Code process from Level 2 to Level 3.

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The following information gives the basic code process from level 2 to level 3, such that people could take the level 3 files and return to level 2.

1) Alter Fill value
   a. If ELS, IBS or SNG, skip to next step.
   b. If ION, change fill value from 28671 to 65535 and adjust any fill values present in the DATA object.
   c. If TOF set the fill to 4294967296 and adjust any value greater than 4294967294 in the data (both DATA_ST and DATA_LEF) to this new fill value.
2) Quantize counts
   Counts in level 2 data are valued at the bottom of their quantization bin.
   a. ELS only: if lower count values are any of the following then set them to fill values as they should not be present: 255, 511, 767, 1279, 1535, 2559, 5887, 6143.
   b. Using the quantization tables (see CAPS Users Guide), calculate the upper values of each quantization bin (simply the next quantized lower value minus 1).
   c. Find the center value of the quantization bin by rounding down the average of the lower and upper values.
   d. Replace each DATA bin (lower count value) with their center values. (Fill values remain fill values)
   e. For TOF, do this for both DATA_ST and DATA_LEF
3) Convert to counts per sec from counts per accumulation by dividing by dt (the accumulation period)
   a. ELS only:

      dt = (3 / 4) * (2 / 64) * ...
         (LAST_ENERGY_STEP - FIRST_ENERGY_STEP + 1) * ...
         (LAST_AZIMUTH_VALUE - FIRST_AZIMUTH_VALUE + 1)

   b. IBS only:

      dt = (7 / 8) * (2 / 256) * ...
         (LAST_ENERGY_STEP - FIRST_ENERGY_STEP + 1) * ...
         (LAST_AZIMUTH_VALUE - FIRST_AZIMUTH_VALUE + 1)

      (Note IBS sweep durations may be 255 energy steps + fly-back over 2 seconds, or 127 energy steps + fly-back over 1 second, but 2/256=1/128 so the equation is the same.
   c. ION only

      dt = (7 / 8) * (4 / 64) * ...

(LAST_ENERGY_STEP - FIRST_ENERGY_STEP + 1) * ...
(LAST_AZIMUTH_VALUE - FIRST_AZIMUTH_VALUE + 1)

d. SNG only:
If TELEMETRY_MODE ≠132 then:
dt = (7 / 8) * (4 / 64) * ...
(LAST_ENERGY_STEP - FIRST_ENERGY_STEP + 1) * ...
(LAST_AZIMUTH_VALUE - FIRST_AZIMUTH_VALUE + 1)
else if TELEMETRY_MODE = 132 (rare):
dt = 2* (7 / 8) * (4 / 64) * ...
(LAST_ENERGY_STEP - FIRST_ENERGY_STEP + 1) * ...
(LAST_AZIMUTH_VALUE - FIRST_AZIMUTH_VALUE + 1)
In this mode anodes are summed. Rather than keep dt the same and double the geometric factor we chose to double the effective dt and keep the geometric factor the same.

e. TOF only, but applies to both DATA_ST and DATA_LEF.
For each separate B-cycle of data:
If COLLAPSE_AND_DURTION = 0 or COLLAPSE_AND_DURATION = 1:
dur = 256
If COLLAPSE_AND_DURTION = 2 or COLLAPSE_AND_DURATION = 3:
dur = 512
If COLLAPSE_AND_DURTION = 4 or COLLAPSE_AND_DURATION = 5:
dur = 1024
Then calculate dt by:
For ENERGY_STEP = 1:
dt = (dur/4) * (4/64) * (7/8)
For ENERGY_STEP ≠ 1:
dt = (dur/4) * (4/64) * (7/8) * 2

4) Dead time correct if necessary

a. ELS only:
Assume all data from 2004-001 onward was dead-time corrected onboard Cassini prior to downlink. Therefore nothing to do. (Ignore COLLAPSE_FLAG information here.

b. ION only:
Do not dead time correct. We do not have total counts for all ion species required to dead time correct individual ion species.

c. IBS and SNG
Dead time correct with the usual formula of:
C_cor = C / (1 – C * t_dead)
where C_cor is the dead time correction of counts C (must be in units of counts/sec) and t_dead is taken from the CAPS instrument paper as:
for IBS: 0.86e-6 seconds
for SNG: 0.2e-6 seconds

Note that this equation has the potential to make C_cor negative. For

IBS and SNG data this can not happen, not even in the highest quantized bin.

d. TOF only:
   Dead time correct with the usual formula for TOF data:

   C_cor = C / (1 – C_total * t_dead)

   where C_cor is the dead time correction of counts C at a given TOF channel (must be in units of counts/sec), which C_total is the sum of all counts over all TOF channels for that particular energy bin. t_dead is taken from the CAPS instrument paper as 2.187e-6 seconds

   Note that this equation has the potential to make C_cor negative. This can happen for TOF data for very large counts (which are present in the data but rare and likely not meaningful). In any TOF case where the denominator is smaller than 0.5 then all data at that energy step is set to fill values.

5) Cross talk correct if necessary
   a. If ELS or TOF, no cross talk correct required
   b. IBS, ION and SNG
      i. If any one of the anode has a fill value, set all anode to fill value – do not apply cross talk matrix
      ii. Else if SNG and TELEMETRY_MODE = 132 (rare anode pairs) then set all counts to fill. We simply do not have a cross talk matrix for anode-pairs to apply
      iii. If neither of the above apply, Cross talk correct the data using the cross talk matrices provided in the PDS CAPS users guide (for ION use the SNG one), one energy step (or step-pair) at a time over all anodes.

         For IBS cross talk correction, multiple this inv_alpha matrix by a column vector of anode counts

```
inv_alpha = [
     1.02575 , -0.143420, -0.0385874
    -0.135635,  1.02600 , -0.0406647
    -0.136521, -0.135645,  1.01217    ];
```

         For SNG or ION use the inv_alpha that is the matrix inverse of alpha where :

```
alpha = [
    0.748, 0.101, 0.015, 0.007, 0.004, 0.000, 0.000, 0.000
    0.101, 0.748, 0.101, 0.015, 0.007, 0.004, 0.000, 0.000
    0.015, 0.101, 0.748, 0.101, 0.015, 0.007, 0.004, 0.000
    0.007, 0.015, 0.101, 0.748, 0.101, 0.015, 0.007, 0.004
    0.004, 0.007, 0.015, 0.101, 0.748, 0.101, 0.015, 0.007
    0.000, 0.004, 0.007, 0.015, 0.101, 0.748, 0.101, 0.015
    0.000, 0.000, 0.004, 0.007, 0.015, 0.101, 0.748, 0.101
    0.000, 0.000, 0.000, 0.004, 0.007, 0.015, 0.101, 0.748 ];
```

inv_alpha = inv(alpha);

   iv. If any of the corrected counts for a given energy step (or energy step pair) are negative, replace all anodes with fill values.

6) Check for data A-cycle records that are outside limits of those in ANC and ACT files.
   a. if IBS:
      i. Compare A_CYCLE_NUMERs in IBS with those in the corresponding ANC file.
      ii. If the first IBS.A_CYCLE_NUMBER is below the first ANC.A_CYCLE_NUMBER then delete remove the IBS data corresponding to that first IBS.A_CYCLE_NUMBER.
      iii. Likewise, if the last IBS.A_CYCLE_NUMBER is above the last ANC.A_CYCLE_NUMBER then remove the data records corresponding to that last IBS.A_CYCLE_NUMBER.
      iv. If the A-cycle numbers do not overlap then we do not have energy table information, mcp level information nor actuator angles for those data records… hence we remove them from the process.
   b. ELS, IBS, SNG and TOF data do not appear to have these issues, but worth checking just in case as we need to align the data products with the values in the ANC and ACT files later.
7) Get Energy sweep tables and MCP voltages from ANC files for each record in your data file (ELS/IBS/ION/SNG/TOF).
   a. Match the data sets by A-cycle number. If the data file A_CYCLE_NUMBER is 65535 (fill) match by TIME. (Not yet found an instance of ANC's A_CYCLE_NUMBER being fill.)
   b. Copy out the following mcp/cem voltages and energy tables:
      i. ELS mcp: ANC.ELS_MCP_ADJ
      ii. ELS energy table: Not in ANC file, there has only ever been 1.
      iii. IBS mcp: ANC. IBS_CEM_DAC
      iv. IBS energy table: Use table =3 for all. It should be from ANC.IBS_SWEEP_TABLE_NUMBER however that is predominantly value 4 (there is no actual sweep table 4) and can flick to 0 or 1 occasionally. Just 3 irrespective of that for all data from 2004 onwards.
      v. SNG mcp: ANC.AUX_HVU2_ST_DAC
      vi. ION and TOF mcps: ANC.AUX_HVU2_ST_DAC and ANC.AUX_HVU2_LEF_DAC (for TOF DATA_ST you care about the AUX_HVU2_ST_DAC, for DATA_LEF the AUX_HVU2_LEF_DAC.)
      vii. SNG/ION/TOF energy table: use ANC.IMS_SWEEP_TABLE_NUMBER but beware of the following caveats

c. IF ION, SNG or TOF there are many sweep tables it could be (or it could be unknown and hence a fill value) be careful of the sweep table number – if it's 0 then compare it with neighboring A-cycles. If the neighbors are 1 or 2 then change the IMS_SWEEP_TABLE_NUMBER to 1 or 2 too to match the neighbors. If there is a neighbor at 0, keep it at zero. Note the TOF comment that follows.
d. If ION/SNG/TOF sweep table is 193, replace it with the fill value table (240). 193 is not an expected value and does not correspond to any actual table.
e. TOF data has no A-cycle numbers, so use start time and the COLLAPSE_AND_DURATION flag to find the time range of those records (be it 8-16 or 32 A-cycles long) and look in the ANC files for records over those times. (Be mindful that the TOF.TIME is often 1-second offset from ANC.TIME so you'll need to account for that). If the energy tables and voltages over ALL those A-cycles is the same, then keep that… they vary, replace the energy table and voltages with fill values.

8) Get actuator information
   a. Replace any ACT.DATA values larger than 112 with the fill value (-999 for ACT.DATA)
   b. Check that all A-cycles in the data file (ELS/IBS/ION/SNG) have corresponding A-cycles records in the ACT file
      (Files 200729118, 200809312 and 201207700 do not)
   c. From the corresponding ACT file, interpolate the data (ignoring fill values in the ACT data) to 1 second resolution. Use a linear interpolation for all except the final 3 second of the file.
   d. If the final 3 seconds of the last ACT.DATA record are fill, then interpolate those last 3 using a cubic spline with the 4 valid data points of that A-cycle record.
   e. For each record in the data file (ELS/IBS/ION/SNG) check that you have 1-second resolution actuator data for that period. (It's possible there may not be ACT data for the period you're interested in)
   f. For TOF data you must use the TIME and COLLAPSE_AND_DURATION flags to find the duration of the interval and match that with the ACT.TIME values (remembering to account for the 1-second offset between TOF.TIME and ACT.TIME) to locate the actuator angle records. If there is an ACT.A_CYCLE_NUMBER missing in this region we assume there is no ACT data for the whole B-cycle.

9) Get telemetry information for the records
   a. Use the TELEMETRY_MODE flag and the description given in the level 2 format files to figure out the bps rate.
      Ignore where it's a Solar Wind mode or not.
   b. Only TELEMETRY_MODE values of 1,2,4,8,16,32,64 and 130,132,136 are listed as valid.
   c. TOF only:
      If TOF.TELEMETRY_MODE of 129,144,160, or 192, use the bps value

for the telemetry mode that is 128 less.
If TOF.TELEMETRY_MODE is 0 = we have no idea., this should not be present and is not the fill value either. Move to another file.

10) Remove mcp test/low voltages – by setting the data to fill values during these occasions.
    a. If there was no actuator info during this period set data to fill.
    b. MCP test removal.
        i. SNG, ION, IBS, TOF: If IMS_SWEEP_TABLE_NUMBER ==16 (mcp calibration table) then set all data to fill.
           (IBS tests were timed with IMS tests, so this works well.)
        ii. SNG, ION, IBS, TOF: If IMS_SWEEP_TABLE_NUMBER ==240 (fill value on sweep table number, often when mcp is powered off) then set all data to fill.
        iii. ELS: MSSL provided a list of calibration times – if within those time ranges then set to fill. (list provided as appendix A)
    c. Mcps or cem off or fill value (as below), set data to fill
        i. ELS: if ELS_MCP_ADJ = 0 (off) or -1 (fill)
        ii. IBS: if IBS_CEM_DAC = 0 (off) or +1 (fill)
        iii. SNG: if HVU2_ST_DAC = 0 (off) or +1 (fill)
        iv. ION or TOF: both of
            1. if HVU2_ST_DAC = 0 (off) or +1 (fill)
            2. if HVU2_LEF_DAC = 0 (off) or +1 (fill)
               (Why both? Why not? If one if off both are likely to be.)
    d. Check for low non-usual operations voltages
        i. ELS: if ELS_MCP_ADJ < +2000, set data to fill
        ii. IBS: if IBS_CEM_DAC > -2000, set data to fill
        iii. ION, SNG, TOF, if AUX_HVU2_ST_DAC > -2000, set data to fill
             (Note am ignoring the AUX_HVU2_LEF_DAC for ION and TOF).

11) Convert energy tables to eV values.
    Using the correct voltage sweep table (if from IMS remember to use the correct table) convert voltages to eV.
    a. Calculate upper and lower ranges using the dE/E of the correct sensor. If there are overlaps or gaps between neighboring bin's ranges do not worry about it.
    b. If there is energy step summing of two steps, the center energy value of the summed bin is the log mean of the centers of the two steps (equivalent to sqrt(Step1 * Step2)). The upper and lower ranges of this summed step-pair is the upper end of the highest bin to the lowest end of the lower bin.
    c. If the voltage table was the fill value table, then all energies are fill values of 65535.

12) Group records to entire sweep of data for ELS, ION and SNG
    a. Move through data file until FIRST_ENERGY_STEP = 1
       (should be the very first record when starting the file.)
    b. Continue moving through data file until LAST_ENERGY_STEP = 63.

c. ELS only: if energy bins stay at one step (for calibration) for the entire 6 hour data file, then ignore that file and move on.
   This does occur, an entire file of nothing but ELS step 31.
d. Check that this period is 63 or 32 records long, if any other length then skip it and return to (a) to find start of next sweep.
e. Check that all 63 or 32 records have the same values in TIME, FIRST_AZIMUTH_VALUE, LAST_AZIMUTH_VALUE and TELEMETRY_MODE; error if not.
f. Create a new record for this full sweep of data, copying across Time, mcp voltages, SAM_ION_NUMBER (if ION) and other such info.
g. Calculate duration of this new record using the know sweep duration for a single azimuth for your data product and the First/Last Azimuth numbers
h. Copy out data to new record that is 2D, energy step by anode. This is of size 63x8. If there were 32 records only, then the first 32x8 are the data, and the remaining 31x8 are all fill as PDS requires fixed size packets.
i. Copy out dimension 1 info, that's the energy tables with their lower and upper limits. This is a size 63 array for each or lower, center, upper.
j. Copy out dimension 2 info, which is the anodes position in spacecraft theta, again with lower and upper limits, as such this is a size 8 array (for 8 anodes) for each of lower, center, upper.
k. Copy out dimension 3 info, a scalar value for spacecraft phi, for minimum, representative, maximum. This uses the 1-second ACT data from earlier, converts to spacecraft phi (270degs – ACT angle) and does a min(), mean() and max() on them to get the values.
   Only do this if you have the expected number of 1-second actuator values. i.e. for a 4-s SNG Azimuth I'd use 5 actuator angles for the min/mean/max, - where the 5th is the end time of the 4 second duration interval (and the 1st is the start time). As such if I don't have 5 Actuator angles I set these phi values all to fill. For SNG 8-Azimuth-sums (A-cycle resolution at 32-s) I'd expect 33 act angles, etc.
   This is not always true as the ACT.TIMEs are not always exactly 32-seconds apart, and are sometimes a little less, meaning you can occasionally get more or less 1-second intervals. You need to correct for this. For ION and SNG I'd expect 5, 9, 17 or 33 act angles per record, while for ELS it's the same but also 3.
l. Repeat thorough file.

13) Group records to entire sweep of data for IBS
   a. IBS sweeps are a subset of a bigger range that can vary, so does not start at 1.
   b. The first FIRST_ENERGY_STEP record you see is the start of your sweep.
   c. Keep going through the file until the next FIRST_ENERGY_STEP is smaller than the last one. That's your energy sweep range.

d. Check that this period is 255 or 127 records long, if any other length then skip it and return to (a) to find start of next sweep.
e. Check that all 255 or 127 records have the same values in TIME, FIRST_AZIMUTH_VALUE, LAST_AZIMUTH_VALUE and TELEMETRY_MODE; error if not.
f. Also check that IBS_CEM_DAC has not varied during this time, if so, set all data to fill values and the IBS_CEM_DAC value in the output record to fill. [Due to the way IBS works, one sweep of data can occur over the course of 2 A-cycles. When this is combined with Azimuth summing there is no good way to list those A-cycles, so the first half of the sweep has the earlier A-cycle number and the 2^{nd} the latter A-cycle number. Therefore if the IBS_CEM_DAC value is different between those two A-cycle numbers you need to exclude the data by setting everything to fill. This also has the confusion that the FIRST_AZIMUTH_VALUE number is with respect to the earlier of the two A-cycle numbers]
g. Create a new record for this full sweep of data, copying across Time, mcp voltages, and other such info.
h. Calculate time, t (in seconds, later to be converted to UTC), and dt of this new record using the know sweep duration for a single azimuth for your data product and the First/Last Azimuth numbers but being careful about the A-cycle confusion mentioned above. Easiest is to take the first record (highest energy) of the sweep and do either of these two equations for the start time of the period:
   t = TIME(a) + (FIRST_AZIMUTH_VALUE(a) - 1)*2*half_az_sec
   or
   t = TIME(a) + OFFSET_TIME(a)/1000
   where a is the index of the highest energy step of that sweep, and half_az_sec is 1 if there are 255 energy steps or 0.5 if 127 energy steps.
   dt is then given by:
   dt = (LAST_AZIMUTH_VALUE(a) - FIRST_AZIMUTH_VALUE(a)+1) *…
   half_az_sec
   Unfortunately the half_az_sec term is needed as a the first/last azimuth value has no idea if it's a 1s Azimuth or a 2s Azimuth.
i. Copy out data to new record that is 2D, energy step by anode. This is of size 255x3. If there were 127 records only, then the first 127x3 are the data, and the remaining 128x3 are all fill as PDS requires fixed size packets.
j. Copy out dimension 1 info, that's the energy tables with their lower and upper limits. This is a size 255 array for each or lower, center, upper.
k. Copy out dimension 2 info, which is the anodes position in spacecraft theta, again with lower and upper limits, as such this is a size 3 array (for 3 anodes) for each of lower, center, upper. HOWEVER, due to the cross-fan geometry of IBS, anode 1 and 3 will be fill and only anode 2 given as only it has a field of view parallel to the spin axis. The FMT

files give limited info on how the end user can then work out anode 1 and 3.

l. Copy out dimension 3 info, a scalar value for spacecraft phi, for minimum, representative, maximum. This uses the 1-second ACT data from earlier, converts to spacecraft phi (270degs – ACT angle) and does a min(), mean() and max() on them to get the values.
   Only do this if you have the expected number of 1-second actuator values. i.e. for a 4-s SNG Azimuth I'd use 5 actuator angles for the min/mean/max, - where the 5th is the end time of the 4 second duration interval (and the 1st is the start time). As such if I don't have 5 Actuator angles I set these phi values all to fill. For SNG 8-Azimuth-sums (A-cycle resolution at 32-s) I'd expect 33 act angles, etc.
   This is not always true as the ACT.TIMEs are not always exactly 32-seconds apart, and are sometimes a little less, meaning you can occasionally get more or less 1-second intervals. You need to correct for this. For IBS I'd expect 3, 17, 33, 65, 129 or 257 act angles per record for 2-s Azimuths, or 2, 9, 17, 33, 65 or 129 for the 1-s Azimuths.
m. Repeat thorough file.

14) Group records to entire sweep of data for TOF

a. Look at the B_CYCLE_NUMBER of the first record.
b. Continue stepping through the records until the B_CYCLE_NUMER is not the same. This will provide up to the expected 32 records
c. Check that all those records have the same values in TIME, COLLAPSE_AND_DURATION, ST_START_CHANNEL, ST_INTERVAL, ST_ENERGY_COLLAPSE, LEF_START_CHANNEL, LEF_INTERVAL, LEF_ENERGY_COLLAPSE
d. Check that all have the same TELEMETRY_MODE or if not the same are 128 apart (same) mod(TELEMETRY_MODE,24)); error if not.
e. One B-cycles covers many A-cycles, so from earlier, check that the IMS energy table has not changed during the B-cycle, and that both mcp voltages (LEF and ST) are neither fill nor varying; if so, set them and the data to fill values in the output record. Allow a variance of 1V for the mcp voltages, only if voltages differ by beyond that range consider them varying.
f. Create a new record for this full sweep of data, copying across Time, mcp voltages, and other such info.
g. Calculate time, t and dt from the COLLAPSE_AND_DURATION info.
h. Copy out data to new record that is 2D, energy step by anode. This is of size 32x512 TOF channel. No attempt is made to reorder the data from the Level 2 files so every other TOF channel may be fill anyway, etc. Be careful when you don't have 32 records to populate the records you do have in the correct part of this array. If the first record's step is at 4, then [1:3,*] will all be fills, then [4,*] will be that first step, etc.
i. Although the data is 32x512, this will be placed in to a 1D stream in the PDS file, so this is really size 32x1x1x512.

j. Copy out dimension 1 info, that's the energy tables with their lower and upper limits. This is a size 32 array for each or lower, center, upper.
k. Copy out dimension 2 info, which is the anodes position in spacecraft theta, again with lower and upper limits, as such this is a size 1 array (for 1 anode) for each of lower, center, upper.
l. Copy out dimension 3 info, a scalar value for spacecraft phi, for minimum, representative, maximum. This uses the 1-second ACT data from earlier, converts to spacecraft phi (270degs – ACT angle) and does a min(), mean() and max() on them to get the values.
   Only do this if you have the expected number of 1-second actuator values. i.e. for a 256-s TOF B-cycle I'd use 257 actuator angles for the min/mean/max, - where the 257^{th} is the end time of the 256 second duration interval (and the 1^{st} is the start time). As such if I don't have 256 Actuator angles I set these phi values all to fill.
   This is not always true as the ACT.TIMEs are not always exactly 32-seconds apart, and are sometimes a little less, meaning you can occasionally get more or less 1-second intervals. You need to correct for this. For TOF I'd expect 257, 513 or 1025 act angles per B-cycle.
m. Copy out dimension 4 info, the TOF channel number in unit of seconds I assume the TOF channel number is the start of the channel range so I use these equations for a given energy step:
   DIM2_TOFST_LOWER(ST_step) = dTOF*…
   (ST_START_CHANNEL(a) + ST_step * ST_INTERVAL(a));
   DIM2_TOFST(ST_step) = dTOF*…
   (0.5 + ST_START_CHANNEL(a) + ST_step*TOF.ST_INTERVAL(a));
   TOF2.DIM2_TOFST_UPPER(,ST_step) = dTOF*…
   (1.0 + ST_START_CHANNEL(a) + ST_step*ST_INTERVAL(a));

   [For LEF it's the same, replace LEF for ST above.]

   where dTOF = 1/(80e6)/16, ST_step is 0:step:511, meaning from 0 to up to 511 in steps of 'step', where step can be 1, 2 or 4, and a is the index of the record of the highest energy step.
   step if found by examining the DATA_ST record:
      i. If 3 of every 4 TOF channels are fill, step = 4
      ii. Else if every 2^{nd} TOF channel is fill, step = 2
      iii. Else if none are fill, step = 1
      iv. There could be an issue that one of the non-fill actual records might be a fill value… so you have to go by the general pattern over the whole 512 TOF channels.
n.
o.
p.
q. Repeat thorough file.

15) Get ANC position/orientation/velocity info from SPICE using the center time of the re-ordered records.
The PDS archived yearly meta-kernels were used that were available as of August 2013. The website they were taken from is:
PDS archived file: http://naif.jpl.nasa.gov/naif/data_archived.html
From here I calculate:
SC_SATURN_POS_X, SC_SATURN_POS_Y, SC_SATURN_POS_Z,
SC_SATURN_POS_R,
SC_SATURN_VEL_X, SC_SATURN_VEL_Y, SC_SATURN_VEL_Z,
SC_SUN_POS_X, SC_SUN_POS_Y, SC_SUN_POS_Z,
SC_SUN_VEL_X, SC_SUN_VEL_Y, SC_SUN_VEL_Z,
SC_ANGULAR_VEL_X, SC_ANGULAR_VEL_Y, SC_ANGULAR_VEL_Z,
Plus:
SATURN_RIGHT_ASCENSION and SATURN_DECLINATION,
SC_LOCAL_TIME, SC_LAT,
and
SC_ORIENT_XX, SC_ORIENT_XY, SC_ORIENT_XZ,
SC_ORIENT_YX, SC_ORIENT_YY, SC_ORIENT_ZZ,
SC_ORIENT_ZX, SC_ORIENT_ZY, SC_ORIENT_ZZ,
which are used to work out the SC_TO_J2000 and J2000_TO_RTP transformation matrices.
(I do not use the equivalent information from the ANC uncalibrated files, only the data has to be reversible between level 2 and level 3, not ancillary data.)

The data now has dimensions in the spacecraft co-ordinate system and we've now provided transformation matrices to the common systems.
16) Write out data to a PDS compatible file, one per data type… with the exception of splitting out the TOF data to two separate files: TOFLEF and TOFST so that each only contains one DATA object.
17) Write PDS label file and FMT files.

Appendix A: ELS mcp times

This text file lists the dates and time periods affected by gain tests.
LKG.

21-sep-2000 (DOY 265) approx 07:00 to 08:00

12-jul-2002 (DOY 193) approx 22:00 to 23:00
20-oct-2002 (DOY 293) approx 04:30 to 05:30

18-jan-2003 (DOY 018) approx 01:00 to 02:00

10-jan-2004 (DOY 010) approx 11:30 to 12:30
05-feb-2004 (DOY 036) approx 12:30 to 13:30
08-may-2004 (DOY 130) approx 08:30 to 09:30
09-jul-2004 (DOY 191) test scheduled but no data available
05-aug-2004 (DOY 218) 09:39 to 10:17
17-sep-2004 to 18-sep-2004 (DOYs 261-262) 23:29 to 00:07
09-oct-2004 (DOY 283) 20:20 to 20:59
05-nov-2004 (DOY 310) 20:19 to 20:56 (in. data gap at start)
17-dec-2004 (DOY 352) 08:49 to 09:26

17-jan-2005 (DOY 017) 14:59 to 15:37 (inc. data gap at start)
16-feb-2005 (DOY 047) 17:59 to 18:37
03-apr-2005 (DOY 093) 17:39 to 18:17
05-may-2005 (DOY 125) 07:15 to 07:52
12-jul-2005 (DOY 193) 11:55 to 12:33
11-aug-2005 (DOY 223) 23:06 to 23:44
06-sep-2005 (DOY 249) 15:21 to 15:59
02-oct-2005 (DOY 275) 12:21 to 12:58
20-oct-2005 (DOY 293) 05:33 to 06:11 (inc. data gap at start)
30-nov-2005 (DOY 334) 00:27 to 01:04

07-jan-2006 to 08-jan-2006 (DOYs 007-008) 23:35 to 00:13
06-feb-2006 (DOY 037) 05:32 to 06:10
20-mar-2006 (DOY 079) 08:38 to 09:16
20-apr-2006 (DOY 110) 11:58 to 12:36
13-may-2006 (DOY 133) 16:50 to 17:28
04-jun-2006 (DOY 155) 11:59 to 12:37
18-jun-2006 (DOY 169) 18:19 to 19:07 (inc. data gap at start)
28-jun-2006 (DOY 179) 09:30 to 10:08
21-jul-2006 (DOY 202) 11:59 to 12:36
30-jul-2006 (DOY 211) 03:59 to 04:37
14-aug-2006 (DOY 226) 07:20 to 07:58
27-aug-2006 (DOY 239) 21:31 to 22:09
09-sep-2006 (DOY 252) 05:25 to 06:02
19-sep-2006 (DOY 262) 12:00 to 12:38
09-oct-2006 (DOY 282) 07:49 to 08:26
20-oct-2006 (DOY 293) 02:29 to 03:06
27-oct-2006 (DOY 300) 11:59 to 12:37
11-nov-2006 to 12-nov-2006 (DOYs 315-316) 23:29 to 00:07
25-nov-2006 (DOY 329) 03:37 to 04:14
08-dec-2006 (DOY 342) 19:59 to 20:37
19-dec-2006 (DOY 353) 05:29 to 06:07

02-jan-2007 (DOY 002) 00:28 to 01:06

14-jan-2007 (DOY 014) 12:52 to 13:29
28-jan-2007 (DOY 028) 05:59 to 06:37
09-feb-2007 (DOY 040) 11:59 to 12:37
05-mar-2007 (DOY 064) 00:11 to 00:48
19-mar-2007 (DOY 078) 12:29 to 13:07
13-apr-2007 (DOY 103) 05:08 to 05:46
24-apr-2007 (DOY 114) 07:29 to 08:06
04-may-2007 (DOY 124) 22:59 to 23:37
19-may-2007 (DOY 139) 11:59 to 12:37
01-jun-2007 (DOY 152) 05:59 to 06:36
11-jun-2007 (DOY 162) 12:57 to 13:31
22-jun-2007 (DOY 173) 20:39 to 21:15
04-jul-2007 (DOY 185) 12:08 to 12:45
16-jul-2007 (DOY 197) 09:19 to 09:57
30-jul-2007 (DOY 211) 10:03 to 10:39
12-aug-2007 (DOY 224) 08:09 to 08:45
28-aug-2007 (DOY 240) 12:09 to 12:45
22-sep-2007 (DOY 265) 05:05 to 05:42
05-oct-2007 (DOY 278) 00:20 to 00:55
27-oct-2007 (DOY 300) 12:18 to 12:57
11-nov-2007 (DOY 315) 01:53 to 02:30
22-nov-2007 (DOY 326) 10:08 to 10:45
16-dec-2007 (DOY 350) 00:20 to 00:56
30-dec-2007 (DOY 364) 01:41 to 02:18

09-jan-2008 (DOY 009) 22:49 to 23:26
05-feb-2008 (DOY 036) 08:14 to 08:51
18-feb-2008 (DOY 049) 00:29 to 01:06
05-mar-2008 (DOY 065) 20:19 to 20:56
15-mar-2008 (DOY 075) 12:19 to 12:58
23-apr-2008 (DOY 114) 09:19 to 09:56
04-may-2008 (DOY 125) 12:19 to 12:57
14-may-2008 (DOY 135) 01:19 to 01:56
05-jun-2008 (DOY 157) 12:08 to 12:45
18-jun-2008 (DOY 170) 12:08 to 12:46
02-jul-2008 (DOY 184) 00:19 to 00:56
13-jul-2008 (DOY 195) 09:41 to 10:18
28-jul-2008 (DOY 210) 00:19 to 00:56
13-aug-2008 (DOY 226) 00:02 to 00:46
28-aug-2008 (DOY 241) 07:33 to 08:09
13-sep-2008 (DOY 257) 15:07 to 15:46
26-sep-2008 (DOY 270) 00:19 to 00:57
11-oct-2008 (DOY 285) 07:41 to 08:18
26-oct-2008 (DOY 300) 00:09 to 00:45
07-nov-2008 (DOY 312) 00:09 to 00:45
25-nov-2008 (DOY 330) 07:22 to 07:59

12-dec-2008 (DOY 347) 00:19 to 00:57
25-dec-2008 (DOY 360) 00:19 to 00:57

09-jan-2009 (DOY 009) 03:41 to 04:18
08-feb-2009 (DOY 039) 00:08 to 00:45
07-mar-2009 (DOY 066) 00:19 to 00:57
21-mar-2009 (DOY 080) 00:19 to 00:57
08-apr-2009 (DOY 098) 18:42 to 19:19
19-apr-2009 (DOY 109) 00:08 to 00:46
11-may-2009 (DOY 131) 14:42 to 15:19
04-jun-2009 (DOY 155) 00:19 to 00:56
19-jun-2009 (DOY 170) 02:14 to 02:51
29-jun-2009 (DOY 180) 11:42 to 12:19
19-jul-2009 (DOY 200) 12:13 to 12:51
03-aug-2009 (DOY 215) 00:19 to 00:57
18-aug-2009 (DOY 230) 07:42 to 08:18
02-oct-2009 (DOY 275) 02:19 to 02:57
17-oct-2009 (DOY 290) 00:17 to 00:56
01-nov-2009 (DOY 305) 00:17 to 00:56
15-nov-2009 to 16-nov-2009 (DOYs 319 to 320) 23:44 to 00:22
30-nov-2009 (DOY 334) 13:12 to 13:50
15-dec-2009 (DOY 349) 20:17 to 20:56

16-jan-2010 (DOY 016) 00:17 to 00:56
30-jan-2010 (DOY 030) 00:17 to 00:56
25-feb-2010 (DOY 056) 19:43 to 20:21
01-mar-2010 (DOY 060) 05:33 to 06:07
16-mar-2010 (DOY 075) 00:43 to 01:21
31-mar-2010 (DOY 090) 16:17 to 16:54
15-apr-2010 (DOY 105) 00:17 to 00:54
29-apr-2010 (DOY 119) 23:16 to 23:51
12-may-2010 (DOY 132) 20:17 to 20:54
30-may-2010 (DOY 150) 00:17 to 00:54
13-jun-2010 (DOY 164) 16:17 to 16:54
29-jun-2010 (DOY 180) 14:22 to 14:59
14-jul-2010 (DOY 195) 00:17 to 00:55
28-jul-2010 (DOY 209) 12:17 to 12:55
09-aug-2010 (DOY 221) 06:17 to 06:54
28-aug-2010 (DOY 240) 00:16 to 00:54
09-sep-2010 (DOY 252) 00:17 to 00:54
27-sep-2010 (DOY 270) 11:47 to 12:24
12-oct-2010 (DOY 285) 00:17 to 00:54
27-oct-2010 (DOY 300) 00:17 to 00:54
26-nov-2010 (DOY 330) 00:17 to 00:54
11-dec-2010 (DOY 345) 00:17 to 00:54
26-dec-2010 (DOY 360) 00:17 to 00:54

08-jan-2011 (DOY 008) 00:17 to 00:54
09-feb-2011 (DOY 040) 17:16 to 17:54
24-feb-2011 (DOY 055) 00:16 to 00:54
11-mar-2011 (DOY 070) 00:17 to 00:54
26-mar-2011 (DOY 085) 00:17 to 00:54
10-apr-2011 (DOY 100) 00:17 to 00:54
25-apr-2011 (DOY 115) 00:17 to 00:54
Gap due to commanding error
11-jun-2011 (DOY 162) 18:17 to 18:54
Huge gap due to 'shorting' problem in CAPS

04-apr-2012 (DOY 095) 00:17 to 00:54
18-apr-2012 (DOY 109) 21:16 to 21:55
05-may-2012 (DOY 126) 00:17 to 00:57
19-may-2012 (DOY 140) 05:19 to 05:50
01-jun-2012 (DOY 153) 02:33 to 03:10