AIA/SDO FITS Keywords for Scientific Usage and Data Processing at Levels 0, 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 current Stanford SDO DRMS and SUMS computer database. Phil Scherrer's "JSOC Keywords used for metadata" document [current update 5/8/09] will be used to define and explain the keyword usage.)

1. Level-0 Keywords

1.1 Basic Image Information for Level-0

Definition of Level-0 Metadata for the Image Header (Note: The only intended external use of this level is for JSOC-OPS quick-look viewing in near-real time.)

Metadata for Level-0, when the image comes down, consists 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 image status packet list in Section 1.2 below.)

Metadata for Level-0 may be updated further in the next 24 hours as the final versions of SDO roll information and Flight Dynamics System data are received.

Data Image for Level-0

Decompressed raw data recompressed using non-lossy compression, such as rice.

The following keywords come 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 9 keywords above will be useful in identifying and reconstructing the acquired image.
IMGAPID = ***AHAPID***, Image Application ID {Level-1 also}
IMGFPT is the first packet time in "ISO" units constructed from ***AHTCS*** and ***AHTCSS***.
TLMDSNAM Telemetry data series name (string) with first packet of image
TAPCODE = ***AHTAPC***, "Take a Picture code"
BITSELID = ***AHBITID***, Bit select id, r
LUTID = ***AHLUTID***, Lookup table id
COMPID is the compression id; n, k; constructed from ***AHCPIDN*** and ***AHCPIDK***.
FSN = the least significant 30b of ***AHTLFSN*** and is the Frame Serial Number {Level-1 also}
CAMERA = the most significant 2b of ***AHTLFSN*** +1 = [1, 2, 3, 4] and is the AIA camera (telescope) number associated with the image {Level-1 also}

CROPID is the id associated in the crop table with each image frame to generated onboard and will contain
FID, the Frame Definition Block ID (8b; crop table) {Level-1 also}
to be extracted from the de-crop table during the jsoc processing. The Frame Definition Block ID identifies the Frame Definition Block (FDB) (generated and stored in the FDB database on the ground), from which the following can be obtained:

AFDBID = Frame Definition Block ID (8b; from FDB)
AFDBSM = SummingMode (4b; from FDB) for summing: 1x1, 2x2, 4x4 (= 0, 1, 2)
AFDBNW = Number of Windows (4b; from FDB) for number of Region Of Interest(s) (ROI) (= 0, 1, 2)
ROI_NAX1 = Number of CCD Columns (16b; from FDB and de-crop table) for width of ROI 1 in pixels {Level-1 also}
ROI_NAY1 = Number of CCD Rows (16b; from FDB and de-crop table) for height of ROI 1 in pixels {Level-1 also}
ROI_NAX2 = Number of CCD Columns (16b; from FDB and de-crop table) for width of ROI 2 in pixels {Level-1 also}
ROI_NAY2 = Number of CCD Rows (16b; from FDB and de-crop table) for height of ROI 2 in pixels {Level-1 also}

ROI_LLX1 = CCD X-variable location of lower left corner pixel of ROI 1 {Level-1 also}
ROI_LLY1 = CCD Y-variable location of lower left corner pixel of ROI 1 {Level-1 also}
ROI_LLX2 = CCD X-variable location of lower left corner pixel of ROI 2 {Level-1 also}
ROI_LLY2 = CCD Y-variable location of lower left corner pixel of ROI 2 {Level-1 also}

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 lower-left corner pixel (LLC) information for the origin of the ROI 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 more than one ROI is indicated, they most likely will be strips across the CCD. The summing mode keyword, **AFDBSM**, will also be useful in reconstructing the image.

Derived Keywords:

NUMWIN = **AFDBNW** [number of window ROIs:
= 0 for full (4kx4k) CCD;
= 1 for 1 ROI;
= 2 for 2 ROIs]
NAXIS = 2, 2, 1 [corresponds to number of axes of images for **NUMWIN** = 0,
1, 2, respectively, to not confuse simple FITS file readers.] {Level-1 also}
NAXIS1 = 4096, **ROI_NAX1,** total number of pixels in area{Level-1 also}
NAXIS2 = 4096, **ROI_NAY1,** 0 {Level-1 also}
[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.]

1.2 Additional Information for Level-0 from Image Status Packet (ISP) [APID 027, as of May 2008]

ATCS027 = APID027_TIMECODE_SECONDS (32b; from ISP), APID027 timecode in seconds
ATCSS027 = APID027_TIMECODE_SUBSECS (32b; from ISP), APID027 timecode in subseconds, [Quality/Sanity Check time]
AIVNIMST = *A831A* = AIA_VER_NUM_IMAGE_STATUS (16b; from ISP), ISP version number
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
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, as follows

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) {Level-1 also}, from which the frame serial number of this image, ***AHFSN***, can be sanity checked (independent of the camera number)

AIAHFSN = AIA_IMG_HIST_FSN (32b; from ISP), the FSN of the image from which the histogram data was obtained

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

AIAECTI = *A82CA* = AIA_IMG_AEC_TABLE_ID (16b; from ISP), Automatic Exposure Control (AEC) table used with image

AIASEN = *A82BF* = AIA_IMG_AS_ENCODER (16b; from ISP) {Level-1 also as **APER_SEL**}, aperture selection encoder reading

AIFDBID = *A8315* = AIA_IMG_FDB_ID (16b; from ISP), frame definition block id, [Quality/Sanity Check ***AFDBID*?**]

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

AIFCPS = *A8225* = AIA_IMG_FC_POSITION (16b; from ISP) {Level-1 also as **FOCUSPOS**}, currently loaded target value for the focus position mechanism

AIFTSWTH = AIA_IMG_FLT_TYPE_SW_TH (16b; from ISP), filter switch threshold for 131A wavelength (exposure)

AIFRMLID = AIA_IMG_FRMLIST_ID (16b; from ISP), framelist id for this image

AIFTSID = AIA_IMG_FTS_ID (16b; from ISP), framelist timeline schedule (FTS) id 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

AIWEN = *A8292* = AIA_IMG_FW_ENCODER (8b; from ISP) {Level-1 also as **FILWLSEL**}, filter wheel selector encoder reading (0-255) for this image

AIMGSHCE = *A8213* = AIA_IMG_SH_CMDED_EXPOSURE (19b; from ISP) {Level-1 also as **CMDEXPT**}, commanded exposure for this image

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

AECMODE = AIA_IMG_AEC_MODE (1b; from ISP), mode of AEC (on/off)

AISTATE = *A8284* = AIA_IMG_ISS_LOOP (1b; from ISP), ISS on/off

AIAECENF = AIA_IMG_AEC_ENA_FLAG (1b; from ISP), AEC enable flag for this image

AIFILTYP = AIA_IMG_FILTER_TYPE (1b; from ISP) {Level-1 also as **FILT_TYP**}, filter type, “thick”, “thin” (used for 131 A only), or “open”

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)
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
AICFGDL4 = AIA_IMG_CFG_DELAY_4 (8b; from ISP), readout delay for this image
AIFOENFL = AIA_IMG_FOCUS_ENA_FLAG (1b; from ISP), flag to indicate if focus table used or not
AIMGFSN = AIA_IMG_FRLIST_POS (8b; from ISP), position within framelist of this frame
AIMGTYP = AIA_IMG_IMAGE_TYPE (8b; from ISP) {Level-1 also as **IMG_TYP**}, "dark" (0) or "light" (1) shutter type
AIAWVLEN = AIA_IMG_WAVELENGTH (8b; from ISP)
WAVELNTH = ***AIAWVLEN*** = AIA_IMG_WAVELENGTH (8b; from ISP) {Level-1 also}, wavelength of this observation, with 2 each for camera (telescope) 1, 2, 4, and 4 each 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

WAVEUNIT = "nm" {Level-1 also},
WAVE_STR = string(**WAVELNTH**+***AIFILTYP***) {Level-1 also}, (with no decimal in **WAVELNTH**)
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
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
AIMGSHEN = *A8296* = AIA_IMG_SH_ENCODER (8b; from ISP), shutter selector encoder reading (0-255) for this image
ACSUM027 = APID027_CHECKSUM (16b; from ISP), ISP checksum (last of ISP telemetry words)

1.3 More FITS keywords for *Level-0*

NERRORS int, Number of decompression errors
NPACKETS int, Number of packets in image
QUALLEV0 int, Level-0 (only) quality word

1.4 Other FITS keywords for *Level-0* and *Level-1* also

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
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
EXPSDEV 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.)
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
INT_TIM = ***AICFGDL4*** - ***AICFGDL3*** (+ rollover) double, interval time between readout delay and shutter operation delay plus rollover

DATAVALS	int, Actual number of data values in image
MISSVALS	int, Missing values: **TOTVALS - DATAVALS**
TOTVALS	int, Expected number of data values (pixels)
PERCENTD	int, Actual number of data values in image as percent of the total: (**DATAVALS/TOTVALS**) *100.0
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
DATAP01	pixel value corresponding to lowest 1 percentile
DATAP10	pixel value corresponding to lowest 10 percentile
DATAP25	pixel value corresponding to lowest 25 percentile
DATAP75	pixel value corresponding to lowest 75 percentile
DATAP90	pixel value corresponding to lowest 90 percentile
DATAP95	pixel value corresponding to lowest 95 percentile
DATAP98	pixel value corresponding to lowest 98 percentile
DATAP99	pixel value corresponding to lowest 99 percentile
END	{FITS required}

2. More Level-1 Keywords

BSCALE	Multiplier for data values
BZERO	Offset for data values
QUALLEV1	int, Level-1 quality word
SUM_MODE = AFDBSM	int, Summing Mode
APER_SEL = *AIASEN*	long int, Aperture selection encoder reading
FILWLSEL = *AIWEN*	int, Filter wheel selector encoder reading (0-255)
FILT_TYP = *AIFILTYP*	string, filter type of 'thick', 'thin', or 'open'
IMG_TYP = *AIMGTYP*	string, image type of 'light' or 'dark'
CMDEXPT = *AIMGSHCE*	float, Commanded exposure
FOCUSPOS = *AIFCPS*	long int, Focus position, i.e., currently loaded target value for the focus
CUT_OUT	int, Is this a cut out?, 0 = no, 1=yes

DARK	string, Name of dark processed image
DARK_VER	float, Version number of dark image
FLAT	string, Name of processed flat field image
FLAT_VER	float, Version number of flat field image
DN_GAIN	float, Value of DN per electron gain factor
DN_GN_V	float, Version number of DN gain value
EFF_AREA	float, Value of effective area in cm^2
EFF_AR_V	float, Version number of effective area value
ATT_PT_V	float, Version number of S/C camera attitude pointing
FILENAME	Name of data file
LVL_NUM	Level number of image
REL_VER	Relative version number of reformatter, data, and/or metadata
PIPELNVR	Pipeline version"
SCIRFBSV	Science reference bore sight version number

2.1 Other Keywords for Higher Levels (1.0, and 1.5)

These keywords are to be populated separately for each instrument in Level-1.0, and above, when information becomes available following the guidelines in Phil Scherrer's "JSOC Keywords used for metadata" document [current update 5/8/09]. Please refer to this document, which gives a full description of the following image coordinate mapping keywords, discussing the FITS standards, including instrument and spacecraft pointing. Below the keywords and a brief description are presented. The lower case, Italicized, letters specify mapping from array axes (j) to image axes (i).

CTYPE*i*	Text, type of image coordinate axis ***i*** for other Cxxxx keywords
CRPIX*j*	Reference pixel along array axis ***j***, with the first pixel numbered 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.
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***.
R_SUN	Radius of the Sun's image in pixels, for the visible light (float)
DSUN_OBS	Distance from Sun's center to SDO in m (float)
RSUN_REF	Radius of the Sun in m, (float)

SAT_ROT Position angle of solar pole wrt the SDO Z axis (float, degrees)
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.
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)
XCEN1 X co-ordinate of ROI 1 array center (float)
YCEN1 Y co-ordinate of ROI 2 array center (float)
XCEN2 X co-ordinate of ROI 1 array center (float)
YCEN2 Y co-ordinate of ROI 2 array center (float)

where **a** = **CROTA2** for ROI 1,

XCEN1 = CRVAL1 + CDELT1*cos(a)*((ROI_NAX1+1)/2 – CRPIX1)
– CDELT2*sin(a)*((ROI_NAY1+1)/2 – CRPIX2)
YCEN1 = CRVAL2 + CDELT1*sin(a)*((ROI_NAX1+1)/2 – CRPIX1)
+ CDELT2*cos(a)*((ROI_NAY1+1)/2 – CRPIX2)

and for ROI 2,

XCEN2 = CRVAL1 + CDELT1*cos(a)*((ROI_NAX2+1)/2 – CRPIX1)
– CDELT2*sin(a)*((ROI_NAY2+1)/2 – CRPIX2)
YCEN2 = CRVAL2 + CDELT1*sin(a)*((ROI_NAX2+1)/2 – CRPIX1)
+ CDELT2*cos(a)*((ROI_NAY2+1)/2 – CRPIX2)

FOVX1 = CDELT1 * ROI_NAX1 ROI 1 X-Axis Field of View in CUNITi
FOVY1 = CDELT2 * ROI_NAY1 ROI 1 Y-Axis Field of View in CUNITi
FOVX2 = CDELT1 * ROI_NAX2 ROI 2 X-Axis Field of View in CUNITi
FOVY2 = CDELT2 * ROI_NAY2 ROI 2 Y-Axis Field of View in CUNITi
TEMPCCD Temperature at CCD
TEMPCEB Temperature at common electronics box
TEMPSMIR Temperature at secondary mirror
TEMPPMIR Temperature 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)
EXTEND	FITS file may contain extensions
COMMENT	ASCII comment (can be multiple)
HISTORY	ASCII history record (can be multiple)
DARK	
FLAT_FIELD	Set when applied to image
LEAP_SEC	Current number of leap seconds to add to TAI

More level definitions

Definition of Level-1.0 (Note: This temporary level is generated on demand from Level-0 and is held for up to 60 days.)

1. Header
   Metadata for Level-0 reduced to those scientific FITS keywords needed for analysis at Level-1, updating the image coordinate mapping keywords to meaningful and nearly correct values, plus other keywords needed for Level -1 and above.
2. Data
   Decompressed raw data (level 0) with overscan pixels removed, dark pedestal and current, as well as flat field, corrections applied, bad pixel and cosmic-ray map created, image flipped to align with Solar North, and, finally, image rescaled to integer.

Definition of Level-1.5 (Note: The output from this level will be used to generate the permanently stored data.)

1. Header
   Metadata for Level-1.0 updated for the applied calibrations below (that will irreversibly modify the data).
2. Data
   Floating-Point Level-1.0 data images that are de-spiked, or replaced, using the bad pixel map; adjusted for plate scale, rotation, and sub-pixel registration; roll corrected; and finally rescaled to integer.

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

Level 0		Level 1	Brief Description	Sample Keyword	Section
SIMPLE	=	**SIMPLE**		T	1.4
BITPIX	=	**BITPIX**		16	1.4
BLANK	=	**BLANK**		-32768	1.4 (definition)
NAXIS	=	**NAXIS**		2	1.1
		EXTEND		T	2
ORIGIN	=	**ORIGIN**		'SDO/JSOC-SDP'	1.4
DATE	=	**DATE**		'2008-01-08T18:57:38'	1.4
DATE-OBS	=	**DATE-OBS**		'2008-01-08T18:56:00.005'	1.4, App. 1
T_OBS	=	**T_OBS**		**'**2008-01-08T18:56:03.005'	1.4, App. 1
EXPTIME	=	**EXPTIME**		5.039	1.4, App. 1
EXPSDEV	=	**EXPSDEV**		0.019	1.4, App. 1
TELESCOP	=	**TELESCOP**		'SDO/AIA'	1.4
INSTRUME	=	**INSTRUME**		'AIA_i'	1.4
CAMERA	=	**CAMERA**		3	1.1 (Header)
WAVELNTH	=	**WAVELNTH**		17.1	1.2, 1.4
WAVEUNIT	=	**WAVEUNIT**		'nm'	1.2
WAVE_STR	=	**WAVE_STR**		'17101'	1.2
FSN	=	**FSN**	Frame Serial Number	75000	1.1 (Header)
IMGAPID	=	**IMGAPID**	Packet APID, "Image Application ID"		1.1 (Header)
TAPCODE			"Take a Picture code"		1.1 (Header)
BITSELID			Bit Select ID, r		1.1 (Header)
COMPID			Compression ID; n, *k*		1.1 (Header)
CROPID	=	**CROPID**	Crop table ID		1.1 (Crop table)
FID	=	**FID**	Frame Definition Block ID		1.1 (Crop table)
IMGFPT			First packet time		1.1
TLMDSNAM			Telemety data series name with first packet of image		1.1

AFDBSM	=	**SUM_MODE**		1.1 (FDB)
NUMWIN		(= **AFDBNW**, Number of windows)		1.1 (FDB)
AFDBNW		Number of ROIs		1.1 (FDB)
ROI_NAX1	=	**ROI_NAX1**	4096	1.1
ROI_NAX1	=	**ROI_NAX1**	4096	1.1
ROI_NAX2	=	**ROI_NAX2**	0	1.1
ROI_NAX2	=	**ROI_NAX2**	0	1.1
NAXIS1	=	**NAXIS1**	4096	1.1
NAXIS2	=	**NAXIS2**	4096	1.1
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
NERRORS		Number of decompression errors		1.3
NPACKETS		Number of packets in image		1.3
QUALLEV0		Level-0 Quality word		1.3
DATAVALS	=	**DATAVALS**	Actual number of data values in image	1.4
MISSVALS	=	**MISSVALS**	Missing values: TOTVALS – DATAVALS	1.4
TOTVALS	=	**TOTVALS**	Expected number of data values (pixels)	1.4
PERCENTD	=	**PERCENTD**	Percentage of good data 100.0	1.4
DATAMIN	=	**DATAMIN**	81.0	1.4
DATAMAX	=	**DATAMAX**	4100.0	1.4
DATAMEDN	=	**DATAMEDN**	218.345670	1.4
DATAMEAN	=	**DATAMEAN**	218.345670	1.4
DATARMS	=	**DATARMS**	22.687300	1.4
DATASKEW	=	**DATASKEW**	218.345670	1.4
DATAKURT	=	**DATAKURT**	218.345670	1.4
ATCS027		APID027 timecode in seconds (used to define exposure)		1.2 (ISP)
ATCSS027		APID027 timecode in subseconds (used to define exposure)		1.2 (ISP)
AIVNIMST		ISP version number		1.2 (ISP)
AIMGOTS		seconds time tag		1.2 (ISP)
ASQHDR		**[=** ***ASQTNUM*** (2b) {=Camera} + ***ASQFSN*** (30b) {=FSN}]		1.2 (ISP)
ASQTNUM		[= Camera – 1]		1.2 (ISP)
ASQFSN		[another FSN]		1.2 (ISP)

AIAHFSN			the FSN of the image from which the histogram data was obtained	1.2 (ISP)
AECDELAY			time since image used for AEC	1.2 (ISP)
AIAECTI			Automatic Exposure Control (AEC) tables used with this image	1.2 (ISP)
AIASEN	=	**APERT_SEL**	aperture selection encoder reading	1.2 (ISP)
AIFDBID			[another FDB ID]	
AIMGOTSS			subseconds time tag	1.2 (ISP)
AIFCPS	=	**FOCUSPOS**	currently loaded target value	1.2 (ISP)
AIFTSWTH			filter switch threshold for 131A wavelength (exposure)	1.2 (ISP)
AIFRMLID			framelist id for this image	1.2 (ISP)
AIFTSID			framelist timeline schedule (FTS) id	1.2 (ISP)
AIHISMXB			bin number of maximum of standard histogram for previous image in this wavelength used for the current AEC	1.2 (ISP)
AIHIS192			cumulative histogram value at bin #192	1.2 (ISP)
AIHIS348			cumulative histogram value at bin #348	1.2 (ISP)
AIHIS604			cumulative histogram value at bin #604	1.2 (ISP)
AIHIS860			cumulative histogram value at bin #860	1.2 (ISP)
AIFWEN	=	**FILWLSEL**	filter wheel selector encoder reading	1.2 (ISP)
AIMGSHCE	=	**COMDEXPT**	5.0	1.2 (ISP)
AECTYPE			AEC table for current wavelength	1.2 (ISP)
AECMODE			mode of AEC	1.2 (ISP)
AISTATE			ISS on/off	1.2 (ISP)
AIAECENF			AEC enable flag for this image	1.2 (ISP)
AIFILTYP	=	**FILT_TYP**	01	1.2 (ISP)
AIMSHOBC			shutter timer register value	1.2 (ISP)
AIMSHOBE			shutter timer register value	1.2 (ISP)
AIMSHOTC			shutter timer register value	1.2 (ISP)
AIMSHOTE			shutter timer register value	1.2 (ISP)
AIMSHCBC			shutter timer register value	1.2 (ISP)
AIMSHCBE			shutter timer register value	1.2 (ISP)
AIMSHCTC			shutter timer register value	1.2 (ISP)
AIMSHCTE			shutter timer register value	1.2 (ISP)
AICFGDL1			mechanism delay 1	1.2 (ISP)
AICFGDL2			clear table delay	1.2 (ISP)
AICFGDL3			shutter operation delay	1.2 (ISP)

AICDGDL4		readout delay		1.2 (ISP)
AIFOENFL		flag to indicate if focus table used or not		1.2 (ISP)
AIMGFSN		position within framelist of this frame		1.2 (ISP)
AIMGTYP =	**IMG_TYP**		‘LIGHT’	1.2 (ISP)
AIAWVLEN		(coded wavelength for this observation)		1.2 (ISP)
AIAGP1		general purpose register word 1		1.2 (ISP)
AIAGP2		general purpose register word 2		1.2 (ISP)
AIAGP3		general purpose register word 3		1.2 (ISP)
AIAGP4		general purpose register word 4		1.2 (ISP)
AIAGP5		general purpose register word 5		1.2 (ISP)
AIAGP6		general purpose register word 6		1.2 (ISP)
AIAGP7		general purpose register word 7		1.2 (ISP)
AIAGP8		general purpose register word 8		1.2 (ISP)
AIAGP9		general purpose register word 9		1.2 (ISP)
AIAGP10		general purpose register word 10		1.2 (ISP)
AIGT1SVY		GT 1 Sun vector in y direction		1.2 (ISP)
AIGT1SVZ		GT 1 Sun vector in z direction		1.2 (ISP)
AIGT2SVY		GT 2 Sun vector in y direction		1.2 (ISP)
AIGT2SVZ		GT 2 Sun vector in z direction		1.2 (ISP)
AIGT3SVY		GT 3 Sun vector in y direction		1.2 (ISP)
AIGT3SVZ		GT 3 Sun vector in z direction		1.2 (ISP)
AIGT4SVY		GT 4 Sun vector in y direction		1.2 (ISP)
AIGT4SVZ		GT 4 Sun vector in z direction		1.2 (ISP)
AIMGSHEN		shutter selector encoder reading		1.2 (ISP)
INT_TIM =	**INT_TIM**	[= ***AICFGDL4*** - ***AICFGDL3*** (+ rollover), interval time between readout delay and shutter operation delay plus rollover]		1.4
	BSCALE	multiplier for data values		2
	BZERO	offset for data values		2
	QUALLEV1	Level-1 Quality word		2
	FOVX1	Field of View in CUNITi	1020	2.1
	FOVY1	Field of View in CUNITi	1020	2.1
	FOVX2	Field of View in CUNITi	0	2.1
	FOVY2	Field of View in CUNITi	0	2.1
	CTYPE1		‘SOLARX’	2.1

CTYPE2		‘SOLARY’	2.1
CROTA2		0.0	2.1
CDELT1		0.5	2.1
CDELT2		0.5	2.1
CRPIX1		-357.291	2.1
CRPIX2		850.624	2.1
CRVAL1		0.0	2.1
CRVAL2		0.0	2.1
CUNIT1		‘arcsec’	2.1
CUNIT2		‘arcsec’	2.1
CRDER1	Estimate of random error in 1 as CUNITi		2.1
CRDER2	Estimate of random error in 2 as CUNITi		2.1
CSYSER1	Estimate of systematic error in 1 as CUNITi		2.1
CSYSER2	Estimate of systematic error in 2 as CUNITi		2.1
RSUN_REF		960.0	2.1
X0		2047.0	2.1
Y0		2047.0	2.1
R_SUN	Radius of the Sun’s image in pixels		2.1
SAT_ROT	Position angle of solar pole wrt the SDO Z axis		2.1
INST_ROT	Rotation of the camera from the SDO Z axis		2.1
IM_SCALE		0.5	2.1
XCEN1		434.895	2.1
YCEN1		-169.062	2.1
TEMPCCD	Temp. at CCD	-60.5	2.1
TEMPCEB	Temp. at common electronics box	-30.3	2.1
TEMPSMIR	Temp. at secondary mirror	17.9	2.1
TEMPPMIR	Temp. at primary mirror	25.2	2.1
PZTOFFS1	PZT offset		2.1
PZTOFFS2	PZT offset		2.1
PZTOFFS3	PZT offset		2.1
DATAP01		722.00000	2
DATAP10		726.00000	2
DATAP25		730.00000	2
DATAP75		1094.0000	2

		DATAP90	1368.0000	2
		DATAP95	1662.0000	2
		DATAP98	2282.0000	2
		DATAP99	2826.0000	2
		FILENAME	Name of data file	2
		LVL_NUM	Level number of image	2
		REL_VER	Relative version number of reformatter, data, and/or metadata	2
		PIPELNVR	Pipeline version	2
		EXTEND	FITS file extension? T or F	2
		COMMENT	Comment	2
		HISTORY	ASCII history record, one or more	2
END	=	**END**		1.4

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. The 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, **EXPSDEV;** 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
EXPSDEV      = 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
```