ZTFOS-SW-00150 Digitized Pixel Data: Pixel values shall be digitized to 32 bits per pixel.
ZTFOS-SW-00155 FITS File Format: The ZTF camera image output data shall be stored in FITS files.
ZTFOS-SW-00156 FITS Name Format: FITS filenames are proposed to use the following pattern for image names:

ZTF_<timestamp>_<fieldID>_<filterID>_c<ccdID>_<type>.fits.fz

<timestamp> is the time of the observation, in the format YYYYMMDD.<fractional day>
<fieldID> is the ID information for the observation (i.e. field name, "flat", etc) and shall be a six number identifier
<ccdID> is the CCD identifier (1-16, guide, focus) and shall be a two number identifier for the science CCDs
<type> is a key for the image type (o=object, b=bias, d=dark, f=dome flat, t=twilight flat, p=pointing, c=focus, e=test, i=illumination test, g=fringe, s=seeing, x=other, n=none))
<filterID> is a filter code (i.e. Sloan i is "Si"), codes TBD based on selected filters

Examples:

```
ZTF_20170401.4421_007374_Si_c07_o.fits.fz
ZTF_20170401.1173_flat_Si_c13_f.fits.fz
```

This naming scheme is proposed as it allows the ability to tell what the image is from the file name, instead of requiring reading the image header.

ZTFOS-SW-00157 FITS File Configuration: FITS files will be created for each CCD as a multi-extension FITS file with the following components:

- One extension image for each CCD amplifier (4 total)
- One overscan image (size TBD) for each amplifier (4 total)

The global FITS header will contain all of the information required to interpret the observation. Each extension image header will contain information appropriate to that image (size, CCD quadrant, etc).
ZTFOS-SW-00160 FITS Compression: FITS image data shall be compressed using FITS tile compression with the Rice algorithm. [*TBD: The number of noise bits, if any, to use in the compression scheme.*]

Note: This is in order to minimize the data load on the HPWREN downlink system from Palomar.

ZTFOS-SW-00165 FITS Keywords: The following keywords shall be included in the ZTF FITS file header:

Basic parameters

These are the basics that every image should have.

```
SIMPLE  =                    T / file does conform to FITS standard
BITPIX  =                  -32 / Number of bits per data pixel
NAXIS   =                    2 / number of data axes
```

```
NAXIS1  =                    0 / length of data axis 1
NAXIS2  =                    0 / length of data axis 2
EXTEND  =                    T / FITS dataset may contain extensions
ORIGIN  = 'Zwicky Transient Facility' / Data origin
OBSERVER= 'ZTF Robotic Software' / Observer
ROBOSOFT= '1.0   20170401'     / Robotic software version
FITSSOFT= '1.0 May 12 2015'    / FITS software version
IMGTYPE = 'object  '           / Image type
IMAGETYP= 'object  '           / Image type
FILENAME= '64_HD115617_2_Si_o_20150309_095409.043.fits' /  File name
ORIGNAME= '64_HD115617_2_Si_o_20150309_095409.043.fits' / Original filename
NFRAMES =                    8 / Number of frames in cube
END
```

Telescope parameters

These parameters are reported by the TCS.

```
OBSERVAT= 'Palomar Observatory' / Observatory
TELESCOP= 'P48     '           / Observatory telescope
OBSLAT  =            33.356322 / Observatory longitude (deg)
OBSLON  =          -116.865005 / Observatory latitude (deg E)
OBSALT  =                1713. / Observatory altitude (m)
HOURANG = '+00:05:26.04'       / Hour angle
RA      = '+13:18:24.48'       / Requested right ascension
DEC     = '-18:18:56.4'        / Requested declination
TELRA   = '+13:18:23.37'       / Telescope right ascension
TELDEC  = '-18:18:56.4'        / Telescope declination
TRACKRA =                   0. / Track speed RA rel to sidereal "/hr
TRACKDEC=                   0. / Track speed Dec rel to sidereal "/hr
AZIMUTH =               178.33 / Telescope azimuth (deg)
ELVATION=                38.27 / Telescope elevation (deg)
AIRMASS =                1.612 / Airmass
FOCUSPOS=                14.96 / Focus position
DOME_AZ =                177.9 / Dome azimuth (deg)
WINDSCAL=              84.9973 / Wind screen altitude (deg)
```

Queue parameters

Queue parameters are set by the astronomers for an observation and then loaded into the observing queue, where the robotic system uses them to complete the observation.

```
PROGRMPI= 'Kulkarni'           / Queue program PI
PROGRMID= '64      '           / Queue program ID
QCOMMENT= ‘Cool star'          / Queue comment
FIELDED = ‘007374’             / ZTF field ID number
OBJRA   = '+13h18m24.3114s'    / Object RA
OBJDEC  = '-18d18m40.3033s'    / Object Dec
OBJRAD  =             57.29578 / Object RA  (deg)
OBJDECD =             57.29578 / Object Dec (deg)
EQINOX  =                2000. / Equinox
RA_RATE =                   0. / RA tracking rate ("/hr)
DEC_RATE=                   0. / Dec tracking rate ("/hr)
MAGNITUD=                 4.74 / Object magnitude
```

Filter parameters

The filter system will report the selected filter and information about the selected filter as a check that the right filter is in place.

```
FILTER  = 'SDSS i'''           / Filter name
FILTERID= '4'                  / Filter ID
FILPOS  = '2'                  / Filter position
```

Shutter parameters

The shutter open and close times will be reported.

```
SHUTOPEN= '2015-02-13 08:09:10.123'  / Shutter open time
SHUTCLSD= '2015-02-13 08:10:10.123'  / Shutter close time
```

Camera parameters

These are the parameters for the setup for the CCD system. The sectioning information may need to be modified or eliminated in light of the multi-extension formatting of the images, but are left here for completeness. ROISEC should remain, as it flags if a section of the CCD was used.

```
INSTRUME= 'ZTF/MOSAIC'         / Instrument name
DETECTOR= 'STA Archon'         / Robo-AO Visible Camera CCD
DETSOFT = 'Ver. 2 Rev. 93'     / Detector software firmware
DETFIRM = 'DU8201_BV'          / Detector firmware version
DETSIZE = '[1:1024,1:1024]'    / CCD size (pixels)
CCDSEC  = '[1:2064,1:2064]'    / Detector section
ROISEC  = '[1:1024,1:1024]'    / Region of interest
AMPSEC  = '[1:2048,1:4096]'    / amplifier section
TRIMSEC = '[15:2062,1:4096]'   / trim section
DATASEC = '[15:2062,1:4096]'   / data section
BIASSEC = '[2063:2078,1:4096]' / bias section
DETSEC  = '[10241:12288,1:4096]' / detector section
PIXSCALE=             -1.49275 / Pixel scale, in arcsec per pixel
EXPOSURE=                   60. / Total Exposure Time (sec)
EXPTIME =                    1. / Requested exposure time (sec)
AEXPTIME=                    1. / Actual exposure time (sec)
MODE_NUM=                    6 / Mode identifying key
CCDSUM  = '1 1     '           / CCD binning
CTYPE1  = 'RA---TAN'           / Name of coord X axis
CTYPE2  = 'DEC--TAN'           / Name of coord Y axis
```

Time parameters

These parameters have to do with the time of operations. Some are calculated and some are overlapping values from various subsystems; this may be simplified.

```
UTC     = '20150908_203340.319079' / Time of observation
UTSHUT  = '20150908_203340.319079' / Shutter open time
UTC-OBS = '2015-02-01 15:39:09.056' / UTC time shutter open
DATE-OBS= '2015-02-01 15:39:09.056' / UTC time shutter open
OBSJD   =        2457055.15219 / Julian day corresponds to UTC-OBS (day)
OBSMJD  =          57054.65219 / MJD corresponds to UTC-OBS (day)
OBSLST  = '16:37:49.60'        / Mean LST corresponds to UTC-OBS
HJD     =        2457055.15121 / Heliocentric Julian Day (days)
END_TIME= '2015-04-16 00:18:56.548' / End of observation time
DATE    = '2015-04-16 00:18:57.406' / File write date
```

Weather parameters

Weather parameters reported by the TCS/weather station.

```
UT_WEATH= '2015-08-22 00:23:52.000' / UT of weather data
TEMPTURE=                 12.2 / Outside air temperature (C)
WINDSPD =                 12.1 / Outside wind speed
WINDDIR =                 334. / Outside wind direction (deg)
DEWPOINT=                 -36. / Dewpoint (C)
WETNESS =                  -7. / Wetness sensor reading
HUMIDITY=                   2. / Humitidy
PRESSURE=               -9999. / Atmospheric pressure, millibars
CLOUDS  =               0.0157 / Cloud sensor reading
```

Instrument monitor parameters

Parameters that report the state of the dewar and other values monitored by the instrument monitoring system. More parameters will be added once we know what all the values are.

```
CCDTMP01=              163.003 / CCD temperature 1 (K)
.. .. ..
CCDTMPNN=              163.003 / CCD temperature NN (K)
HEADTEMP=               137.11 / Cryo cooler cold head temp (K)
DEWPRESS=                   0. / Dewar pressure (milli-torr)
DETHEAT =                  17. / Detector focal plane heater power (%)
```

Other parameters

These are other parameters that will be included in the header.

```
MOONRA  =           107.026422 / Moon J2000.0 R.A. (deg)
MOONDEC =            16.728243 / Moon J2000.0 Dec. (deg)
MOONILLF=              0.95035 / Moon illuminated fraction (frac)
MOONPHAS=            25.749736 / Moon phase angle (deg)
MOONESB =                 -0. / Moon excess in sky brightness V-band
MOONALT =           -28.318935 / Moon altitude (deg)
SUNAZ   =           117.956303 / Sun azimuth (deg)
SUNALT  =             9.685611 / Sun altitude (deg)
SEEING  =                  1.2 / Seeing measurement
```

FITS multi-extension frame header

All ZTF data will be in a FITS cube:
- Science CCD data will be in four FITS files with eight cube frames each
- Focus images will have three cube frames
- Guide frames will be in one cube per science observation

This is the header for each individual frame; they are meant to be simple as all the information should be contained in the main header. ONLY information that is connected to an individual frame should be included in this header. This also includes the header parameters for the compression of the FITS image.

```
XTENSION= 'BINTABLE   '        / IMAGE extension
BITPIX  =                    8 / number of bits per data pixel
NAXIS   =                    2 / number of data axes
NAXIS1  =                 3072 / length of data axis 1
NAXIS2  =                 3080 / length of data axis 2
PCOUNT  =              2590014 / size of special data area
GCOUNT  =                    1 / one data group (required keyword)
CCD_ID  = '3'                  / ID value of CCD detector
CCDNAME = 'W53C2   '           / Detector name or serial number
CCD_TAG = '1'                  / Flag that maps the image to the CCD
GAIN    = '1.7     '           / Gain e-/adu
READNOI = '3.4     '           / Read noise e-
DARKCUR = '< 0.1   '           / Dark current e-/s @ 150 K
TFIELDS =                    3 / number of fields in each row
TTYPE1  = 'COMPRESSED_DATA'    / label for field   1
TFORM1  = '1PB(1296)'          / data format of field: variable length array
TTYPE2  = 'ZSCALE  '           / label for field   2
TFORM2  = '1D      '           / data format of field: 8-byte DOUBLE
TTYPE3  = 'ZZERO   '           / label for field   3
TFORM3  = '1D      '           / data format of field: 8-byte DOUBLE
ZIMAGE  =                    T / extension contains compressed image
ZSIMPLE =                    T / file does conform to FITS standard
ZBITPIX =                  -32 / data type of original image
ZNAXIS  =                    2 / dimension of original image
ZNAXIS1 =                 2064 / length of original image axis
ZNAXIS2 =                 2064 / length of original image axis
ZTILE1  =                 2064 / size of tiles to be compressed
ZTILE2  =                    1 / size of tiles to be compressed
ZQUANTIZ= 'SUBTRACTIVE_DITHER_1' / Pixel Quantization Algorithm
ZDITHER0=                 4661 / dithering offset when quantizing floats
ZCMPTYPE= 'RICE_1  '           / compression algorithm
ZNAME1  = 'BLOCKSIZE'          / compression block size
ZVAL1   =                   32 / pixels per block
ZNAME2  = 'BYTEPIX '           / bytes per pixel (1, 2, 4, or 8)
ZVAL2   =                    4 / bytes per pixel (1, 2, 4, or 8)
EXTNAME = '1     '             / Data cube number
HDUVERS =                    1 / Version of format
END
```

ZTFOS-SW-00170 Output Data Rate: The software and hardware shall manage data input rates from the camera as high as 160 Mb/s/CCD. (See Smith and Kaye.)

ZTFOS-SW-00175 Data Storage: The disk space provided for storing FITS images shall be large enough to allow storage of two weeks of science and operational data.

Note: The FITS files will be moved off the disk as quickly as possible, usually as quickly as they are produced. In the event of a network outage, the system should be able to store at least one night's worth of data, which is three Terabytes. (See Smith and Kaye.) If the FITS tile compression gives a 1/2 compression factor, this requirement can be reduced by the equivalent amount to 1.5 Terabytes.

ZTFOS-SW-00176 Data Transfer: Data shall be transferred to the servers at IPAC once they are compressed after observation. The transfer shall use a push architecture, where the robotic system initializes the transfer once an observation is complete. Confirmation of data transfer shall be done and the observation flagged as successfully transferred once the process is complete.

ZTFOS-SW-00177 Data Removal: Data stored in the on-site computer system shall be cleared at a rate that keeps enough open disk space for at least one night of observing at all times. Data shall be checked as successfully transferred before removal.