Spin Timings and Offsets for Cluster Prime Parameters

Steven J. Schwartz
Queen Mary & Westfield College
Mile End Road
London E1 4NS
United Kingdom
e-mail: S.J.Schwartz@qmw.ac.uk

and

Patrick W. Daly
Max-Planck-Institut für Aeronomie
D-37189 Katlenburg-Lindau
Germany
email: daly@linmpi.gwdg.de

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1	2	23 Feb 95	Algorithm and recommended calculation thereof made more precise; CIS algorithm different. Sections affected include 2.4 and 3.3 (and section 5)
1	2a	1 May 95	Corrected typographical errors and added T_{SRP} to list following equation (5). Approved by IWG and under configuration control.
1	3	22 Jan 96	Reset cycle time up-dated to be that given in DDID.

Executive Summary

The start, stop, centre, and time tag times for spin-averaged data to populate the Cluster Science Data System Prime Parameter Database are defined. This spin starts at a fixed offset from the spacecraft sun reference pulse. **The nominal offset for the mission will be** $(75/1024) \times 360°$ $(\approx 26.367°)$, although the flexibility to change this during the mission should be included in all relevant software. Algorithms to calculate these times in a uniform manner from the spacecraft housekeeping data are included.

Contents

Applicable Documents

1. "Reference Document for CSDS CDF Implementation" DS-QMW-TN-0003
2. "Report of the Data Products Task Group for the Cluster Science Data System" DS-MPA-TN-0001
3. "Experiment Interface Document" CL-EST-RS-0002/EID A
4. "Data Delivery Interface Document" CL-ESC-ID-0001

1 Background

The need to coordinate, where possible, the Prime Parameters generated by different instruments was recognized early in the history of CSDS. The Report of the Data Products Task Group (DS-MPA-TN-0001) includes a discussion of "what is a spin" and concludes that, for spin averaged data, a spin is "The time from one sun pulse, plus *offset*, to the next, plus the same *offset*." Agreeing on such an offset has proved elusive, however, and the authors were asked at an Implementation Working Group Meeting held in the UK on 21-22 November, 1994 to consult the instrument groups and bring this matter to a conclusion.

The rationale is to build a Prime Parameter Database which, as much as possible, has data synchronized amongst different instruments. Specifically, the data averaged to make up a spin should be collected over the same interval and the time tag associated with that spin be identical. This facilitates the construction, without recourse to interpolation, of fundamental plasma parameters requiring multi-instrument data, such as the plasma $\beta \equiv \sum(n_j \kappa T_j)/(B^2/2\mu_o)$ or electron to proton temperature ratio, T_e/T_p. Since the different satellites will spin at slightly different rates, synchronization can only be achieved within the data from each spacecraft individually.

This document defines the spin to be used by CSDS Prime Parameters, and includes algorithms for calculating the necessary times from the information provided on the raw data CD-ROMs.

2 Mission-wide *offset*

The need for a mission-wide *offset* has been set out in the Introduction above. The various factors and complications surrounding this issue are recorded here for completeness.

2.1 Particle Instrument Constraints

While many instruments send back data at higher time resolution than one spin, and can construct averages over any interval on the ground, all the particle instruments' data samplings are synchronized with respect to the sun pulse. Moreover, some instruments compute spin-averaged moments on board. Thus the start of a sampling interval must be decided in advance. Moreover, the algorithm to define a Prime Parameter spin must be clearly stated so that averaging during Prime Parameter generation on the ground, for those instruments which return high time resolution data, can be done without reference to other instrument data.

The particle instruments need to ensure that the start of a sampling period is such as to minimise interference from other instruments, the spacecraft, and/or sunlight while ensuring that important regions of velocity space are covered. All of these kinds of constraints translate into the phase of the instrument in relation to some physical direction (e.g., x-GSE), and then in terms of the instrument location on the spacecraft to re-cast this constraint in terms of phase (or *offset*) relative to the spacecraft Sun Reference Pulse (SRP). More specifically, the instrument teams have provided the following information:

2.1.1 PEACE

The primary concern of PEACE is to avoid the sun direction when PEACE is measuring the lowest energy electrons, for which the risk of contamination by photoelectrons is the greatest. This can be achieved for all energy sweep modes with an offset of 11/1024 of a spin ($\approx 3.867°$) and repeats in cycles of 64/1024 ($= 12.5°$) of a spin, so the PEACE constraint allows offsets of

$$\frac{11 + 64m}{1024} \times 360° \qquad m = 0, 1, 2, \ldots$$

2.1.2 CIS

The primary CIS concern is to enable HIA to resolve the solar wind beam by being in the right energy range at that phase of the spin. The optimum CIS offset is 30.3°, although CIS have indicated that they could tolerate offsets in roughly the range $0° - 70°$. Of the PEACE allowed values, $m = 1$ ($\approx 26.367°$) is preferred by CIS, with $m = 2$ ($\approx 48.867°$) a second choice.

2.1.3 RAPID

RAPID needs to avoid a sun pulse occurring in their sector 9, which translates into an avoidance range of $101.2° - 123.7°$, corresponding to PEACE $m = 5$ (116.367°). Avoiding adjacent values $m = 4$ and $m = 6$ would also be prudent.

2.2 Can *offset* be Constant throughout the Mission?

All indications suggest that the recommended *offset* is appropriate for the entire mission. Once in flight, however, experience with the instruments may reveal unforeseen interferences, or physical requirements, which might suggest that a different *offset* would be better. Accordingly, all experimenters and data centres should NOT assume a fixed value throughout the mission.

2.3 Mechanism to Change *offset*

Changing the *offset* has implications for spacecraft/instrument operations and for CSDS National Data Centres (and through them to the PI supply of data reduction software). Accordingly, changes to *offset* will require referral to the SWT (or equivalently the Master Science Plan) and coordination within CSDS. There would not seem to be any reason for such a change to be initiated by CSDS, so the envisaged sequence of events would be:

1. One (or more) PIs propose changing *offset* to *new_offset* with effect from a specified date and time to the Project Scientist.

2. This change is agreed, or otherwise, via the Master Science Plan in the same category as any other major change, e.g., spacecraft separation, spin period, etc.

3. This agreement is reported to CSDS as soon as it is reached, so that national data centres can modify their software/procedures appropriately.

2.4 Exceptions

It will not be possible to generate a complete set of Prime Parameters from one spacecraft which all have identical time tags for three reasons:

1. STAFF and WHISPER work to internal clocks and convolve data over their own interval (~ 4 sec) on board. This interval will drift with respect to the Sun Reference Pulse. Accordingly, the Prime Parameters from these instruments can not be synchronized with other instruments whose sampling is fixed with respect to the Sun Reference Pulse.

2. Experimenters may wish, from time to time, to alter their offsets in order to assess instrument operations or target a specific scientific objective. Certainly, PEACE have indicated that they may wish to alter temporarily their offset on an infrequent basis. Other instruments should not try to follow such temporary adjustments by PEACE (or any other single instrument), but instead work to the CSDS *offset*.

3. CIS will operate according to the CSDS *offset* as defined here. However, CIS parameters from 16 spins are collected together on board prior to telemetry. CIS will construct a single Sun Reference Pulse time for the beginning of this set, and then use the average spin period as contained in the SATT file to reconstruct the intervening Sun Reference Pulse times. This is likely to generate slightly different times due to several factors, including jitter in the individual pulse times and the frequency of up-dating the SATT average spin period, which have not been quantified at present.

Apart from these exceptions, ALL CSDS Prime Parameters should have identical time tags and represent averages (or integrations) over identical time intervals.

In principle, the requirement of identical time tags does *not* imply identical instrumental operation timings. For example, the solar wind ion beam occupies only a fraction of a spin, so CIS could *operate* with their optimal offset of 30.3° but assign the conventional CSDS time tag to the data. Such a procedure may, of course, interfere with other parts of CIS and therefore not be practical. In general, the data (including the time tags) should be accurate rather than misleading but conforming.

2.5 The Value of *offset*

The detailed particle instrument considerations above imply that

$$\boxed{offset = \frac{75}{1024} \times 360^\circ}$$

(i.e., approximately 26.367°) best meets all constraints. This means that a spin commences $\approx 26.367°$ *after* a Sun Reference Pulse and ends the same lag after the next SRP. A more precise statement is provided in the algorithm contained within the next section.

Software writers are urged to build into their code an offset value to be input, specified as a parameter, or whatever, rather than hard-wiring this value.

3 Algorithms for Calculating Time

3.1 T_{SRP}

The time T_{SRP} of the Sun Reference Pulse can be calculated from the VC0 Housekeeping Data on the CD-ROM. This provides a 20-bit unsigned integer, N_{SRP}, representing the number of cycles of the high frequency clock since the last ~ 5.15s reset pulse [see DDID 5.1.3.3.1 concerning time between reset cycles]. The high frequency clock has a frequency of 131,072Hz ($= 2^{17}$) yielding an accuracy of $\sim 7.63\mu$s. The time of the reset pulse has to be corrected for the delay between collection and placing in the telemetry. This delay is $2 \times 5.15222168 = 10.30444336$s and will be used as a constant value for CSDS products (rather than instantaneous values deduced by other means). Thus the time of the Sun Reference Pulse is given by

$$T_{SRP} = T_{RP} - 10.30444336\text{s} + \left(\frac{N_{SRP}}{131,072}\right)\text{s} \tag{1}$$

where T_{RP} is the spacecraft event time (SCET) of the reset pulse found in the DDS packet header of the current housekeeping frame (as separate day, milliseconds of day, and μs of ms fields with day zero being 1 January, 1958). Note that (1) gives the time T_{SRP} to an accuracy ~ 0.01ms and requires a double precision (i.e., 64 bit) variable to hold it.

We note here that there has been considerable confusion over the sun reference pulse timing in relation to the spacecraft orientation. In particular, the EID-A section 3.3.7.3.1 reads:

> "Once per spacecraft revolution the Sun Reference Pulse (SRP) shall be produced when a S/C fixed meridian plane coincides with the sun vector. The SRP will be specified to a nominal spacecraft azimuth of 26.2 deg CCW from $+Y_B$ axis, depending on the active AOCMS sensor."

The range of possible values and/or errors in this value is t.b.d.

3.2 Spin Period

The spin period, τ_{spin}, is the difference between the times of successive Sun Reference Pulses. That is, for spin n,

$$\tau_{spin}(n) = T_{SRP}(n) - T_{SRP}(n-1) \tag{2}$$

This should give sufficient accuracy for CSDS purposes. Note that this definition is formally the spin period for the *previous* spin, but the difference is completely negligible. In any event, it is this difference which presumably drives the spin segment clock which is what the instruments use. More accurate determinations of the spin period (see Appendix I.6.2 of the DDID) may be useful for other purposes, but should NOT be used in Prime Parameter generation in the interests of uniformity and bearing in mind the spin-averaged nature of the data products.

3.3 Start, End, Centre, and Time Tag Times

The start time of a spin is now easily calculated. If *offset* is the angular offset in degrees from the Sun Reference Pulse marking the beginning of a spin, with positive angles corresponding to a start time after the Sun Reference Pulse, then the start time for spin n is

$$T_{start}(n) = T_{SRP}(n) + \frac{offset}{360.0}\tau_{spin}(n) \quad (3)$$

Note that *offset* is presently defined in terms of a precise fraction (75/1024) of 360°, and this fraction may be used as the multiplier of $\tau_{spin}(n)$ in Equation 3 without calculating *offset* in degrees to the requisite accuracy (0.1ms/4s $\sim$ 5 significant figures).

The end time of the spin is defined as the start time of the next spin, i.e.,

$$T_{end}(n) = T_{start}(n+1) \quad (4)$$

This definition ensures that successive spins do not overlap (whereas defining the end time to be the start time plus the spin period could lead to such an overlap).

The centre time is

$$T_{centre}(n) = 0.5\,[T_{start}(n) + T_{end}(n)] \quad (5)$$

To ensure uniformity across CSDS, it is recommended that T_{SRP}, T_{start}, T_{end}, and T_{centre} be calculated and held as seconds or milliseconds since the start of the day in a double precision (64 bit) variable. This will provide at least 6 extra significant figures to the time beyond the millisecond field, thereby restricting the frequency of round-off error (e.g., on different platforms) resulting in a different time tag (see below for algorithm) to 1 in a million, or roughly 1 data point in 3 days of Prime Parameters from all spacecraft and relevant instruments.

The time tag of the CSDS Prime Parameters for spin n is calculated by rounding T_{centre} to the nearest millisecond and then expressing it in terms of the CDF Epoch data type (i.e., milliseconds since 0AD). Thus, if T_{centre} has been calculated in seconds of the day of observation, the time tag in CDF Epoch format is formed by rounding it to the nearest millisecond of the day and adding it to the CDF Epoch corresponding to the beginning of the day (i.e., 00:00:00.000), viz.,

$$T_{tag}(n) = (\text{CDF Epoch of YYYY-MM-DDT00:00:00.000Z}) + \text{nint}(1000 * T_{centre}(n)) \quad (6)$$

It is likely that many data centres will only require time tags as milliseconds of the day and will use separate CDF-writing software to convert this to a full CDF Epoch variable equal to that given in (6). Those which do NOT will need to keep track of leap seconds and other nuisances themselves to ensure conformity across CSDS. The most straightforward and reliable way to generate the CDF Epoch value of 00:00:00.000 on the day is via a function within the CDF library.

3.4 Missing Sun Reference Pulses

If a Sun Reference Pulse is absent, the most recent value of τ_{spin} should be added to $T_{start}(n)$ to determine $T_{start}(n+1)$, and hence $T_{end}(n)$ via (4). This can be repeated any number of times until a Sun Reference Pulse is found.

4 CSDS Definition of a Minute

For completeness, we repeat here the CSDS definition of a minute, as used to generate the Summary Parameter Data. The Summary Parameters associated with a minute are the average of all those measurements made during spins whose middle times lie within the minute boundaries. The time tag is the initial minute boundary plus 30 seconds. Thus all Summary Parameters should have time tags with values equal to hh:mm:30.000 on the day of observation.

5 Summary and Conclusions

In order to synchronize the data in the Prime Parameter Database, the start, end, centre, and tag times of a spin have been defined in terms of an *offset* from the Sun Reference Pulse. We have also defined an algorithm for calculating the CDF Epoch value of the Prime Parameter Database time tags. Our main conclusions, based on information from CIS, PEACE, and RAPID teams, include:

1. The nominal mission value of *offset* is $(75/1024) \times 360°$ which is approximately $26.367°$.

2. Allowance should be included in processing software for *offset* to take a value different from this nominal one.

3. Some instruments (STAFF and WHISPER) will not be able to generate Prime Parameters on a spin basis, but all others can do so, either on board the spacecraft or on the ground from higher time resolution data.

4. Algorithms and recommendations to calculate the start, centre, end, and tag time of a spin are given in (1)-(6), including recommendations about data type, storage, and arithmetic to ensure uniformity.

5. CIS have indicated that their instrument will operate using the above *offset*. However, they will use different algorithms to calculate their time tags. This is apparently a matter of convenience. The errors so introduced are t.b.d.

6. The algorithms given can be used without reference to a particular instrument, i.e., independently by the individual data centres.

7. While some teams may choose to examine the consequences of a temporary change in the value of their *offset*, such changes, which negate the aim of consistent time tags, should be limited in duration and frequency. Other instruments would not be expected to follow such private changes in *offset*.

8. Changing the value of *offset* requires a mission-wide approach, and Section 2.3 provides a possible sequence via referral to both the SWT/Master Science Plan and CSDS.

6 Outstanding Issues

The following aspects require confirmation or further information:

1. The correction of -2×5.15222168 in (1) to the SCET of the reset pulse requires further confirmation, but is not critical.

2. The range of values and/or errors to the phase of the SRP relative to the spacecraft $+Y_B$ axis is required to ensure that some adjustment to *offset* will not (or will) be required in flight to meet the most stringent requirement, namely that of PEACE which is $\sim (1/1024)$ of a spin, i.e., $\sim 0.35°$. Again, ESOC input is required.

7 Acknowledgements

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