AIA/SDO FITS Keywords for Scientific Usage and Data Processing at Levels 0, 1.0, and 1.5

(A document in progress; This Version for Level 0 & 1 at SDO Launch)

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 Configuration Keywords and 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, as indicated below.

NAXIS = the number of axes of the overall image, int, (nominally = 2) {Level-1 also}
NAXIS1 = the total number of pixels along axis 1 of overall image, int, (nominally = 4096 for X axis) {Level-1 also}
NAXIS2 = the total number of pixels along axis 2 of overall image, int, (nominally = 4096 for Y axis) {Level-1 also}
CAMERA = the most significant 2b of ***AHTLFSN*** +1 = [1, 2, 3, 4] and the AIA camera (telescope) number associated with the image (int) {Level-1 also}
FSN = the least significant 30b of ***AHTLFSN*** and is the Frame Serial Number (int) {Level-1 also}
FID = the Frame Definition Block (FDB) ID (int) found in the crop/de-crop tables for this image {Level-1 also}
TLMDSNAM = Telemetry data series name (string) with first packet of image
IMGFPT = the first packet time in "ISO" units constructed from ***AHTCS*** and ***AHTCSS***.
IMGAPID = ***AHAPID***, Image Application ID (int)
TAPCODE = ***AHTAPC***, "Take a Picture code" (int)
BITSELID = ***AHBITID***, Bit select id, r (int)
COMPID = the compression id; n, k; constructed from ***AHCPIDN*** and ***AHCPIDK***. (int)
CROPID = Crop Table ID
LUTID = ***AHLUTID***, Lookup table id (int)
NPACKETS int, Number of packets in image
NERRORS int, Number of decompression errors
EOIERROR short, Last pixel error; End Of Image Error
HEADRERR short, Header error in image
OVERFLOW short, Data overflow error in image

QUALITY int, Level-0 and -1 quality word (QUALITY = 0 means OK) {Level-1 also}

1.2 FITS, JSOC, and Image Statistics Keywords for Level-0 and Level-1

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)

EXTEND FITS file may contain extensions
BLD_VERS string, JSOC build version
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
= DATE_D$OBS = DATE__OBS other forms of this keyword in the database or in printouts
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.)

IMG_TYPE string, shutter image type: 'LIGHT' or 'DARK'
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_TIME = ***AICFGDL4*** **-** ***AICFGDL3*** (+ rollover) double, interval time between readout delay and shutter operation delay plus rollover (i.e., CCD integration duration)

WAVELNTH = ***AIAWVLEN*** = AIA_IMG_WAVELENGTH integer, wavelength of this observation in angstroms, with 2 each for camera (telescope) 1, 2, 4, and 4 each for camera 3 with mapping reference number of each wavelength

= 335 (0), 131 (1) for camera 1
= 211 (2), 193 (3) for camera 2
= 1600 (4), 1700 (5), 4500 (6), 171 (7) for camera 3
= 304 (8), 94 (9) for camera 4

WAVEUNIT = "angstrom"	wavelength unit: angstrom
WAVE_STR = string(**WAVELNTH**+'_'+***AIFILTYP***)	wavelength Filter Position
TOTVALS	int, Expected number of data values (pixels)
DATAVALS	int, Actual number of data values in image
MISSVALS	int, Missing values: **TOTVALS** – **DATAVALS**
PERCENTD	int, Actual number of data values in image as percent of the total: (**DATAVALS/TOTVALS**) *100.0
DATAMIN	short, minimum value from all pixels
DATAMAX	short, maximum value from all pixels
DATAMEDN	short, median value from all pixels
DATAMEAN	float, mean value for all pixels
DATARMS	float, RMS deviation from the mean value of all pixels
DATASKEW	float, Skewness from the mean value of all pixels
DATAKURT	float, Kurtosis of all pixels
BLANK = "-32768"	value signaling undefined integer data
COMMENT	Comment
HISTORY	ASCII history record, one or more, usually by SSW
END	{FITS required; not at end of current Level-0 files (TBD)}

1.3 Image Status Packet (ISP) Keywords [from APID 027, as of May 2008] to be included in Level-0 and Level-1

ISPSNAME	ISP Series Name
ISPPKTIM	Packet time from the following two ISP keywords, Prime key value for the ISP record
ATCS027 = APID027_TIMECODE_SECONDS,	APID027 timecode in seconds
ATCSS027 = APID027_TIMECODE_SUBSECS,	APID027 timecode in subseconds, [Quality/Sanity Check time]
ISPPKTVN	Packet version number
AIVNMST = AIA_VER_NUM_IMAGE_STATUS,	ISP version number
AIMGOTS = AIA_IMG_OBT_TIME_SH_SEC,	seconds time tag read from OBC shutter time tag register for the shutter operation making this image
ASQHDR = AIA_SEQ_HEADER,	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, from which the camera (telescope) number that took this image, **CAMERA** (= ***ASQTNUM*** + 1), can be sanity checked

ASQFSN = AIA_SEQ_FRAME_SN from which the frame serial number of this image, ***AHFSN***, can be sanity checked (independent of the camera number)

AIAHFSN = AIA_IMG_HIST_FSN, the FSN of the image from which the histogram data was obtained

AECDELAY = AIA_IMG_AEC_DELAY, time since image used for AEC

AIAECTI = AIA_IMG_AEC_TABLE_ID, Automatic Exposure Control (AEC) table used with image

AIASEN = AIA_IMG_AS_ENCODER aperture selection encoder reading{TBD, Level-1 as **APER_SEL**}

AIFDBID = AIA_IMG_FDB_ID, frame definition block id, [Quality/Sanity Check ***AFDBID*?**]

AIMGOTSS = AIA_IMG_OBT_TIME_SH_SS, subseconds time tag read from OBC shutter time tag register for the shutter operation making this image

AIFCPS = AIA_IMG_FC_POSITION currently loaded target value for the focus position mechanism {TBD, Level-1 as **FOCUSPOS**}

AIFTSWTH = AIA_IMG_FLT_TYPE_SW_TH, filter switch threshold for 131A wavelength (exposure)

AIFRMLID = AIA_IMG_FRMLIST_ID, framelist id for this image

AIFTSID = AIA_IMG_FTS_ID, framelist timeline schedule (FTS) id for this image

AIHISMXB = AIA_IMG_HIST_MAX_BIN, bin number of maximum of standard histogram for previous image in this wavelength used for the current AEC

AIHIS192 = AIA_IMG_HISTC_BN_192, cumulative histogram value at bin #192

AIHIS348 = AIA_IMG_HISTC_BN_348, cumulative histogram value at bin #348

AIHIS604 = AIA_IMG_HISTC_BN_604, cumulative histogram value at bin #604

AIHIS860 = AIA_IMG_HISTC_BN_860, cumulative histogram value at bin #860

AIFWEN = AIA_IMG_FW_ENCODER filter wheel selector encoder reading (0-255) for this image {TBD, Level-1 as **FILWLSEL**}

AIMGSHCE = AIA_IMG_SH_CMDED_EXPOSURE commanded exposure for image {TBD, Level-1 as **CMDEXPT**}

AECTYPE = AIA_IMG_AEC_TYPE, AEC table for current wavelength (4 tables per wavelength)

AECMODE = AIA_IMG_AEC_MODE, mode of AEC (on/off)

AISTATE = AIA_IMG_ISS_LOOP, ISS on/off

AIAECENF = AIA_IMG_AEC_ENA_FLAG, AEC enable flag for this image

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

AIMSHOBC = AIA_IMG_SH_OPEN_BOT_CENTR, shutter timer register value for this position of this image

AIMSHOBE = AIA_IMG_SH_OPEN_BOT_EDGE, (same as above)

AIMSHOTC	= AIA_IMG_SH_OPEN_TOP_CENTR,	(same as above)
AIMSHOTE	= AIA_IMG_SH_OPEN_TOP_EDGE,	(same as above)
AIMSHCBC	= AIA_IMG_SH_CLOSE_BOT_CENTR,	(same as above)
AIMSHCBE	= AIA_IMG_SH_CLOSE_BOT_EDGE,	(same as above)
AIMSHCTC	= AIA_IMG_SH_CLOSE_TOP_CENTR ,	(same as above)
AIMSHCTE	= AIA_IMG_SH_CLOSE_TOP_EDGE,	(same as above)
AICFGDL1	= AIA_IMG_CFG_DELAY_1,	mechanism delay 1 for this image
AICFGDL2	= AIA_IMG_CFG_DELAY_2,	clear table delay for this image
AICFGDL3	= AIA_IMG_CFG_DELAY_3,	shutter operation delay for this image
AICFGDL4	= AIA_IMG_CFG_DELAY_4 ,	readout delay for this image
AIFOENFL	= AIA_IMG_FOCUS_ENA_FLAG,	flag to indicate if focus table used or not
AIMGFSN	= AIA_IMG_FRLIST_POS,	position within framelist of this frame
AIMGTYP	= AIA_IMG_IMAGE_TYPE	software logic shows “dark” (0) only, {replaced by **IMG_TYP**}
AIAWVLEN	= AIA_IMG_WAVELENGTH	
AIAGP1	= AIA_IMG_GP1,	general purpose register word 1
AIAGP2	= AIA_IMG_GP2,	general purpose register word 2
AIAGP3	= AIA_IMG_GP3,	general purpose register word 3
AIAGP4	= AIA_IMG_GP4,	general purpose register word 4
AIAGP5	= AIA_IMG_GP5,	general purpose register word 5
AIAGP6	= AIA_IMG_GP6,	general purpose register word 6
AIAGP7	= AIA_IMG_GP7,	general purpose register word 7
AIAGP8	= AIA_IMG_GP8,	general purpose register word 8
AIAGP9	= AIA_IMG_GP9,	general purpose register word 9
AIAGP10	= AIA_IMG_GP10,	general purpose register word 10
AGT1SVY	= AIA_IMG_GT1_SUNVECTOR_Y,	Guide Telescope (GT) 1 Sun vector in y direction
AGT1SVZ	= AIA_IMG_GT1_ SUNVECTOR _Z,	Guide Telescope (GT) 1 Sun vector in z direction
AGT2SVY	= AIA_IMG_GT2_SUNVECTOR_Y,	Guide Telescope (GT) 2 Sun vector in y direction
AGT2SVZ	= AIA_IMG_GT2_ SUNVECTOR _Z,	Guide Telescope (GT) 2 Sun vector in z direction
AGT3SVY	= AIA_IMG_GT3_SUNVECTOR_Y,	Guide Telescope (GT) 3 Sun vector in y direction
AGT3SVZ	= AIA_IMG_GT3_ SUNVECTOR _Z,	Guide Telescope (GT) 3 Sun vector in z direction
AGT4SVY	= AIA_IMG_GT4_SUNVECTOR_Y	Guide Telescope (GT) 4 Sun vector in y direction
AGT4SVZ	= AIA_IMG_GT4_ SUNVECTOR _Z,	Guide Telescope (GT) 4 Sun vector in z direction
AIMGSHEN	= AIA_IMG_SH_ENCODER,	shutter selector encoder reading (0-255) for this image

2. Level-1 Keywords

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.

Note: Level-1 keywords include those identified as such above plus those following.

2.1 Level-1 Image, Scale, and Processing Keywords

T_OBS_step	T_OBS step (seconds)
T_OBS_epoch	
T_OBS_round	center of slot
BSCALE	Multiplier for data values
BZERO	Offset for data values
QUALLEV0	int, Level-0 quality word in Level-0

QUALITY		int, Level-1 quality word
ROI_NWIN	= Number of Windows (4b; from FDB) for number of Region Of Interest(s) (ROI) (int) (= 0, 1, 2)	
ROI_SUM	= SummingMode (4b; from FDB) for summing (int): 1x1, 2x2, 4x4 (= 0, 1, 2)	
ROI_NAX1	= Number of CCD Columns (from FDB and de-crop table) for width of ROI 1 in pixels (int)	
ROI_NAY1	= Number of CCD Rows (from FDB and de-crop table) for height of ROI 1 in pixels (int)	
ROI_LLX1	= CCD X-variable location of lower left corner pixel of ROI 1 (int)	
ROI_LLY1	= CCD Y-variable location of lower left corner pixel of ROI 1 (int)	
ROI_NAX2	= Number of CCD Columns (from FDB and de-crop table) for width of ROI 2 in pixels (int)	
ROI_NAY2	= Number of CCD Rows (from FDB and de-crop table) for height of ROI 2 in pixels (int)	
ROI_LLX2	= CCD X-variable location of lower left corner pixel of ROI 2 (int)	
ROI_LLY2	= CCD Y-variable location of lower left corner pixel of ROI 2 (int)	

Currently the following 5 keywords are still listed by their ISP names, which start with "**AI**" (second column of 5 keywords below).

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'
CMDEXPT	= ***AIMGSHCE***	float, Commanded exposure
FOCUSPOS	= ***AIFCPS***	long int, Focus position, i.e., currently loaded focus target value

OSCNMEAN	is mean value of overscan rows	
OSCNRMS	is rms deviation from the mean value of overscan rows	
FLAT_REC	is a pointer to the calibration file containing the type of information of the following keywords:	
	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
	FLAT_FIELD	Set when applied to image

BLD_VERSN	give the build version (in Section 1.2 also) from jsoc_version.h and replaces the following 2 keywords:	
	REL_VER	Relative version number of reformatter, data, and/or metadata
	PIPELNVR	Pipeline version

Currently the following keywords are not in Level-1:

CUT_OUT	int, Is this a cut out?, 0 = no, 1=yes
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
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
LEAP_SEC	Current number of leap seconds to add to TAI
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

2.2 Level-1 Coordinate Mapping Keywords

These keywords are to be populated separately for each instrument in Level-1.0, and above, when information becomes available following the definitions, assumptions, and guidelines in Phil Scherrer's "JSOC Keywords used for metadata" document [current update 2/19/10 or later], which can be found on the web at http://jsoc.stanford.edu/doc/keywords/JSOC_Keywords_for_metadata . Please consider Phil's document as another appendix to the present document, because it presents 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. For AIA it is assumed: 1) there is a fixed value for each telescope plate scale, **IMSCL_MP**: 2) the center of the solar disk is the origin. The spacecraft pointing keywords are now included below. Note in the following that 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, where **CTYPE1 = HPLN-TAN (SOLARX), CTYPE2 = HPLT-TAN (SOLARY),** for longitude and latitude, respectively. (see Phil's document for coordinate mapping descriptions).
CUNIT*i*	Physical units for position on image axis ***I***, where **CUNIT1 = CUNIT2** = "arcsec"
CRVAL*i*	Physical value along image axis ***i*** at the center of the pixel, where **CRVAL1 = CRVAL2 = 0.0**
CDELT*i*	Pixel spacing per index value along image axis ***I***, equal to **IM_SCALE** except at higher levels when the image has been rescaled (**CDELT1, CDELT2** in x, y directions, respectively)
CRPIX*j*	Reference pixel along array axis ***j***, with the first pixel numbered 1 (not 0), i.e., location of disk center in x and y directions on image, where **CRPIX1 = X0 + 1, CRPIX2 = Y0 + 1** (see **X0**, **Y0** below).
CROTA*j*	Rotation needed for array axes to get to image axes (in degrees), where **CROTA2 = SAT_ROT** + **INST_ROT** (see below) Note: No **CROTA1**

Currently the following 2 keywords are not in Level-1:

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 on the CCD detector, for the visible light (float)
MPO_REC	is the Master Pointing series record pointer to the Science reference bore sight information and replaces **SCIRFBSV**, the science reference bore sight version number
INST_ROT	Master pointing CCD rotation wrt SDO Z (float, degrees)
IMSCL_MP	Master pointing image scale in arc-sec per CCD pixel (float),

	replacing **IM_SCALE**; This value will be used for the estimate of CDELT for AIA
X0_MP	Master pointing X0 sun center in CCD frame in pixels, start 0.0 (float) for raw image
Y0_MP	Master pointing Y0 sun center in CCD frame in pixels, start 0.0 (float) for raw image
RSUN_LF	Limb fit Solar radius in pixels (float)
X0_LF	Limb fit X0 sun center in CCD frame in pixels (float)
Y0_LF	Limb fit Y0 sun center in CCD frame in pixels (float)
ASD_REC	Ancillary Science Data series record pointer (string)
SAT_Y0	Position of solar center wrt the SDO -Y axis in arcsec (float)
SAT_Z0	Position of solar center wrt the SDO Z axis in arcsec (float)
SAT_ROT	Position angle of solar pole wrt the SDO X axis (float, degrees)
ACS_MODE	ACS pointing mode (ACS are strings)- ACS_AN_ACS_MODE
ACS_ECLP	ACS eclipse flag - ACS_AN_FLAG_CSS_ECLIPSE
ACS_SUNP	ACS sun presense flag - ACS_AN_FLAG_DSS_SUNPRES
ACS_SAFE	ACS safe hold flag - ACS_AN_FLAG_ACE_INSAFEHOLD
ACS_CGT	ACS ID of Controlling Guide Telescope - ACS_AN_NUM_CGT
ORB_REC	Orbit vector series record pointer (string)
DSUN_REF	Reference distance to Sun: 149,597,870,691.0 m (double)
DSUN_OBS	Distance from Sun center to SDO in m (double)
RSUN_REF	Reference radius of the Sun: 696,000,000.0 m (double)
RSUN_OBS	Apparent radius of the Sun seen by SDO (arcsec, double)
GCIEC_X	Geocentric Inertial X position in m (double)
GCIEC_Y	Geocentric Inertial Y position in m (double)
GCIEC_Z	Geocentric Inertial Z position in m (double)
HCIEC_X	Heliocentric Inertial X position in m (double)
HCIEC_Y	Heliocentric Inertial Y position in m (double)
HCIEC_Z	Heliocentric Inertial Z position in m (double)
OBS_VR	Speed of observer in radial direction in m/s (double)
OBS_VW	Speed of observer in solar-west direction in m/s (double)
OBS_VN	Speed of observer in solar-north direction in m/s (double)
CRLN_OBS	Carrington longitude of the observer in degrees (float)
CRLT_OBS	Carrington latitude of the observer in degrees (float)

CAR_ROT Carrington rotation number of CRLN_OBS(integer)

Currently the following keywords are not in Level-1:

XCEN1 X co-ordinate of ROI 1 array center (float) in arcsec
YCEN1 Y co-ordinate of ROI 2 array center (float) in arcsec
XCEN2 X co-ordinate of ROI 1 array center (float) in arcsec
YCEN2 Y co-ordinate of ROI 2 array center (float) in arcsec

Using **a** = **CROTA2** for ROI 1 and ROI 2, we can calculate the following 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 arcsec
FOVY1 = CDELT2 * ROI_NAY1 ROI 1 Y-Axis Field of View in arcsec
FOVX2 = CDELT1 * ROI_NAX2 ROI 2 X-Axis Field of View in arcsec
FOVY2 = CDELT2 * ROI_NAY2 ROI 2 Y-Axis Field of View in arcsec

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

Level 0		Level 1	Brief Description	Sample Keyword	Section
SIMPLE	=	**SIMPLE**		T	1.2
BITPIX	=	**BITPIX**		16	1.2
BLANK	=	**BLANK**		-32768	1.2 (definition)

NAXIS	=	**NAXIS**		2	1.1
NAXIS1	=	**NAXIS1**		4096	1.1
NAXIS2	=	**NAXIS2**		4096	1.1
EXTEND	=	**EXTEND**		T	1.2
		BSCALE	multiplier for data values		2.1
		BZERO	offset for data values		2.1
ORIGIN	=	**ORIGIN**		‘SDO/JSOC-SDP’	1.2
DATE	=	**DATE**		‘2008-01-08T23:57:38’	1.2
TELESCOP	=	**TELESCOP**		‘SDO/AIA’	1.2
INSTRUME	=	**INSTRUME**		‘AIA_3’	1.2
DATE__OBS	=	**DATE__OBS**		‘2008-01-08T18:56:00.005’	1.2, App. 1
T_OBS	=	**T_OBS**		**‘**2008-01-08T18:56:03.005’	1.2, App. 1
CAMERA	=	**CAMERA**		3	1.1 (Header)
IMG_TYPE	=	**IMG_TYPE**		‘LIGHT or DARK’	1.2
EXPTIME	=	**EXPTIME**		5.039	1.2, App. 1
EXPSDEV	=	**EXPSDEV**		0.019	1.2, App. 1
INT_TIME	=	**INT_TIME**	[= ***AICFGDL4*** - ***AICFGDL3*** (+ rollover), interval time between readout delay and shutter operation delay plus rollover]		1.2
WAVELNTH	=	**WAVELNTH**		171	1.2
WAVEUNIT	=	**WAVEUNIT**		‘angstrom’	1.2
WAVE_STR	=	**WAVE_STR**		‘171_01’	1.2
FSN	=	**FSN**	Frame Serial Number	75000	1.1 (Header)
FID	=	**FID**	Frame Definition Block ID		1.1 (Crop table)
TLMDSNAM			Telemety data series name with first packet of image		1.1 (Header)
IMGFPT			First packet time		1.1 (Header)
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			Crop table ID		1.1 (Crop table)
LUTID			Lookup table id		1.1 (Header)
NPACKETS			Number of packets in image		1.1
NERRORS			Number of decompression errors		1.1
EOIERROR			Last pixel error; End Of Image Error		1.1

HEADRERR		Header error in image		1.1
OVERFLOW		Data overflow error in image		1.1
QUALITY =	**QUALLEV0**	Level-0 Quality word		1.1, 2.1
	QUALITY	Level-1 Quality word		1.1, 2.1
TOTVALS =	**TOTVALS**	Expected number of data values (pixels)		1.2
DATAVALS =	**DATAVALS**	Actual number of data values in image		1.2
MISSVALS =	**MISSVALS**	Missing values: TOTVALS – DATAVALS		1.2
PERCENTD =	**PERCENTD**	Percentage of good data	100.0	1.2
DATAMIN =	**DATAMIN**		81.0	1.2
DATAMAX =	**DATAMAX**		4100.0	1.2
DATAMEDN =	**DATAMEDN**		218.345670	1.2
DATAMEAN =	**DATAMEAN**		218.345670	1.2
DATARMS =	**DATARMS**		22.687300	1.2
DATASKEW =	**DATASKEW**		218.345670	1.2
DATAKURT =	**DATAKURT**		218.345670	1.2
	OSCNMEAN			2.1
	OSCNRMS			2.1
	FLAT_REC			2.1
	CTYPE1		‘HPLN-TAN’	2.2
	CUNIT1		‘arcsec’	2.2
	CRVAL1		0.0	2.2
	CDELT1		0.5	2.2
	CRPIX1		2048.0	2.2
	CTYPE2		‘HPLT-TAN’	2.2
	CUNIT2		‘arcsec’	2.2
	CRVAL2		0.0	2.2
	CDELT2		0.5	2.2
	CRPIX2		2048.0	2.2
	CROTA2		0.0	2.2
	R_SUN	Radius of the Sun’s image in pixels, for the visible light		2.2
	MPO_REC	Master Pointing series record pointer		2.2
	INST_ROT	Rotation of the camera from the SDO Z axis		2.2
	IMSCL_MP	Master pointing image scale		2.2

	X0_MP			2.2
	Y0_MP			2.2
	RSUN_LF			2.2
	X0_LF			2.2
	Y0_LF			2.2
	ASD_REC			2.2
	SAT_Y0			2.2
	SAT_Z0			2.2
	SAT_ROT	Position angle of solar pole wrt the SDO Z axis		2.2
	ACS_MODE			2.2
	ACS_ECLP			2.2
	ACS_SUNP			2.2
	ACS_SAFE			2.2
	ACS_CGT			2.2
	ORB_REC			2.2
	DSUN_REF	Reference distance to Sun	149597870691.0	2.2
	DSUN_OBS	Distance from Sun's center to SDO		2.2
	RSUN_REF	Radius of the Sun in	696000000.0	2.2
	RSUN_OBS	Apparent radius of the Sun seen by SDO		2.2
	GCIEC_X			2.2
	GCIEC_Y			2.2
	GCIEC_Z			2.2
	HCIEC_X			2.2
	HCIEC_Y			2.2
	HCIEC_Z			2.2
	OBS_VR			2.2
	OBS_VW			2.2
	OBS_VN			2.2
	CRLN_OBS			2.2
	CRLT_OBS			2.2
	CAR_ROT			2.2
ROI_NWIN =	**ROI_NWIN**	Number of windows or ROIs	0	2.1
	ROI_SUM		0	2.1
	ROI_NAX1		4096	2.1

ROI_NAY1	4096	2.1
ROI_NAX2	0	2.1
ROI_NAY2	0	2.1
ROI_LLX1	0	2.1
ROI_LLY1	0	2.1
ROI_LLX2	0	2.1
ROI_LLY2	0	2.1

Currently all of the ISP keywords are in both Level-0 and Level-1:

ISPSNAME	ISP Series Name	aia.lev0_isp_0011	1.3 (ISP)
ISPPKTIM	Packet time	'2008-01-08T18:56:01.000'	1.3 (ISP)
ISPPKTVN	Packet version number	'001.1'	1.3 (ISP)
AIVNMST	ISP version number		1.3 (ISP)
AIMGOTS	seconds time tag		1.3 (ISP)
ASQHDR	**[=** ***ASQTNUM*** (2b) {=Camera} + ***ASQFSN*** (30b) {=FSN}]		1.3 (ISP)
ASQTNUM	[= Camera – 1]		1.3 (ISP)
ASQFSN	[another FSN]		1.3 (ISP)
AIAHFSN	the FSN of the image from which the histogram data was obtained		1.3 (ISP)
AECDELAY	time since image used for AEC		1.3 (ISP)
AIAECTI	Automatic Exposure Control (AEC) tables used with this image		1.3 (ISP)
AIASEN =	**(APERT_SEL)** aperture selection encoder reading		1.3 (ISP)
AIFDBID	[another FDB ID]		
AIMGOTSS	subseconds time tag		1.3 (ISP)
AIFCPS =	**(FOCUSPOS)** currently loaded target value		1.3 (ISP)
AIFTSWTH	filter switch threshold for 131A wavelength (exposure)		1.3 (ISP)
AIFRMLID	framelist id for this image		1.3 (ISP)
AIFTSID	framelist timeline schedule (FTS) id		1.3 (ISP)
AIHISMXB	bin number of maximum of standard histogram for previous image in this wavelength used for the current AEC		1.3 (ISP)
AIHIS192	cumulative histogram value at bin #192		1.3 (ISP)
AIHIS348	cumulative histogram value at bin #348		1.3 (ISP)
AIHIS604	cumulative histogram value at bin #604		1.3 (ISP)
AIHIS860	cumulative histogram value at bin #860		1.3 (ISP)
AIFWEN =	**(FILWLSEL)** filter wheel selector encoder reading		1.3 (ISP)

AIMGSHCE =	**(COMDEXPT)**	5.0	1.3 (ISP)
AECTYPE	AEC table for current wavelength		1.3 (ISP)
AECMODE	mode of AEC		1.3 (ISP)
AISTATE	ISS on/off		1.3 (ISP)
AIAECENF	AEC enable flag for this image		1.3 (ISP)
AIFILTYP =	(**FILT_TYP**)	01	1.3 (ISP)
AIMSHOBC	shutter timer register value		1.3 (ISP)
AIMSHOBE	shutter timer register value		1.3 (ISP)
AIMSHOTC	shutter timer register value		1.3 (ISP)
AIMSHOTE	shutter timer register value		1.3 (ISP)
AIMSHCBC	shutter timer register value		1.3 (ISP)
AIMSHCBE	shutter timer register value		1.3 (ISP)
AIMSHCTC	shutter timer register value		1.3 (ISP)
AIMSHCTE	shutter timer register value		1.3 (ISP)
AICFGDL1	mechanism delay 1		1.3 (ISP)
AICFGDL2	clear table delay		1.3 (ISP)
AICFGDL3	shutter operation delay		1.3 (ISP)
AICDGDL4	readout delay		1.3 (ISP)
AIFOENFL	flag to indicate if focus table used or not		1.3 (ISP)
AIMGFSN	position within framelist of this frame		1.3 (ISP)
AIMGTYP		‘dark’	1.3 (ISP)
AIAWVLEN	(coded wavelength for this observation)		1.3 (ISP)
AIAGP1	general purpose register word 1		1.3 (ISP)
AIAGP2	general purpose register word 2		1.3 (ISP)
AIAGP3	general purpose register word 3		1.3 (ISP)
AIAGP4	general purpose register word 4		1.3 (ISP)
AIAGP5	general purpose register word 5		1.3 (ISP)
AIAGP6	general purpose register word 6		1.3 (ISP)
AIAGP7	general purpose register word 7		1.3 (ISP)
AIAGP8	general purpose register word 8		1.3 (ISP)
AIAGP9	general purpose register word 9		1.3 (ISP)
AIAGP10	general purpose register word 10		1.3 (ISP)
AGT1SVY	GT 1 Sun vector in y direction		1.3 (ISP)
AGT1SVZ	GT 1 Sun vector in z direction		1.3 (ISP)

AGT2SVY		GT 2 Sun vector in y direction		1.3 (ISP)
AGT2SVZ		GT 2 Sun vector in z direction		1.3 (ISP)
AGT3SVY		GT 3 Sun vector in y direction		1.3 (ISP)
AGT3SVZ		GT 3 Sun vector in z direction		1.3 (ISP)
AGT4SVY		GT 4 Sun vector in y direction		1.3 (ISP)
AGT4SVZ		GT 4 Sun vector in z direction		1.3 (ISP)
AIMGSHEN		shutter selector encoder reading		1.3 (ISP)
COMMENT	=	**COMMENT**	Comment	1.2
HISTORY	=	**HISTORY**	ASCII history record, one or more	1.2
END	=	**END**	End of file	1.2

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
```

Appendix 2: AIA Level-0 Quality Definition

(from Rock Bush, 6/02/09)

QUALITY = 0 means OK.

Bit 0 is the low bit (0x01).
The first 4 bits are determined from the Img struct passed back by imgdecode
The parameter MISSVALS is from Img struct TOTVALS - DATAVALS

Bit	Meaning
0	Overflow Flag Set
1	Header Error Flag Set
2	Compression Error in Image
3	Last Pixel Error
4	Image Status Packet Missing; (FSN != ASQFSN) or ASQFSN missing
5	
6	
7	
8	MISSVALS > 0
9	MISSVALS > 0.01*TOTVALS
10	MISSVALS > 0.05*TOTVALS
11	MISSVALS > 0.25*TOTVALS
or	
8	bits 8 to 11; 4 bit integer quantity
9	if MISSVALS == 0; == 0
10	if MISSVALS != 0; == 0.84*LOG(MISSVALS/TOTVALS) + 15
11	
12	
13	
14	
15	

AIA specific

```
16
17          ISS Loop Open;      AISTATE != 0; AISTATE == "OPEN"
18          9.4nm Mech Error;  AIAWVLEN == 9 &&
                                {(AIFILTYP == 0 && AIFWEN != 269 && AIFWEN != 270)
                                || (AIFILTYP == 1 && AIFWEN !=  11 && AIFWEN !=  12)
                                || (AIFILTYP == 2 && AIFWEN !=  74 && AIFWEN !=  75)}
19          13.1nm Mech Error; AIAWVLEN == 1 &&
                                {(AIFILTYP == 0 && AIFWEN != 269 && AIFWEN != 270)
                                || (AIFILTYP == 1 && AIFWEN !=  11 && AIFWEN !=  12)
                                || (AIFILTYP == 2 && AIFWEN !=  74 && AIFWEN !=  75)}
20          17.1nm Mech Error; AIAWVLEN == 7 &&
                                {(AIFILTYP == 0 && AIFWEN != 203 && AIFWEN != 204)
                                || (AIFILTYP == 1 && AIFWEN !=  11 && AIFWEN !=  12)}
21          19.3nm Mech Error; AIAWVLEN == 3 && {AIASEN !=  6
                                || (AIFILTYP == 0 && AIFWEN != 269 && AIFWEN != 270)
                                || (AIFILTYP == 1 && AIFWEN !=  11 && AIFWEN !=  12)
                                || (AIFILTYP == 2 && AIFWEN !=  74 && AIFWEN !=  75)}
22          21.1nm Mech Error; AIAWVLEN == 2 && {AIASEN !=  24
                                || (AIFILTYP == 0 && AIFWEN != 203 && AIFWEN != 204)
                                || (AIFILTYP == 1 && AIFWEN != 137 && AIFWEN != 138)
                                | (AIFILTYP == 2 && AIFWEN !=  74 && AIFWEN !=  75)}
23          30.4nm Mech Error; AIAWVLEN == 8 &&
                                {(AIFILTYP == 0 && AIFWEN != 203 && AIFWEN != 204)
                                || (AIFILTYP == 1 && AIFWEN != 137 && AIFWEN != 138)
                                || (AIFILTYP == 2 && AIFWEN !=  74 && AIFWEN !=  75)}
24          33.5nm Mech Error; AIAWVLEN == 0 &&
                                {(AIFILTYP == 0 && AIFWEN != 203 && AIFWEN != 204)
                                || (AIFILTYP == 1 && AIFWEN != 137 && AIFWEN != 138)
                                || (AIFILTYP == 2 && AIFWEN !=  74 && AIFWEN !=  75)}
25          160nm Mech Error;  AIAWVLEN == 4 && AIFWEN != 269 && AIFWEN != 270
26          170nm Mech Error;  AIAWVLEN == 5 && AIFWEN != 137 && AIFWEN != 138
27          450nm Mech Error;  AIAWVLEN == 6 && AIFWEN !=  74 && AIFWEN !=  75
28
```

29
30
31

****

AIA Mechanism position definitions from Paul Boerner

WAVELEN	FILTER_TYPE	FW_ENCODER	AS_ENCODER"
1600	"Don't check"	"269 or 270"	"Don't check"
	"Don't check"	"269 or 270"	"Don't check"
	"Don't check"	"269 or 270"	"Don't check"
1700	"Don't check"	"137 or 138"	"Don't check"
	"Don't check"	"137 or 138"	"Don't check"
	"Don't check"	"137 or 138"	"Don't check"
4500	"Don't check"	"74 or 75"	"Don't check"
	"Don't check"	"74 or 75"	"Don't check"
	"Don't check"	"74 or 75"	"Don't check"

WAVELEN	FILTER_TYPE	FW_ENCODER	AS_ENCODER"
94	0	"269 or 270"	"Don't check"
	1	"11 or 12"	"Don't check"
	2	"74 or 75"	"Don't check"
131	0	"269 or 270"	"Don't check"
	1	"11 or 12"	"Don't check"
	2	"74 or 75"	"Don't check"
171	0	"203 or 204"	"Don't check"
	1	"11 or 12"	"Don't check"
	2	"Don't Check"	"Don't check"

304	0	"203 or 204"	"Don't check"
	1	"137 or 138"	"Don't check"
	2	"74 or 75"	"Don't check"
335	0	"203 or 204"	"Don't check"
	1	"137 or 138"	"Don't check"
	2	"74 or 75"	"Don't check"

WAVELEN	FILTER_TYPE	FW_ENCODER	AS_ENCODER"
193	0	"269 or 270"	6
	1	"11 or 12"	6
	2	"74 or 75"	6
211	0	"203 or 204"	24
	1	"137 or 138"	24
	2	"74 or 75"	24

****

Fits keyword and Image Status Packet (ISP) keyword translation:

ASQFSN	AIA_SEQ_FRAME_SN	longlong
AISTATE	AIA_IMG_ISS_LOOP	string
AIAWVLEN	AIA_IMG_WAVELENGTH	int
AIASEN	AIA_IMG_AS_ENCODER	int
AIFILTYP	AIA_IMG_FILTER_TYPE	short
AIFWEN	AIA_IMG_FW_ENCODE	int
AIFOENFL	AIA_IMG_FOCUS_ENA_FLAG	short

****

AIAWVLEN lookup values:

0,	1,	2,	3,	4,	5,	6,	7,	8,	9
{ 33.5,	13.1,	21.1,	19.3,	160.0,	170.0,	450.0,	17.1,	30.4,	9.4 }