1 |
| **NAXISX1** | = **NAXISX1** | = | 4096 | | 1.1 |
| **NAXISY1** | = **NAXISY1** | = | 4096 | | 1.1 |
| **NAXISX2** | = **NAXISX2** | = | 0 | | 1.1 |
| **NAXISY2** | = **NAXISY2** | = | 0 | | 1.1 |
| **NAXISX3** | = **NAXISX3** | = | 0 | | 1.1 |
| **NAXISY3** | = **NAXISY3** | = | 0 | | 1.1 |
| **FOVX1** | = **FOVX1** | = | 1020 | "Field of View in CUNITi" | TBD |
| **FOVY1** | = **FOVY1** | = | 1020 | "Field of View in CUNITi" | TBD |
| **FOVX2** | = **FOVX2** | = | 0 | "Field of View in CUNITi" | TBD |
| **FOVY2** | = **FOVY2** | = | 0 | "Field of View in CUNITi" | TBD |
| **FOVX3** | = **FOVX3** | = | 0 | "Field of View in CUNITi" | TBD |
| **FOVY3** | = **FOVY3** | = | 0 | "Field of View in CUNITi" | TBD |
| ***AHTCS*** | Packet Time Code Seconds | | | | 1.1 (Header) |
| ***AHTCSS*** | Packet Time Code Sub Seconds | | | | 1.1 (Header) |
| ***ATCS027*** | APID027 timecode in seconds | | | (used to define exposure) | 1.2.1 (ISP) |
| ***ATCSS027*** | APID027 timecode in subseconds | | | (used to define exposure) | 1.2.1 (ISP) |
| ***AIMGSHEN*** | shutter selector encoder reading | | | | 1.2.1 (ISP) |
| ***AIMGOTS*** | seconds time tag | | | | 1.2.1 (ISP) |
| ***AIMGOTSS*** | subseconds time tag | | | | 1.2.1 (ISP) |
| ***AIMGSHCE*** | = **COMDEXPT** | = | 5.0 | | 1.2.1 (ISP) |
| ***AIMSHOBC*** | shutter timer register value | | | | 1.2.1 (ISP) |
| ***AIMSHOBE*** | shutter timer register value | | | | 1.2.1 (ISP) |
| ***AIMSHOTC*** | shutter timer register value | | | | 1.2.1 (ISP) |
| ***AIMSHOTE*** | shutter timer register value | | | | 1.2.1 (ISP) |
| ***AIMSHCBC*** | shutter timer register value | | | | 1.2.1 (ISP) |
| ***AIMSHCBE*** | shutter timer register value | | | | 1.2.1 (ISP) |
| ***AIMSHCTC*** | shutter timer register value | | | | 1.2.1 (ISP) |
| ***AIMSHCTE*** | shutter timer register value | | | | 1.2.1 (ISP) |
| **EXPTIME** | = **EXPTIME** | = | 5.039 | | 1.2.3, App. 1 |
| **EXPTM_SD** | = **EXPTM_SD** | = | 0.019 | | 1.2.3, App. 1 |
| **T_OBS** | = **T_OBS** | = | '2008-01-08T18:56:03.005' | | App. 1 |
| **DATE_OBS** | = **DATE_OBS** | = | '2008-01-08T18:56:00.005' | | 1.2.3 |
| **MJD** | = **MJD** | = | 2454474 | | 1.2.3 |
| **TIME** | = **TIME** | = | 24960.005 | | 1.2.3 |
| **BLANK** | = **BLANK** | = | -32768 | | (definition) |
| **DATE** | = **DATE** | = | '2008-01-08T18:57:38' | | 1.2.3 |
| **ORIGIN** | = **ORIGIN** | = | 'SDO/JSOC-SDP' | | 1.2.3 |
| **TELESCOP** | = **TELESCOP** | = | 'SDO/AIA' | | 1.2.3 |
| **INSTRUME** | = **INSTRUME** | = | 'AIA_i' | | 1.2.3 |
| | **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 |

***AHTLFSN*** **[ = AHTELID** (2b) {=**CAMERA** -1} + **AHFSN** (30b) {=Frame Serial Number}]

| | | |
|---|---|---|
| **AHTELID** | Camera -1 | 1.1 |
| **CAMERA** | = **CAMERA** = 3 | 1.1 |
| **AHFSN** | = **FSN** Frame Serial Number = 75000 | 1.1, 1.2.1 |
| ***ASQHDR*** | **[ =** ***ASQTNUM*** (2b) {=Camera} + ***ASQFSN*** (30b) {=FSN}] | 1.2.1 (ISP) |
| ***AIASEN*** | = **APERT_SEL** aperture selection encoder reading | 1.2.1 (ISP) |
| ***AIFWEN*** | = **FILT_WHL_SEL** filter wheel selector encoder reading | 1.2.1 (ISP) |
| ***AIFILTYP*** | = **FILT_TYP** = 1 | 1.2.1 (ISP) |
| ***AIMGTYP*** | = **IMG_TYP** = 'LIGHT' | 1.2.1 (ISP) |
| ***AIFOENFL*** | flag to indicate if focus table used or not | 1.2.1 (ISP) |
| ***AIFTSWTH*** | filter switch threshold for 131A wavelength (exposure) | 1.2.1 (ISP) |
| ***AIAWVLEN*** | (coded wavelength for this observation) | 1.2.1 (ISP) |
| **WAVELNTH** | **= WAVELNTH** = 17.1 | 1.2.1, 1.2.3 |
| ***AISTATE*** | ISS on/off | 1.2.1 (ISP) |
| ***AIGT1SVY*** | GT 1 Sun vector in y direction | 1.2.1 (ISP) |
| ***AIGT1SVZ*** | GT 1 Sun vector in z direction | 1.2.1 (ISP) |
| ***AIGT1SVY*** | GT 2 Sun vector in y direction | 1.2.1 (ISP) |
| ***AIGT1SVZ*** | GT 2 Sun vector in z direction | 1.2.1 (ISP) |
| ***AIGT1SVY*** | GT 3 Sun vector in y direction | 1.2.1 (ISP) |
| ***AIGT1SVZ*** | GT 3 Sun vector in z direction | 1.2.1 (ISP) |
| ***AIGT1SVY*** | GT 4 Sun vector in y direction | 1.2.1 (ISP) |
| ***AIGT1SVZ*** | GT 4 Sun vector in z direction | 1.2.1 (ISP) |
| ***AIAECTI*** | Automatic Exposure Control (AEC) tables used with this image | 1.2.1 (ISP) |
| ***AIAECENF*** | AEC enable flag for this image | 1.2.1 (ISP) |
| ***AECTYPE*** | AEC table for current wavelength | 1.2.1 (ISP) |
| ***AECDELAY*** | time since image used for AEC | 1.2.1 (ISP) |
| ***AECMODE*** | mode of AEC | 1.2.1 (ISP) |
| ***AIFCPS*** | = **FOCUS_POS** currently loaded target value | 1.2.1 (ISP) |
| ***AIFTSID*** | framelist timeline schedule (FTS) id | 1.2.1 (ISP) |
| ***AIFRMLID*** | framelist id for this image | 1.2.1 (ISP) |
| ***AIMGFSN*** | position within framelist of this frame | 1.2.1 (ISP) |
| ***AICFGDL1*** | mechanism delay 1 | 1.2.1 (ISP) |
| ***AICFGDL2*** | clear table delay | 1.2.1 (ISP) |
| ***AICFGDL3*** | shutter operation delay | 1.2.1 (ISP) |
| ***AICDGDL4*** | readout delay | 1.2.1 (ISP) |
| ***AIHISMXB*** | bin number of maximum of standard histogram for previous image in this wavelength used for the current AEC | 1.2.1 (ISP) |
| ***AIHIS192*** | cumulative histogram value at bin #192 | 1.2.1 (ISP) |
| ***AIHIS348*** | cumulative histogram value at bin #348 | 1.2.1 (ISP) |
| ***AIHIS604*** | cumulative histogram value at bin #604 | 1.2.1 (ISP) |
| ***AIHIS860*** | cumulative histogram value at bin #860 | 1.2.1 (ISP) |
| ***AIAHFSN*** | the FSN of the image from which the histogram data was obtained | 1.2.1 (ISP) |
| ***AIAGP1*** | general purpose register word 1 | 1.2.1 (ISP) |

| | | | | | |
|---|---|---|---|---|---|
| ***AIAGP2*** | general purpose register word 2 | | | 1.2.1 (ISP) | |
| ***AIAGP3*** | general purpose register word 3 | | | 1.2.1 (ISP) | |
| ***AIAGP4*** | general purpose register word 4 | | | 1.2.1 (ISP) | |
| ***AIAGP5*** | general purpose register word 5 | | | 1.2.1 (ISP) | |
| ***AIAGP6*** | general purpose register word 6 | | | 1.2.1 (ISP) | |
| ***AIAGP7*** | general purpose register word 7 | | | 1.2.1 (ISP) | |
| ***AIAGP8*** | general purpose register word 8 | | | 1.2.1 (ISP) | |
| ***AIAGP9*** | general purpose register word 9 | | | 1.2.1 (ISP) | |
| ***AIAGP10*** | general purpose register word 10 | | | 1.2.1 (ISP) | |
| ***AIVNIMST*** | ISP version number | | | 1.2.1 (ISP) | |
| ***ACSUM027*** | ISP checksum (last of ISP telemetry words) | | | 1.2.1 (ISP) | |
| **CTYPE1** | **= CTYPE1** | = | ‘SOLARX’ | 2.0 | |
| **CTYPE2** | **= CTYPE2** | = | ‘SOLARY’ | 2.0 | |
| **CROTA1** | **= CROTA1** | = | 0.0 | 2.0 | |
| **CROTA2** | **= CROTA2** | = | 0.0 | 2.0 | |
| **CDELT1** | **= CDELT1** | = | 0.5 | 2.0 | |
| **CDELT2** | **= CDELT2** | = | 0.5 | 2.0 | |
| **CRPIX1** | **= CRPIX1** | = | -357.291 | 2.0 | |
| **CRPIX2** | **= CRPIX2** | = | 850.624 | 2.0 | |
| **CRVAL1** | **= CRVAL1** | = | 0.0 | 2.0 | |
| **CRVAL2** | **= CRVAL2** | = | 0.0 | 2.0 | |
| **CUNIT1** | **= CUNIT1** | = | ‘ARCSEC’ | 2.0 | |
| **CUNIT2** | **= CUNIT2** | = | ‘ARCSEC’ | 2.0 | |
| **CRDER1** | **= CRDER1** | = | ‘Estimate of random error in 1 as CUNITi’ | | 2.0 |
| **CRDER2** | **= CRDER2** | = | ‘Estimate of random error in 2 as CUNITi’ | | 2.0 |
| **CSYSER1** | **= CSYSER1** | = | ‘Estimate of systematic error in 1 as CUNITi’ | | 2.0 |
| **CSYSER2** | **= CSYSER2** | = | ‘Estimate of systematic error in 2 as CUNITi’ | | 2.0 |
| **RSUN_REF** | **= RSUN_REF** | = | 960.0 | 2.0 | |
| **X0** | **= X0** | = | 2047.0 | 2.0 | |
| **Y0** | **= Y0** | = | 2047.0 | 2.0 | |
| **SDO_ROLL** | **= SDO_ROLL** | = | 0.0 | 2.0 | |
| **R_SUN** | **= R_SUN** | = | ‘Radius of the Sun’s image in pixels’ | 2.0 | |
| **SAT_ROT** | **= SAT_ROT** | = | ‘Position angle of solar pole wrt the SDO Z axis’ | | 2.0 |
| **INST_ROT** | **= INST_ROT** | = | ‘Rotation of the camera from the SDO Z axis’ | | 2.0 |
| **IM_SCALE** | **= IM_SCALE** | = | 0.5 | 2.0 | |
| **XCEN** | **= XCEN** | = | 434.895 | 2.0 | |
| **YCEN** | **= YCEN** | = | -169.062 | 2.0 | |
| **TEMPCCD** | **= TEMPCCD** | = | -60.5 ‘Temp. at CCD’ | 2.0 | |
| **TEMPCEB** | **= TEMPCEB** | = | -30.3 ‘Temp. at common electronics box’ | | 2.0 |
| **TEMPSMIR** | **= TEMPSMIR** | = | 17.9 ‘Temp. at seconday mirror’ | 2.0 | |
| **TEMPPMIR** | **= TEMPPMIR** | = | 25.2 ‘Temp. at primary mirror’ | 2.0 | |
| **PZTOFFS1** | PZT offset | | | 2.0 | |
| **PZTOFFS2** | PZT offset | | | 2.0 | |
| **PZTOFFS3** | PZT offset | | | 2.0 | |
| **PERCENTD** | **= PERCENTD** | = | 100.0 | TBD | |
| **DATAMIN** | **= DATAMIN** | = | 81.0 | TBD | |

| | | | |
|---|---|---|---|
| **DATAMAX = DATAMIN** | = | 4100.0 | TBD |
| **DATAMEDN = DATAMEDN** | = | 218.345670 | TBD |
| **DATAMEAN = DATAMEAN** | = | 218.345670 | TBD |
| **DATARMS = DATARMS** | = | 22.687300 | TBD |
| **DATASKEW = DATASKEW** | = | 218.345670 | TBD |
| **DATAKURT = DATAKURT** | = | 218.345670 | TBD |
| **DATAP01 = DATAP01** | = | 722.00000 | TBD |
| **DATAP10 = DATAP10** | = | 726.00000 | TBD |
| **DATAP25 = DATAP25** | = | 730.00000 | TBD |
| **DATAP75 = DATAP75** | = | 1094.0000 | TBD |
| **DATAP90 = DATAP90** | = | 1368.0000 | TBD |
| **DATAP95 = DATAP95** | = | 1662.0000 | TBD |
| **DATAP98 = DATAP98** | = | 2282.0000 | TBD |
| **DATAP99 = DATAP99** | = | 2826.0000 | TBD |
| **FILENAME = FILENAME** | = | 'NAME OF DATA FILE' | 2.0 |
| **LVL _NUM = LVL _NUM** | = | 'LEVEL NUMBER' | 2.0 |
| **VERSION = VERSION** (of reformatter) | | | 2.0 |
| **PIPELINE VERSION = PIPELINE VERSION** | | | 2.0 |
| **QUALLEV1** | = | QUALITY (of data) | 2.0 |
| **EXTEND** | = | 'FITS FILE EXTENDED? T or F | 2.0 |
| **COMMENT** | = | 'COMMENT' | 2.0 |
| **HISTORY** | = | 'ASCII HISTORY RECORD, ONE OR MORE' | 2.0 |
| **END = END** | | | |

**Appendix 1:** AIA Camera Exposure Time Calculation

Telemetry parameters required from AIA Image Status Packet:

***AIMGOTS*** = AIA_IMG_OBT_TIME_SH_SEC
***AIMGOTSS*** = AIA_IMG_OBT_TIME_SH_SS
cmdexp = double(***AIMGSHCE***) = AIA_IMG_SH_CMDED_EXPOSURE
shopbc = double(***AIMSHOBC***) = AIA_IMG_SH_OPEN_BOT_CENTR
shopbe = double(***AIMSHOBE***) = AIA_IMG_SH_OPEN_BOT_EDGE
shoptc = double(***AIMSHOTC***) = AIA_IMG_SH_OPEN_TOP_CENTR
shopte = double(***AIMSHOTE***) = AIA_IMG_SH_OPEN_TOP_EDGE
shclbc = double(***AIMSHCBC***) = AIA_IMG_SH_CLOSE_BOT_CENTR
shclbe = double(***AIMSHCBE***) = AIA_IMG_SH_CLOSE_BOT_EDGE
shcltc = double(***AIMSHCTC***) = AIA_IMG_SH_CLOSE_TOP_CENTR
shclte = double(***AIMSHCTE***) = AIA_IMG_SH_CLOSE_TOP_EDGE

***AIMGSHCE*** is the commanded exposure (19 bits) starting from ~0.005 s (due to size of narrow shutter slit) in 0.001 s steps to 524.28 s [$(2^{19} -1)*10^{-3} = 524287*10^{-3}$] (timings are from document AIA01259 rev H). The maximum exposure of the AIA shutter mechanism is ~268.4 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 commanded exposure value can be used to determine the rollover value. The expected value of the commanded exposure to the nearest 0.1 sec just before each of the three possible rollover steps is 67.1 s, 134.2 s, and 201.3 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 67.108864 s needs to be added to the respective shutter close minus open time before averaging. Please note that the programmer needs to take care near the rollover steps because the hardware and/or software may not work quite the same as in the ideal case presented here.

The actual exposure is the average of the difference of the closing time minus the opening time for each of the four measurements positions, 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.

Using the above, together with Rock Bush's email of 28-Feb-08 on HMI T_OBS and EXPTIME and John Serafin's email of 20-May-08 on a rollover algorithm in C, the following algorithm has been written in IDL for calculating the AIA camera shutter exposure time for each camera, **EXPTIME;** standard deviation, **EXPTIME_SD;** the shutter open start time plus the middle of the exposure time, **T_OBS;** and the date when the observation started, **DATE-OBS.**

```
; Computer quantities (note: all variables should be double precision and time is in seconds):

AIA_Shutter_Open_Start_Time = AIMGOTS + AIMGOTSS        ; combine these in TAI

;Intermediate calculation variables:

   cshclbc = shclbc + 67.108864d0 * nrollct(cmdexp, shclbc)      ;correct for rollovers
   cshclbe = shclbe + 67.108864d0 * nrollct(cmdexp, shclbe)
   cshcltc = shcltc + 67.108864d0 * nrollct(cmdexp, shcltc)
   cshclte = shclte + 67.108864d0 * nrollct(cmdexp, shclte)

   shebc = cshclbc – shopbc                                    ;close time – open time
   shebe = cshclbe - shopbe
   shetc = cshcltc - shoptc
   shete = cshclte - shopte

   mean = (shebc + shebe + shetc + shete)/4.0d0                ;mean and standard deviation
```

```
   exp_sd = sqrt(1/3 * ( (shebc-mean) * (shebc-mean) + (shebe-mean) * (shebe-mean) + $
(shetc-mean) * (shetc-mean) + (shete-mean) * (shete-mean) ))        ;continued from previous line

   if (cmdexp lt 0.072d0) then begin                                ;in narrow slit mode
         mean = mean * 0.35
         exp_sd = expsd * 0.35
   endif
```

**EXPTIME** = mean ;AIA_Shutter_Exposure_Time
**EXPTM_SD** = exp_sd ;AIA_Shutter_Exposure_SD

```
EXPTIME_Offset = (cshclbc + shopbc + cshclbe + shopbe + cshcltc + shoptc + cshclte + $
shopte)/8.0d0                                                       ;continued from previous line
```

**T_OBS** = AIA_Shutter_Open_Start_Time + EXPTIME_Offset ;(add in seconds, calculate DATA_OBS, then convert T_OBS to UTC)

**DATE-OBS** = **T_OBS -** (**EXPTIME**/2.0) ;(add in seconds then convert to UTC time)

Note: the T_OBS time is the shutter open start time plus the middle of the exposure time. As such a shutter exposure offset is the mean of all the open and close times. The EXPTIME is the shutter open time duration. DATE-OBS is the date when observation started.

```
;Rollover procedure nrollct
;for rollovers at 67.1, 134.2 and 201.3 with integers used below that are about one quarter of the
;interval away from the rollover values and thus not critical

   Pro nrollct, cmdexp, clostim

   If (cmdexp < 51.0) then  return 0
   If (cmdexp < 84.0) then  if (clostim > 33.0)  then return 0  else return 1
   If (cmdexp < 117.0)  then return 1
   If (cmdexp < 151.0) then  if (clostim > 33.0)  then return 1  else return 2
   If (cmdexp < 184.0) then  return 2
   If (cmdexp < 217.0) then  if (clostim > 33.0)  then return 2  else return 3
   If (cmdexp < 251.0) then  return 3
   return  if (clostim > 33.0)  then return 3  else return 4
   end
```

**Appendix 2:** AIA Image Status Packet (as of May 2008)

```
# hkdpf file created by make_hkdpf.pl script
FILE STANFORD_TLM_HMI_AIA.txt  1.163   2008/05/16  01:05:39
APID 0x027 158   AIA  "Image Status - Image Status Packet" 20080514
KWD  ATCS027      APID027_TIMECODE_SECONDS          0   0  32  UL1 R  20080514
KWD  ATCSS027     APID027_TIMECODE_SUBSECS          4   0  32  UL1 R  20080514
KWD  AIVNMST      AIA_VER_NUM_IMAGE_STATUS          8   0  16  IU1 R  20070513
KWD  AIMGOTS      AIA_IMG_OBT_TIME_SH_SEC          10   0  32  UL1 R  20070513
KWD  ASQHDR       AIA_SEQ_HEADER                   14   0  32  UL1 R  20080511
KWD  ASQTNUM      AIA_SEQ_TEL_NUM                  14   0  2   UB  R  20080511
KWD  ASQFSN       AIA_SEQ_FRAME_SN                 14   2  30  UL1 R  20080511
KWD  AIAHFSN      AIA_IMG_HIST_FSN                 18   0  32  UL1 R  20080325
KWD  AECDELAY     AIA_IMG_AEC_DELAY                22   0  16  IU1 R  20080325
KWD  AIAECTI      AIA_IMG_AEC_TABLE_ID             24   0  16  IU1 R  20070513
KWD  AIASEN       AIA_IMG_AS_ENCODER               26   0  16  IU1 R  20070513
KWD  AIFDBID      AIA_IMG_FDB_ID                   28   0  16  IU1 R  20070515
KWD  AIMGOTSS     AIA_IMG_OBT_TIME_SH_SS           30   0  16  IU1 R  20070513
KWD  AIFCPS       AIA_IMG_FC_POSITION              32   0  16  IS1 R  20070515
KWD  AIFTSWTH     AIA_IMG_FLT_TYPE_SW_TH           34   0  16  IU1 R  20070513
KWD  AIFRMLID     AIA_IMG_FRMLIST_ID               36   0  16  IU1 R  20070513
KWD  AIFTSID      AIA_IMG_FTS_ID                   38   0  16  IU1 R  20070513
KWD  AIHISMXB     AIA_IMG_HIST_MAX_BIN             40   0  16  IU1 R  20070513
KWD  AIHIS192     AIA_IMG_HISTC_BN_192             42   0  24  UL1 R  20080228
KWD  AIHIS348     AIA_IMG_HISTC_BN_348             45   0  24  UL1 R  20080228
KWD  AIHIS604     AIA_IMG_HISTC_BN_604             48   0  24  UL1 R  20080228
KWD  AIHIS860     AIA_IMG_HISTC_BN_860             51   0  24  UL1 R  20080228
KWD  AIFWEN       AIA_IMG_FW_ENCODER               54   0  9   IU1 R  20080514
KWD  AIMGSHCE     AIA_IMG_SH_CMDED_EXPOSURE        56   0  19  UL1 R  20080210
KWD  AECTYPE      AIA_IMG_AEC_TYPE                 58   3  2   UB  R  20080325
KWD  AECMODE      AIA_IMG_AEC_MODE                 58   5  1   UB  D  20080325
KWD  AISTATE      AIA_IMG_ISS_LOOP                 59   3  1   UB  D  20080228
KWD  AIAECENF     AIA_IMG_AEC_ENA_FLAG             59   6  1   UB  R  20070513
KWD  AIFILTYP     AIA_IMG_FILTER_TYPE              59   7  1   UB  R  20070513
KWD  AIMSHOBC     AIA_IMG_SH_OPEN_BOT_CENTR        60   0  24  UL1 A  20071003
KWD  AIMSHOBE     AIA_IMG_SH_OPEN_BOT_EDGE         63   0  24  UL1 A  20071003
KWD  AIMSHOTC     AIA_IMG_SH_OPEN_TOP_CENTR        66   0  24  UL1 A  20071003
KWD  AIMSHOTE     AIA_IMG_SH_OPEN_TOP_EDGE         69   0  24  UL1 A  20071003
KWD  AIMSHCBC     AIA_IMG_SH_CLOSE_BOT_CENTR       72   0  24  UL1 A  20071003
KWD  AIMSHCBE     AIA_IMG_SH_CLOSE_BOT_EDGE        75   0  24  UL1 A  20071003
KWD  AIMSHCTC     AIA_IMG_SH_CLOSE_TOP_CENTR       78   0  24  UL1 A  20071003
KWD  AIMSHCTE     AIA_IMG_SH_CLOSE_TOP_EDGE        81   0  24  UL1 A  20071003
```

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| KWD | AICFGDL1 | AIA_IMG_CFG_DELAY_1 | 84 | 0 | 8 | UB | R | 20080228 |
| KWD | AICFGDL2 | AIA_IMG_CFG_DELAY_2 | 85 | 0 | 8 | UB | R | 20080228 |
| KWD | AICFGDL3 | AIA_IMG_CFG_DELAY_3 | 86 | 0 | 8 | UB | R | 20080228 |
| KWD | AICFGDL4 | AIA_IMG_CFG_DELAY_4 | 87 | 0 | 8 | UB | R | 20080228 |
| KWD | AIFOENFL | AIA_IMG_FOCUS_ENA_FLAG | 88 | 0 | 1 | UB | R | 20070513 |
| KWD | AIMGFSN | AIA_IMG_FRLIST_POS | 88 | 1 | 8 | IU1 | R | 20070820 |
| KWD | AIMGTYP | AIA_IMG_IMAGE_TYPE | 89 | 1 | 8 | IU1 | R | 20070513 |
| KWD | AIAWVLEN | AIA_IMG_WAVELENGTH | 90 | 1 | 8 | IU1 | R | 20080325 |
| KWD | AIAGP1 | AIA_IMG_GP1 | 92 | 0 | 32 | UL1 | R | 20080325 |
| KWD | AIAGP2 | AIA_IMG_GP2 | 96 | 0 | 32 | UL1 | R | 20080325 |
| KWD | AIAGP3 | AIA_IMG_GP3 | 100 | 0 | 32 | UL1 | R | 20080325 |
| KWD | AIAGP4 | AIA_IMG_GP4 | 104 | 0 | 32 | UL1 | R | 20080325 |
| KWD | AIAGP5 | AIA_IMG_GP5 | 108 | 0 | 32 | UL1 | R | 20080325 |
| KWD | AIAGP6 | AIA_IMG_GP6 | 112 | 0 | 32 | UL1 | R | 20080325 |
| KWD | AIAGP7 | AIA_IMG_GP7 | 116 | 0 | 32 | UL1 | R | 20080325 |
| KWD | AIAGP8 | AIA_IMG_GP8 | 120 | 0 | 32 | UL1 | R | 20080325 |
| KWD | AIAGP9 | AIA_IMG_GP9 | 124 | 0 | 32 | UL1 | R | 20080325 |
| KWD | AIAGP10 | AIA_IMG_GP10 | 128 | 0 | 32 | UL1 | R | 20080325 |
| KWD | AGT1SVY | AIA_GT1_SUNVECTOR_Y | 132 | 0 | 16 | IS1 | R | 20080423 |
| KWD | AGT1SVZ | AIA_GT1_SUNVECTOR_Z | 134 | 0 | 16 | IS1 | R | 20080423 |
| KWD | AGT2SVY | AIA_GT2_SUNVECTOR_Y | 136 | 0 | 16 | IS1 | R | 20080423 |
| KWD | AGT2SVZ | AIA_GT2_SUNVECTOR_Z | 138 | 0 | 16 | IS1 | R | 20080423 |
| KWD | AGT3SVY | AIA_GT3_SUNVECTOR_Y | 140 | 0 | 16 | IS1 | R | 20080423 |
| KWD | AGT3SVZ | AIA_GT3_SUNVECTOR_Z | 142 | 0 | 16 | IS1 | R | 20080423 |
| KWD | AGT4SVY | AIA_GT4_SUNVECTOR_Y | 144 | 0 | 16 | IS1 | R | 20080423 |
| KWD | AGT4SVZ | AIA_GT4_SUNVECTOR_Z | 146 | 0 | 16 | IS1 | R | 20080423 |
| KWD | AIMGSHEN | AIA_IMG_SH_ENCODER | 148 | 0 | 8 | UB | R | 20070513 |
| KWD | ACSUM027 | APID027_CHECKSUM | 150 | 0 | 16 | IU1 | R | 20080514 |