Reprocessing of WEC time corrections 2005 to 2007

Keith Yearby, February 2012

Contents

1 Introduction

For precise time stamping of Cluster science data it is necessary to accurately determine the UT time at which each VC0 reset pulse occurs onboard. This pulse is time correlated with the transmission of the first bit of the housekeeping virtual channel (VC0) and the contents of the onboard time counter at this time is recorded in the On-board Time (OBT) field of the VC0 transfer frame (EID-A section 3.3.1.3.1 and 3.3.7.2.2). The time of the pulse is called the Spacecraft Event Time or SCET, and is given to a standard accuracy of +/- 2ms.

However for inter-spacecraft comparisons of EFW and STAFF waveform data a much higher accuracy is needed. This is achieved by preparing time correction (TCOR) files. The process is described in general in the document ‘Precise reconstitution of the Spacecraft Event Time (SCET)’.

Data for 2005 to 2007 inclusive has already been delivered once, but problems have occurred when delivered files (some overlapping) were merged and split by the CAA in response to data requests by users. To avoid these problems these year's data have been reprocessed as three separate datasets each covering a complete calendar year. The earlier versions should be completely removed from the archive when these new versions are installed. Data users should request only whole years of data to avoid splitting these files.

For each year, the existing DIFF files were concatenated to form year long files (plus up to 2 days before and after), then validated against the WBD data. The DIFF files were then reprocessed using the latest version of 'maketcor' to make ACSII TCOR files. Some manual adjustment of these ASCII TCOR files were needed to correct for the leap second on 2005-12-31.

An initial appraisal of the reprocessed files by the STAFF team showed several periods where data was absent from the new files, but present in the old files.

A new software tool 'tcorcomp' was then written, which systematically compares two TCOR versions. It indicates gaps in the new files where data was present in the old files, and also data that is different in the old and new files. The reprocessed files were compared with the version 1 files covering the bulk of 2005, 2006 and 2007.

A further validation of the files was performed using an enhanced version (1.13) of 'veritcor' which applies the corrections to the RDM and looks for discontinuities in the timing of the corrected dataset. The enhanced version checks for discontinuities in the times of the WEC master clock pulses in addition to the VC0 reset pulse. A manual, iterative, process was employed to fill gaps in the new files with data present in the old files, and adjust where necessary data in the new files that was different to that in the old files.

Finally the ASCII TCOR files were converted to the final CEF format. All new files are version 3, irrespective of whether the highest previous version covering the same period was 1 or 2.

2 Data and references

Source data:

Extracted WBD DIFF measurements for 2005, 2006 and 2007.
Cluster RDM for 2005, 2006 and 2007.

Documents:

Precise reconstitution of the Spacecraft Event Time (SCET), Keith Yearby, 2004 July 7

Software:

Software	Version	Date
readtcal	2.6	2010-07-15
wbddiff2	2.4	2011-05-18
wbdtcor	1.3	2011-05-18
tcaltrend	1.3	2011-04-11
maketcor	5.3	2011-05-24
veritcor	1.13	2012-02-22
tcorcomp	1.4	2012-02-23
tcor2cef	1.8	2012-01-26
diffmer	1.4	2010-06-24

Point Valid DIFF files:

File name	Last modified date
05v3_1_diff.prn	2012-01-04 11:13
05v3_2_diff.prn	2012-01-04 12:10
05v3_3_diff.prn	2012-01-04 12:10
05v3_4_diff.prn	2012-01-04 12:10
06v3_1_diff.txt	2012-01-23 14:55
06v3_1_diff.txt	2012-01-23 14:55
06v3_1_diff.txt	2012-01-23 14:55
06v3_1_diff.txt	2012-01-23 14:55
07v3_1_diff.txt	2012-01-12 14:14
07v3_2_diff.txt	2012-01-12 14:14
07v3_3_diff.txt	2012-01-12 14:14
07v3_4_diff.txt	2012-01-12 14:14

ASCII TCOR files:

File name	Last modified date
05v3m_1_tcor.txt	2012-02-17 17:00:52
06v3m_1_tcor.txt	2012-02-17 17:01:24
07v3m_1_tcor.txt	2012-02-22 15:01:12
05v3m_2_tcor.txt	2012-02-09 11:28:34
06v3m_2_tcor.txt	2012-02-13 11:06:10
07v3m_2_tcor.txt	2012-02-22 15:01:11
05v3m_3_tcor.txt	2012-02-15 16:39:22
06v3m_3_tcor.txt	2012-02-17 17:01:24
07v3m_3_tcor.txt	2012-02-15 10:23:03
05v3m_4_tcor.txt	2012-02-17 17:00:52
06v3m_4_tcor.txt	2012-02-17 17:01:23
07v3m_4_tcor.txt	2012-02-22 15:01:11

3 Preparation of the Point Valid DIFF measurements

3.1 Introduction

For each year, the existing DIFF files were concatenated to form year long DIFF files (plus up to 2 days before and after), then validated against the WBD data.

3.2 Validation using 'wbdtcor'

The WBD DIFFs are compared to the merged DIFF using '**wbdtcor**'. The current version of this software allows for the known timing offsets of the DSN stations (specified in `gsotable.txt`), so ideally the differences reported should be zero.

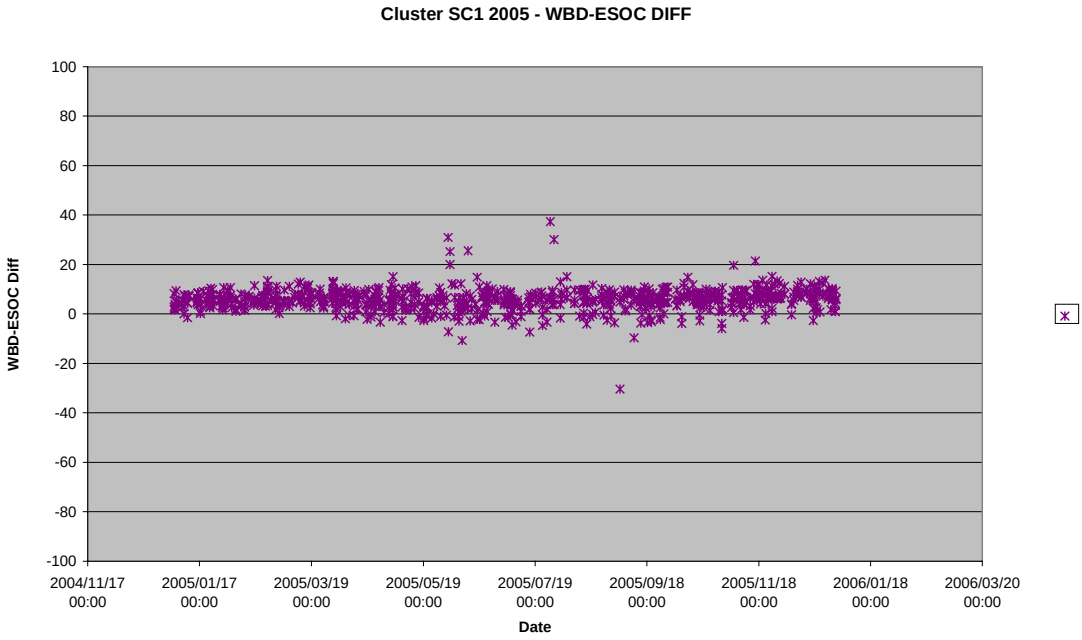
The following WBD observations showed discrepancies apparently due to incorrect calibration of the DSN 27 antenna.

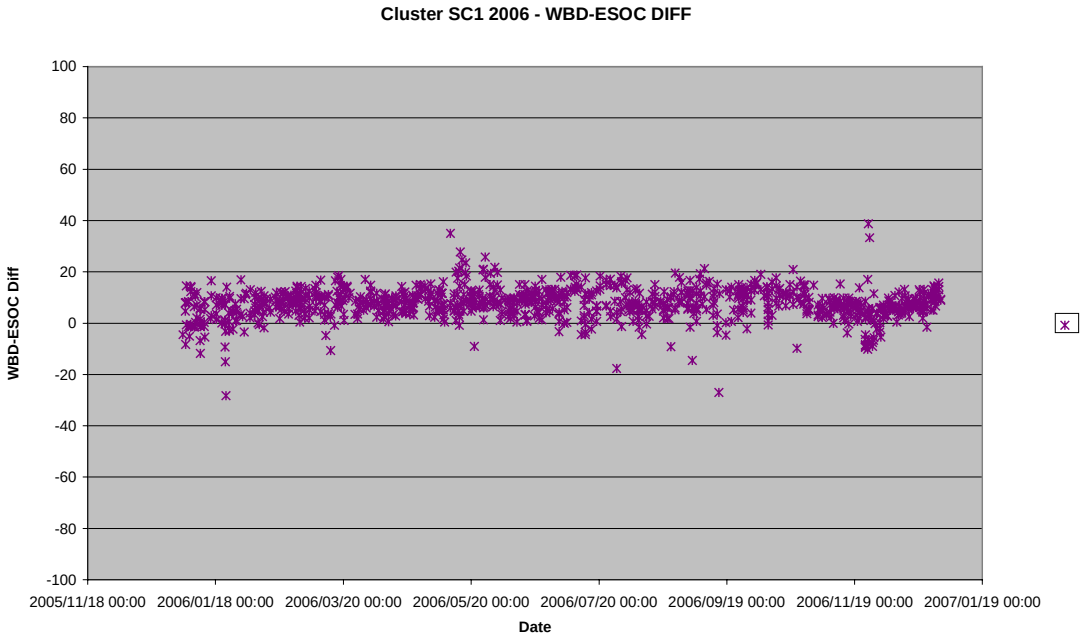
Date/time	WBD DIFF	WBD SCID	ANT	WBD-ESOC
2005/03/23 18:49	359	196	27	157.3
2005/03/26 17:09	400	196	27	157.3
2005/04/13 22:19	524	196	27	154.2
2005/04/16 16:30	500	196	27	156.2
2005/05/05 02:49	-384	183	27	156.3
2005/05/31 17:09	-1494	183	27	186.9
2005/06/07 18:59	111	194	27	154.4
2005/06/10 00:39	73	194	27	153.3
2005/06/10 13:19	628	185	27	154
2005/06/16 14:19	-791	183	27	159.1
2005/06/18 13:49	879	185	27	155.4
2005/06/20 12:39	957	185	27	156.4
2005/06/20 17:29	150	196	27	155.5
2005/06/21 11:19	100	196	27	154.6
2005/06/25 14:59	-213	196	27	138.7
2007/05/30 03:59	-593	183	27	66.7
2007/05/31 12:59	112	196	27	60.5
2007/06/04 13:39	96	196	27	67.6
2007/06/07 13:19	77	196	27	63.6
2007/06/11 13:49	-1136	183	27	70.2
2007/06/12 13:39	40	196	27	61.2
2007/06/14 11:59	28	196	27	62.1
2007/06/19 12:40	-53	185	27	56.4
2007/11/30 01:39	-82	196	27	51

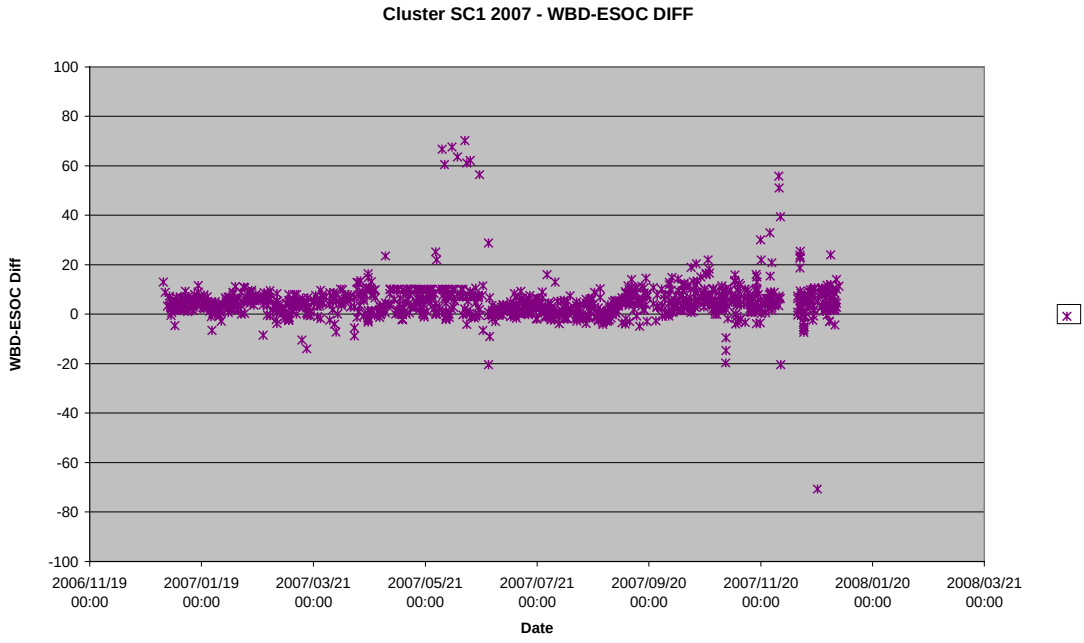
The following WBD observations showed discrepancies apparently due to the Onboard Time (OBT) being calibrated using an ESOC Time Calibration (TCAL) outside of its period of validity.

Date/time	WBD DIFF	WBD SCID	ANT	WBD-ESOC
2005/07/08 14:59	2	183	34	1244.4
2005/07/15 11:09	-1797	196	27	-1964.8
2005/07/22 08:59	2140	196	27	2126.6
2005/07/22 12:39	2177	196	16	2164.4
2005/09/03 08:59	-1164	196	27	-1170.9
2007/11/27 02:20	-633	196	81	-619.9

2007/11/27 03:49	-641	196	27	-625.5
2007/11/29 18:59	-66	196	81	55.8
2007/12/20 20:19	-69	194	66	-70.7






Cluster SC1 2007 - WBD-ESOC DIFF
WBD-ESOC Diff
100
80
60
40
20
0
-20
-40
-60
-80
-100
2006/11/19 00:00
2007/01/19 00:00
2007/03/21 00:00
2007/05/21 00:00
2007/07/21 00:00
2007/09/20 00:00
2007/11/20 00:00
2008/01/20 00:00
2008/03/21 00:00
Date

4 Generation of the ASCII TCOR files

The ASCII TCOR files were reprocessed. 'maketcor' version 5.3 was used. This uses the Sun Reference Pulse to track OBTM changes, rather than the WEC clock. This has the advantages that the short term stability is better, and it is available even when WEC is off.

The following commands were used:

```
../maketcor5 -o 05v3_1_tcor.txt -d 05v3_1_diff.prn
  -f 05_1_shla_files.txt -s 050101 -e 051231
  -w ../wbddiff/wbd_all_c1_ncd.txt
../maketcor5 -o 05v3_2_tcor.txt -d 05v3_2_diff.prn
  -f 05_2_shla_files.txt -s 050101 -e 051231
  -w ../wbddiff/wbd_all_c2_ncd.txt
../maketcor5 -o 05v3_3_tcor.txt -d 05v3_3_diff.prn
  -f 05_3_shla_files.txt -s 050101 -e 051231
  -w ../wbddiff/wbd_all_c3_ncd.txt
../maketcor5 -o 05v3_4_tcor.txt -d 05v3_4_diff.prn
  -f 05_4_shla_files.txt -s 050101 -e 051231
  -w ../wbddiff/wbd_all_c4_ncd.txt
../maketcor5 -o 07v3_1_tcor.txt -d 07v3_1_diff.txt
  -f 07_1_shla_files.txt -s 070101 -e 071231
  -w ../wbddiff/wbd_all_c1_ncd.txt
../maketcor5 -o 07v3_2_tcor.txt -d 07v3_2_diff.txt
  -f 07_2_shla_files.txt -s 070101 -e 071231
  -w ../wbddiff/wbd_all_c2_ncd.txt
../maketcor5 -o 07v3_3_tcor.txt -d 07v3_3_diff.txt
  -f 07_3_shla_files.txt -s 070101 -e 071231
  -w ../wbddiff/wbd_all_c3_ncd.txt
../maketcor5 -o 07v3_4_tcor.txt -d 07v3_4_diff.txt
  -f 07_4_shla_files.txt -s 070101 -e 071231
  -w ../wbddiff/wbd_all_c4_ncd.txt
```

5 Validation of the TCOR files

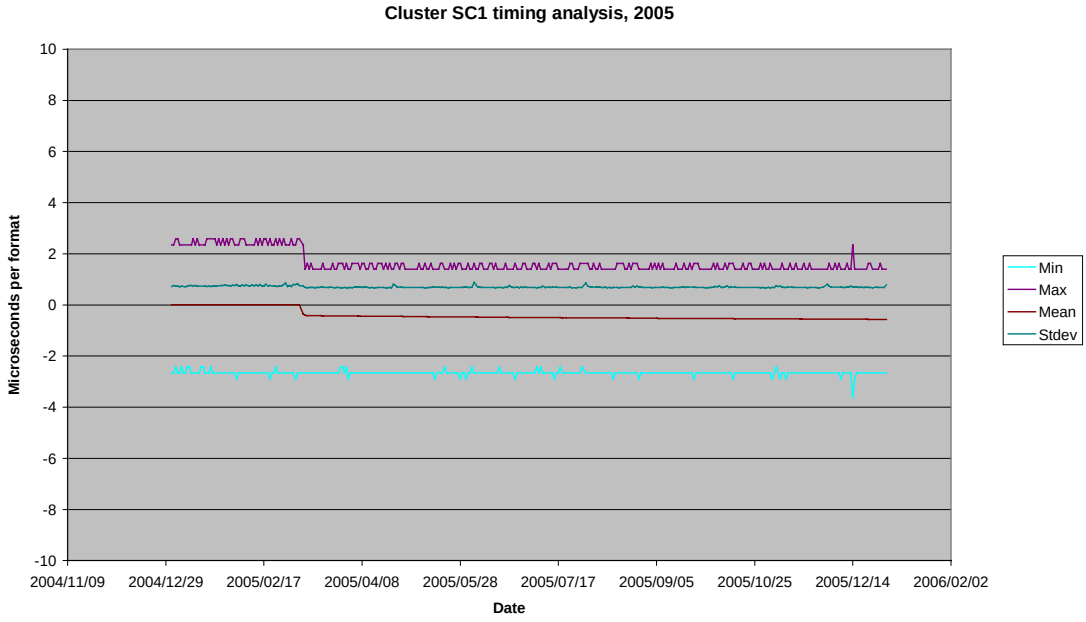
The software tool ‘maketcor’ performs some automatic validation as the files are produced. Data that fails automatic validation are not included in the output files.

Further validation of the TCOR files is performed by generating version 0 CEF files, using these to apply time corrections, then analysing the time tags of the corrected data. The Spacecraft Event Time (SCET) of the housekeeping files time tags are analysed using ‘veritcor’. This takes the time increment between each pair of records in the file, subtracts the nominal value (by default 5.15222168 seconds), and accumulates the minimum, maximum, mean and standard deviation over each 24 hour period. Gaps in the file are allowed for, and by default only records that are time corrected are processed.

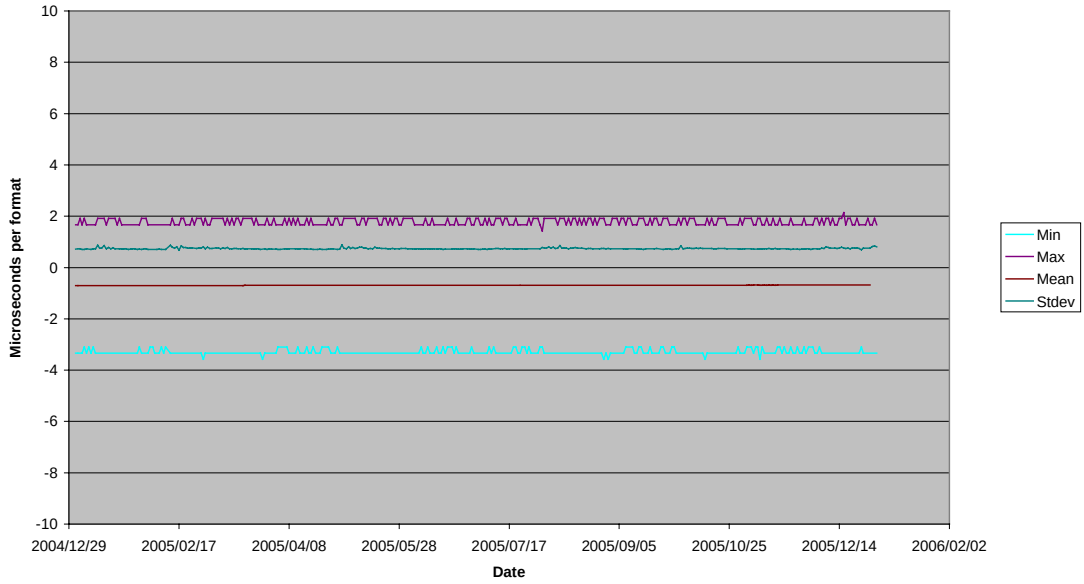
It is known that time jumps of -125.9 µs occur occasionally. These are counted and removed before further analysis. Incorrect identification of these jumps has been a source of undetected errors in some earlier TCOR fles. To avoid this ‘veritcor’ version 1.14 also checks for jumps in the times of the WEC master clock pulses.

‘veritcor’ uses the same HK+TCAL file list file as 'maketcor', although only the HK files are used. Version 1.14 uses the WEC HK files, although the file list may list the SC HK files (as used by maketcor), provided that the WEC HK files are located in the same directory and both files are named according to the standard RDM conventions.

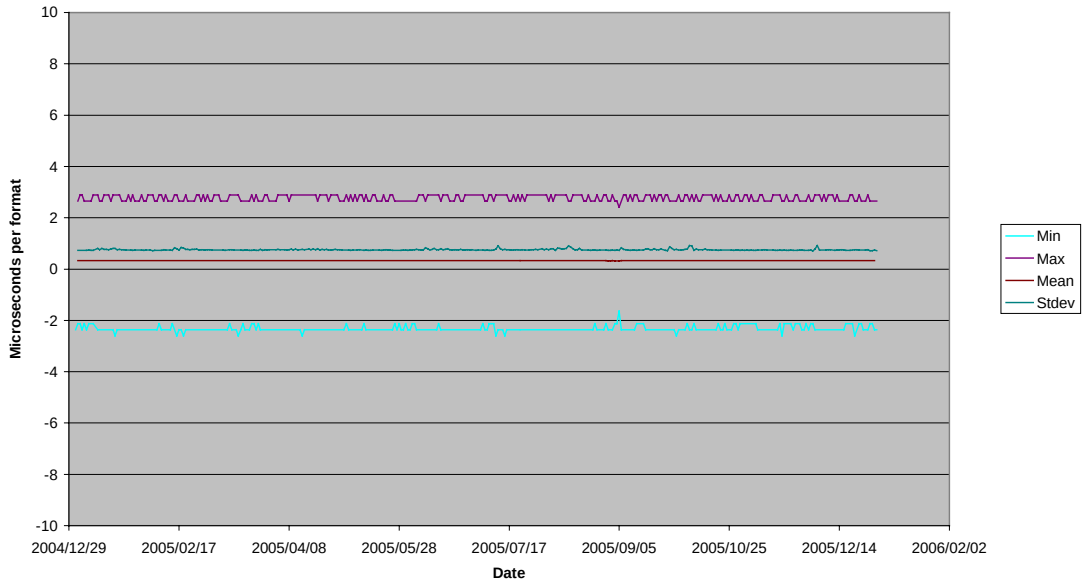
'veritcor' includes the same code module used by TED to apply the TCOR corrections, and requires CEF TCOR files to be installed with the same index files. The '-T .' option specifies that the TCOR files (and the index files) are located in the default directory.



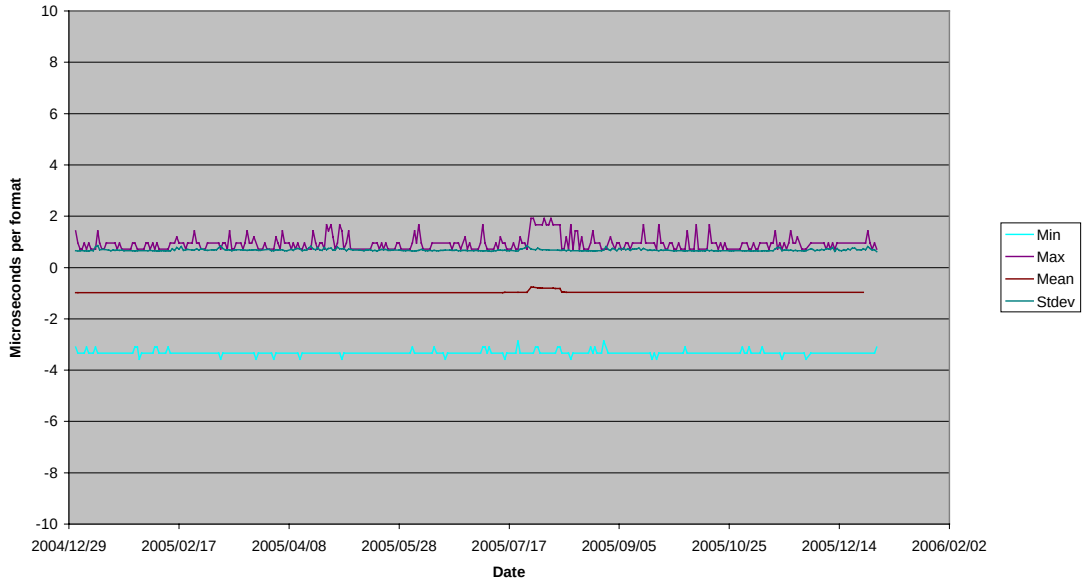
Cluster SC2 timing analysis, 2005



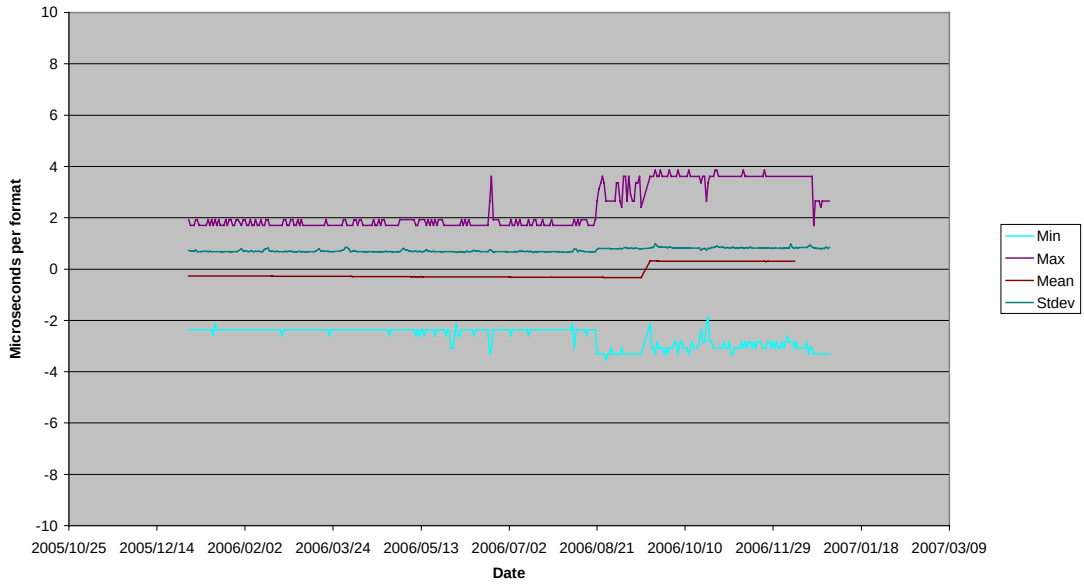
Cluster SC3 timing analysis, 2005



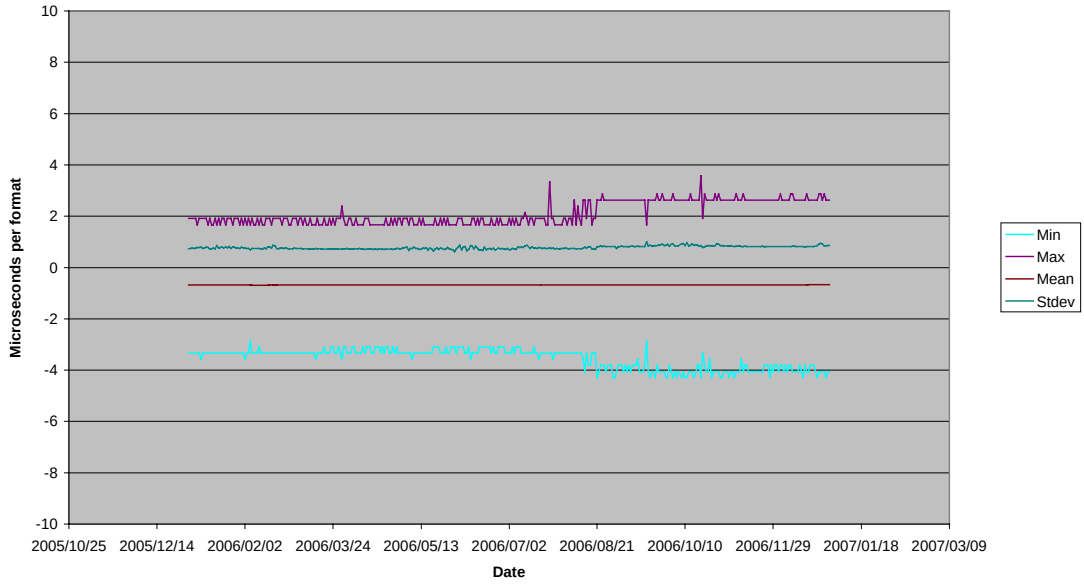
Cluster SC4 timing analysis, 2005



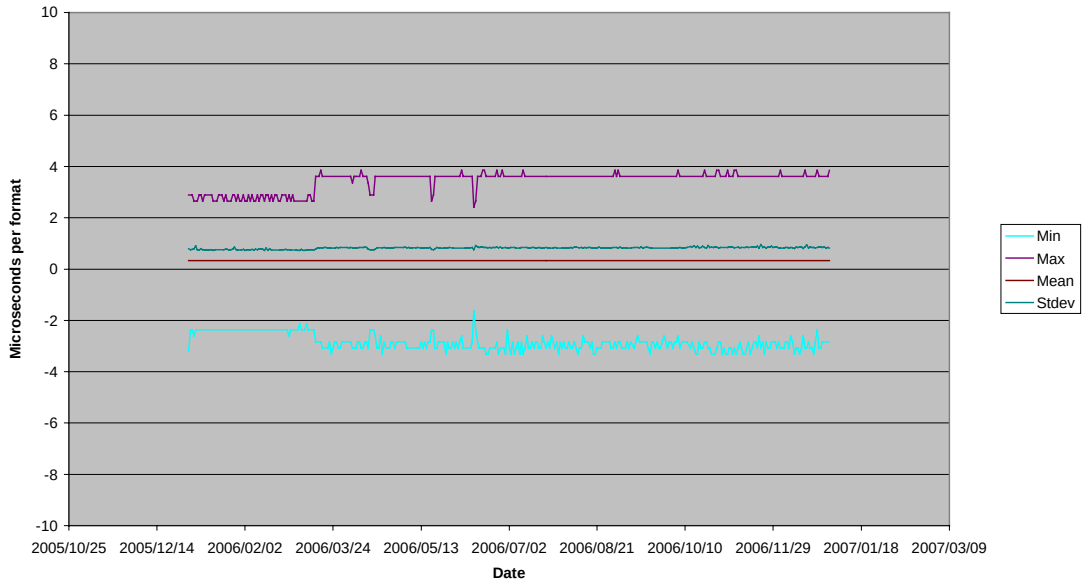
Cluster SC1 timing analysis, 2006



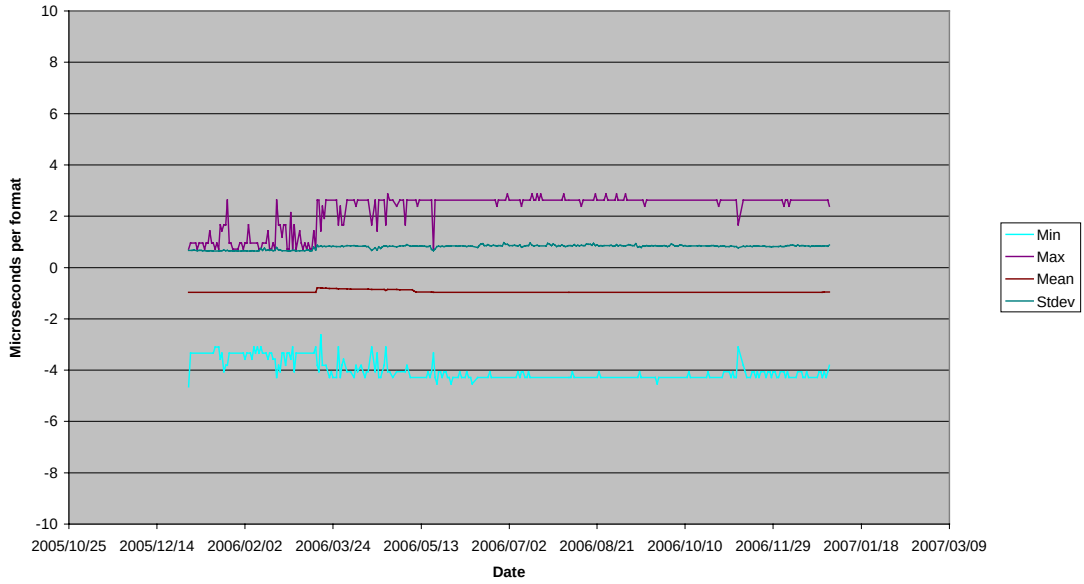
Cluster SC2 timing analysis, 2006



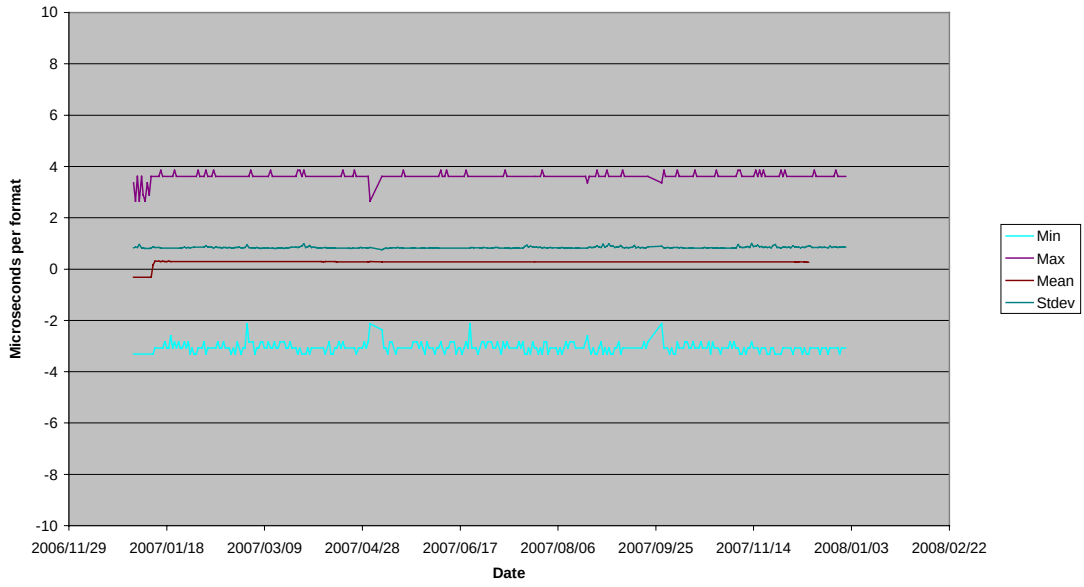
Cluster SC3 timing analysis, 2006



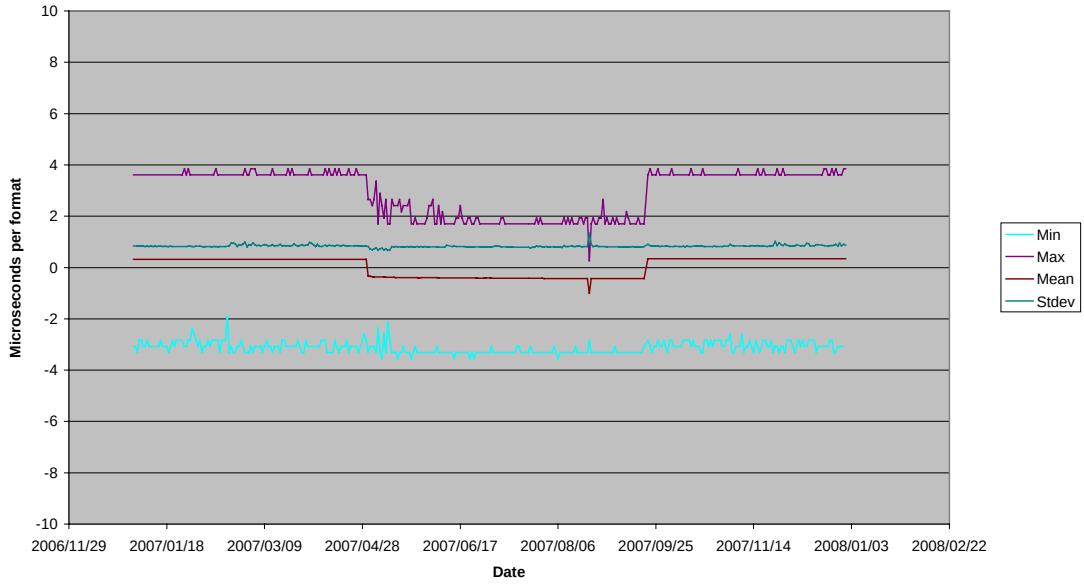
Cluster SC4 timing analysis, 2006



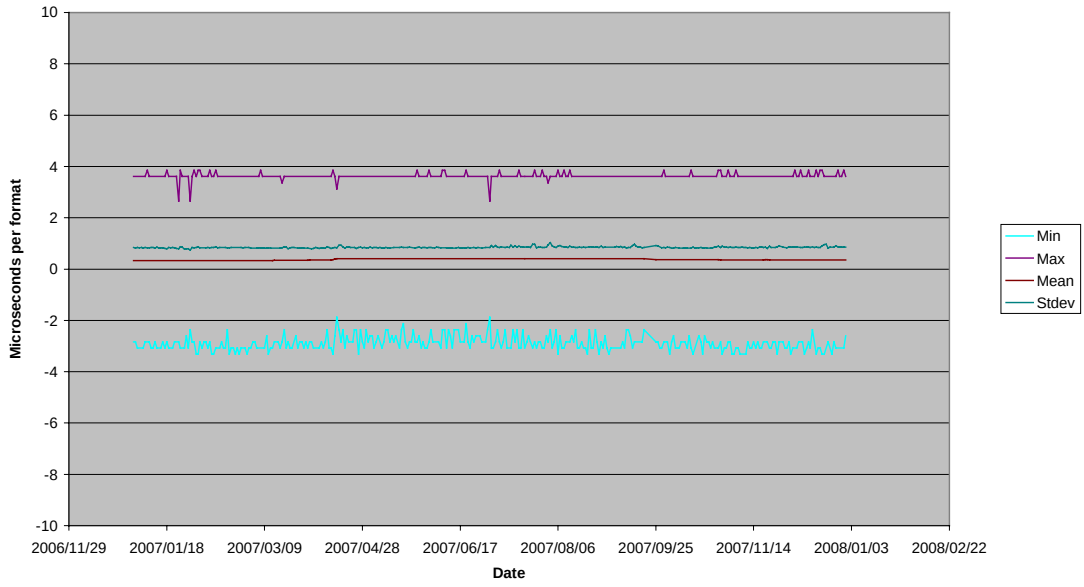
Cluster SC1 timing analysis, 2007

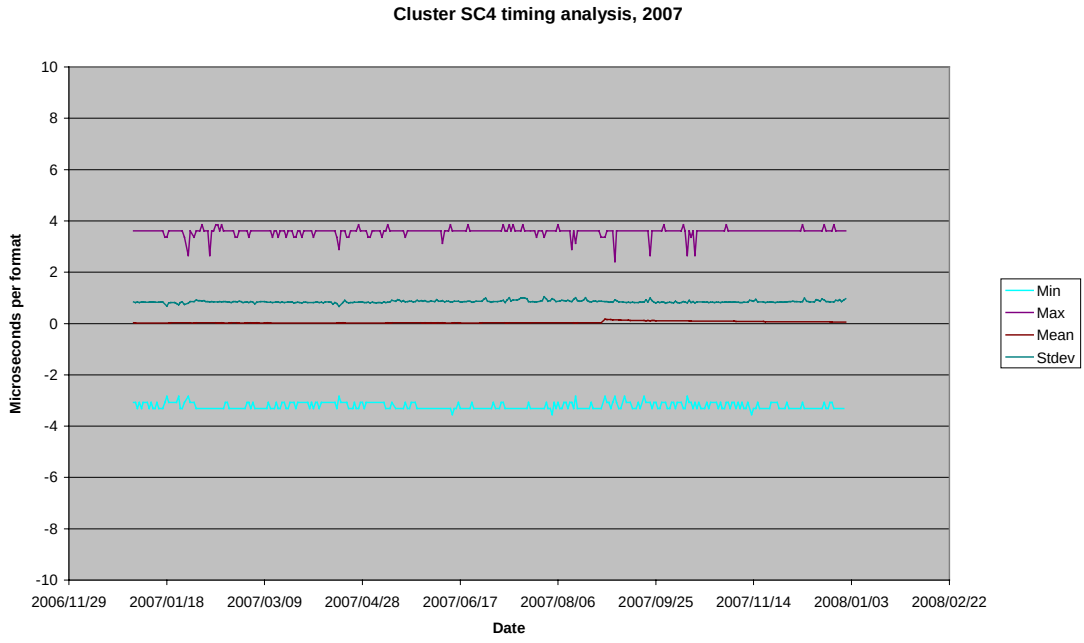


Cluster SC2 timing analysis, 2007



Cluster SC3 timing analysis, 2007




Cluster SC4 timing analysis, 2007
Microseconds per format
10
8
6
4
2
0
-2
-4
-6
-8
-10
2006/11/29
2007/01/18
2007/03/09
2007/04/28
2007/06/17
2007/08/06
2007/09/25
2007/11/14
2008/01/03
2008/02/22
Date
Min
Max
Mean
Stdev

6 Production of the CEF files

The final CEF files were produced by running TCOR2CEF on the validated ASCII format TCOR files, with version number 3 specified.

```
hoodie% ../tcor2cef -t 05v3m_1_tcor.txt
TCOR2CEF, version 1.8
TCOR file:         05v3m_1_tcor.txt, s/c: 1, records: 3320
Generated CEF name: C1_CP_DWP_TCOR__20050101_V00
Time range:        2005-01-01T00:00:00Z/2005-12-31T23:59:57Z
Warning:   Value out of range: 2005-12-31T00:31:18Z -145 1000033 1000033
Warning:   Value out of range: 2005-12-31T00:44:11Z -134 1000033 1000033
Warning:   Value out of range: 2005-12-31T02:05:05Z -249 1000033 1000033
Warning:   Value out of range: 2005-12-31T02:07:03Z -42 1000033 1000033
Warning:   Value out of range: 2005-12-31T02:13:04Z -249 1000033 1000033
Finished, CEF size: 372655 bytes
Total duration:    31535997 seconds
Corrected:         30162980 seconds (95.6 %)

hoodie% ../tcor2cef -t 05v3m_2_tcor.txt
TCOR2CEF, version 1.8
TCOR file:         05v3m_2_tcor.txt, s/c: 2, records: 3405
Generated CEF name: C2_CP_DWP_TCOR__20050101_V00
Time range:        2005-01-01T00:00:00Z/2005-12-31T23:59:59Z
Warning:   Value out of range: 2005-12-30T20:13:35Z -169 1000047 1000046
Warning:   Value out of range: 2005-12-30T22:47:12Z -158 1000046 1000045
Warning:   Value out of range: 2005-12-31T02:05:08Z -146 1000045 1000045
Warning:   Value out of range: 2005-12-31T02:07:01Z -25 1000045 1000045
Warning:   Value out of range: 2005-12-31T02:13:02Z -146 1000045 1000037
Finished, CEF size: 375430 bytes
Total duration:    31535999 seconds
Corrected:         30844569 seconds (97.8 %)

hoodie% ../tcor2cef -t 05v3m_3_tcor.txt
TCOR2CEF, version 1.8
TCOR file:         05v3m_3_tcor.txt, s/c: 3, records: 3162
Generated CEF name: C3_CP_DWP_TCOR__20050101_V00
Time range:        2005-01-01T00:00:00Z/2005-12-31T23:59:57Z
Warning:   Value out of range: 2005-12-31T01:15:43Z -116 1000034 1000034
Warning:   Value out of range: 2005-12-31T02:07:04Z -19 1000034 1000034
Warning:   Value out of range: 2005-12-31T02:13:05Z -116 1000034 1000038
Finished, CEF size: 350621 bytes
Total duration:    31535997 seconds
Corrected:         30556380 seconds (96.9 %)

hoodie% ../tcor2cef -t 05v3m_4_tcor.txt
TCOR2CEF, version 1.8
TCOR file:         05v3m_4_tcor.txt, s/c: 4, records: 3509
Generated CEF name: C4_CP_DWP_TCOR__20050101_V00
Time range:        2005-01-01T00:00:00Z/2005-12-31T23:59:59Z
Warning:   Value out of range: 2005-07-30T23:27:24Z 0 -3436 -3438
Warning:   Value out of range: 2005-07-30T23:30:40Z 0 -3438 -3442
Warning:   Value out of range: 2005-07-30T23:37:21Z 0 -3443 -3458
Warning:   Value out of range: 2005-12-30T20:44:18Z -248 999996 1000000
Warning:   Value out of range: 2005-12-31T00:44:14Z -237 1000000 1000000
Warning:   Value out of range: 2005-12-31T01:16:05Z -351 1000000 1000001
Warning:   Value out of range: 2005-12-31T02:07:00Z -58 1000001 1000001
Warning:   Value out of range: 2005-12-31T02:13:01Z -340 1000001 1000022
Finished, CEF size: 386835 bytes
Total duration:    31535999 seconds
```

```
Corrected:         30233568 seconds (95.9 %)

hoodie% ../tcor2cef -t 06v3m_1_tcor.txt -s 070101 -e 071231 -v 3
TCOR2CEF, version 1.8
TCOR file:         06v3m_1_tcor.txt, s/c: 1, records: 3640
Generated CEF name: C1_CP_DWP_TCOR__20070101_V03
Time range:        2006-01-01T00:00:01Z/2006-12-31T23:59:59Z
Warning:   Value out of range: 2006-01-01T04:30:07Z 0 -1000968 -1000968
Warning:   Value out of range: 2006-01-01T04:31:07Z 0 -1000968 -1000970
Finished, CEF size: 407824 bytes
Total duration:    31535998 seconds
Corrected:         29066629 seconds (92.2 %)

hoodie% ../tcor2cef -t 06v3m_2_tcor.txt
TCOR2CEF, version 1.8
TCOR file:         06v3m_2_tcor.txt, s/c: 2, records: 3665
Generated CEF name: C2_CP_DWP_TCOR__20060101_V00
Time range:        2006-01-01T00:00:04Z/2006-12-31T23:59:59Z
Warning:   Value out of range: 2006-01-01T09:10:05Z 0 -1000200 -1000200
Warning:   Value out of range: 2006-01-01T09:10:56Z 0 -1000200 -1000200
Finished, CEF size: 404215 bytes
Total duration:    31535995 seconds
Corrected:         30869931 seconds (97.9 %)

hoodie% ../tcor2cef -t 06v3m_3_tcor.txt
TCOR2CEF, version 1.8
TCOR file:         06v3m_3_tcor.txt, s/c: 3, records: 2997
Generated CEF name: C3_CP_DWP_TCOR__20060101_V00
Time range:        2006-01-01T00:00:01Z/2006-12-31T23:59:59Z
Warning:   Value out of range: 2006-01-01T14:00:07Z 0 -1001346 -1001346
Warning:   Value out of range: 2006-01-01T14:00:43Z 0 -1001346 -1001348
Finished, CEF size: 332026 bytes
Total duration:    31535998 seconds
Corrected:         30734258 seconds (97.5 %)

hoodie% ../tcor2cef -t 06v3m_4_tcor.txt
TCOR2CEF, version 1.8
TCOR file:         06v3m_4_tcor.txt, s/c: 4, records: 3706
Generated CEF name: C4_CP_DWP_TCOR__20060101_V00
Time range:        2006-01-01T00:00:03Z/2006-12-31T23:59:59Z
Warning:   Value out of range: 2006-01-01T18:10:06Z 0 -999988 -999988
Warning:   Value out of range: 2006-01-01T18:10:58Z 0 -999988 -999988
Warning:   Value out of range: 2006-03-20T04:37:21Z 0 -2426 -2515
Finished, CEF size: 410960 bytes
Total duration:    31535996 seconds
Corrected:         30178383 seconds (95.7 %)

hoodie% ../tcor2cef -t 07v3m_1_tcor.txt -s 070101 -e 071231 -v 3
TCOR2CEF, version 1.8
TCOR file:         07v3m_1_tcor.txt, s/c: 1, records: 3608
Generated CEF name: C1_CP_DWP_TCOR__20070101_V03
Time range:        2007-01-01T00:00:00Z/2007-12-31T23:59:59Z
Finished, CEF size: 400281 bytes
Total duration:    31535999 seconds
Corrected:         29724112 seconds (94.3 %)

hoodie% ../tcor2cef -t 07v3m_2_tcor.txt -s 070101 -e 071231 -v 3
TCOR2CEF, version 1.8
TCOR file:         07v3m_2_tcor.txt, s/c: 2, records: 3654
Generated CEF name: C2_CP_DWP_TCOR__20070101_V03
```

```
Time range:        2007-01-01T00:00:00Z/2007-12-31T23:59:59Z
Warning:   Value out of range: 2007-05-05T16:30:08Z 66 -2100 -2544
...
Warning:   Value out of range: 2007-05-12T23:50:06Z 0 -7920 -7926
Finished, CEF size: 403151 bytes
Total duration:    31535999 seconds
Corrected:         29682701 seconds (94.1 %)

hoodie% ../tcor2cef -t 07v3m_3_tcor.txt -s 070101 -e 071231 -v 3
TCOR2CEF, version 1.8
TCOR file:         07v3m_3_tcor.txt, s/c: 3, records: 3121
Generated CEF name: C3_CP_DWP_TCOR__20070101_V03
Time range:        2007-01-01T00:00:00Z/2007-12-31T23:59:59Z
Warning:   Value out of range: 2007-04-16T17:37:08Z 0 2907 2910
Warning:   Value out of range: 2007-04-16T17:41:31Z 0 2910 2914
Warning:   Value out of range: 2007-04-16T17:47:06Z 0 2914 2923
Finished, CEF size: 345637 bytes
Total duration:    31535999 seconds
Corrected:         30232587 seconds (95.9 %)

hoodie% ../tcor2cef -t 07v3m_4_tcor.txt -s 070101 -e 071231 -v 3
TCOR2CEF, version 1.8
TCOR file:         07v3m_4_tcor.txt, s/c: 4, records: 3519
Generated CEF name: C4_CP_DWP_TCOR__20070101_V03
Time range:        2007-01-01T00:00:00Z/2007-12-31T23:59:59Z
Finished, CEF size: 390933 bytes
Total duration:    31535999 seconds
Corrected:         29510391 seconds (93.6 %)
```

The file comparison utility (diff) was used to check that the only changes between the version 0 files used for validation, and the final version, are in the filenames, version numbers, and generation date. Eg.:

```
diff C1_CP_DWP_TCOR__20050101_V00.cef \
     C1_CP_DWP_TCOR__20050101_V03.cef
```

Finally, the CEF files were checked using CEFpass.

```
setenv CEFPATH ~/CAA/headers
~/CAAtools/CEFpass C1_CP_DWP_TCOR__20050101_V03.cef
```

7 Caveats

The following general caveats apply to 2005 to 2007 TCOR data.

TCOR data is not available at all times. For this period, TCOR coverage is around 92% to 98%. The reasons for lack of availability are usually:

- In the 48 hours before a new time correlation, when it is not known which time correlation (TCAL) was applied to the data.
- The discontinuity in the On Board Time at 'power down' or 'decoder only' eclipses, or CTU reboots, leading to non-availability of the DIFF measurements.
- It should be noted however, that in many cases missing TCOR data occurs when the payload is off, so is of no consequence.

Interpolation between TCOR records in CEF files is only permitted in limited circumstances. The time corrections are provided at the start and end times of each period of the same telemetry mode. The OFFSET is constant throughout each period, and the same value will be written in the records at the start and end of the period. If the OFFSET values before and after the required time are different, or either has the fill value of -1e31, then OFFSET is not available for that period. No interpolation between different OFFSET values is allowed. The DIFF may be obtained by linear interpolation of the DIFF values immediately before and after the required time. However, if either DIFF has the fill value of -1e31, then DIFF is not available for that period. It is not allowed to interpolate over a fill value.