STAFF PRODUCTS FOR THE CLUSTER ACTIVE ARCHIVE

L. Mirioni[1,2], N. Cornilleau-Wehrlin[1], P. Robert[1], M. Maksimovic[2], Y. de Conchy[2], and C. C. Harvey[3]

[1]*CETP-IPSL-CNRS, 10-12 avenue de l'Europe, 78140 VÉLIZY-VILLACOUBLAY, FRANCE*
[2]*LESIA, Observatoire de Paris-Meudon, 5 place Jules Jansen, 92195 MEUDON CEDEX, FRANCE*
[3]*CESR, 9 avenue du Colonel Roche, BP 4346, 31028 TOULOUSE CEDEX 4, FRANCE*

ABSTRACT

Cluster Spatio-Temporal Analysis of Field Fluctuations (STAFF) high resolution data that will be available at Cluster Active Archive (CAA) comprise two main parts, the three component waveform data, in the frequency range 0.1 - 10 Hz or 0.1 - 180 Hz, depending on the spacecraft telemetry rate, on one hand, and the Spectrum Analyser data on the other hand. The latter are the elements of the complex spectral matrix of 5 components, the 3 magnetic components from the STAFF experiment and the 2 electric components from the Electric Fields and Waves (EFW) experiment, in the frequency range 8 - 4000 Hz.
The already delivered 2001-2002 data, comprise the waveform data in telemetry units and their dynamic spectra plots (PS and PNG images, one plot per 3 hours period) and the spectral matrix data in physical units.
Data will be delivered contractually, at the rhythm of 2 years of data per year. In the future, graphical plots of STAFF-SA data will be delivered as well as Level 3 data files, containing wave polarisation characteristics.
For the waveform data, work is in progress on how to deliver continuous good quality data in physical units.

1. INTRODUCTION

The scientific rationale underpinning the Cluster Active Archive (CAA) activities is to:

- maximise the scientific return from the mission by making all Cluster data available to the worldwide scientific community;
- ensure that the unique data set returned by the Cluster mission is preserved in a stable, long-term archive for scientific analysis beyond the end of the mission;
- provide this archive as a major contribution by ESA and the Cluster science community to the International Living With a Star programme.

In the case of the Spatio-Temporal Analysis of Field Fluctuations (STAFF) experiment, the main responsibilities will be to deliver to CAA high resolution STAFF data in an agreed format at the best possible quality level, as far as possible in physical units (Level 2 data). When not in physical units (possible case of the waveform data) the calibration files and the relevant software to calibrate the data will be delivered with the adequate documentation. Additional value added products will be delivered too, on the best effort basis, as well as graphical displays.

This paper is to be considered as an appetiser of what a scientist may expect to find in the CAA database regarding STAFF data. A more detailed description of available products will be found in [2].

2. INSTRUMENT HARDWARE

The Cluster STAFF experiment (see [3] and [4]) comprises a boom-mounted three-axis search coil magnetometer to measure magnetic fluctuations in the frequency range 0.1 Hz - 4 kHz, a preamplifier and an electronics box that houses the two complementary data-analysis packages: an on-board waveform unit and a digital Spectrum Analyser.
STAFF is one of the five experiments of the Wave Experiment Consortium (WEC).

2.1. The Magnetic Waveform Unit

The magnetic waveform unit (STAFF-SC) is made of three sections in order to fulfil different filtering and waveform digitalisation, output interface and onboard calibration. The three magnetic components of the magnetic field (B_x, B_y and B_z), at the output of the search coil preamplifier are filtered simultaneously in either one of the two bandwidths 0.1 - 10 Hz and 0 - 180 Hz, then they are digitised simultaneously by a 16 bits sampling and hold device at 25 and 450 Hz repectively.

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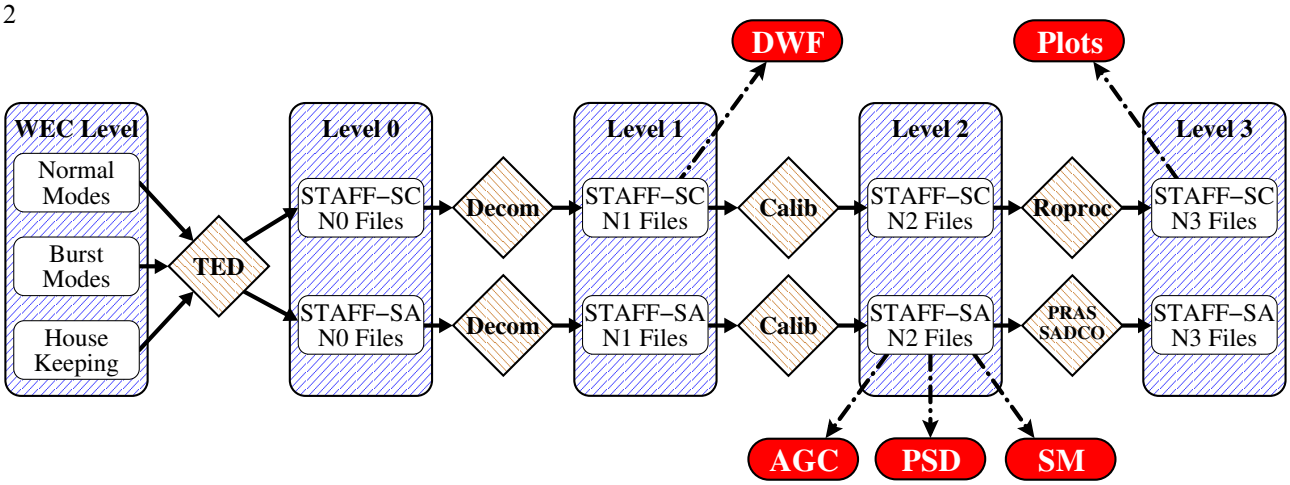

Figure 1. Global picture of the STAFF data processing chains. At the time of writing, only Decommutated WaveForm (DWF), Automatic Gain Control (AGC), Power Spectral Density (PSD), Spectral Matrix (SM) CEF files and STAFF-SC dynamic spectra (graphical plots) are stored in the CAA.

2.2. The Spectrum Analyser

The Spectrum Analyser (STAFF-SA) is designed to perform the complete auto and cross correlation matrix of 5 sensor channels (B_x, B_y, B_z, E_y, E_z) over a frequency range of more than 9 octaves at a high rate. The "front-end" of the analyser is analogue. The analysis band of 8 - 4000 Hz is divided into 3 logarithmically distributed frequency sub-bands (A, B and C), each being divided into 9 frequency channels. The analysis band is therefore divided into 27 frequency bands, logarithmically spaced. For each of the 3 sub-bands and for each of the 5 sensor channels there is a separate band pass filtering. For each sub-band there are 3 automatic gain-controlled amplifiers.

3. DATA PROCESSING

Fig.1 shows a general picture of how STAFF data are processed and CAA files created.

The Digital Wave Processor (DWP) team produced the TED software that extracts and time-tags the STAFF Level 0 data from the WEC raw data packets, producing different data packets for STAFF-SC and STAFF-SA data that are then decommutated (Level 1).
During the decompression of STAFF-SC data, it is possible to estimate the loss due to the on-board compression from 16 bits to 12 bits. This information will be recorded in a quality factor which is being defined and which will be added to the Level 1 data status.

3.1. STAFF-SC

STAFF-SC data are calibrated with a dedicated command issued from the Roproc Command Language (RCL) code developed by P. Robert [6].
From Level 1 files, RCL performs calibration, filtering, coordinate system transformations, time checking and other processing operations including dynamic spectra and wave polarisation computations to produce Level 2 and Level 3 files.
Value added products such as dynamic spectra (Level 3 graphical plots) are also produced and stored in the CAA.

3.2. STAFF-SA

The calibration procedure for the STAFF-SA is fully described in [5]. This procedure is performed by the code developed by Y. de Conchy and L. Sitruk at LESIA.
The calibrated data are then processed by the PRAS-SADCO software developed by O. Santolik [7] in order to get the polarisation and propagation parameters, in addition to the 5 components of the power spectral density.

3.3. CAA data files and graphical plots

Some of these data (see 4) are translated into the Cluster Exchange Format (CEF) format [1] by L. Mirioni's code, and then stored in the CAA database together with the PostScript/PNG graphical plots [2].

4. AVAILABLE STAFF DATA PRODUCTS IN THE CAA

STAFF data are stored in CEF files, this format is ASCII which allow the end-user to actually see, with a simple text editor, what the file does contain. The file header may seem hard to decrypt because it records every piece of information one may expect but the way data are recorded

Table 1. Summary of STAFF data files in the CAA. A detailed description is given in the text. ⋆ Data of years 2001 and 2002 are already available. ⋆⋆ These files are not produced at the time of writing, but CAA user may find them later on when a suitable calibration method is implemented. ⋆⋆⋆ The definition of these products is under discussion.

Level	Product	Experiment	Mode	Number of files	Format
1	Decommutated WaveForm (DWF)⋆	STAFF-SC	NBR	1 file / 1 sat. / 24 h	CEF
1	Decommutated WaveForm (DWF)⋆	STAFF-SC	HBR	1 file / 1 sat. / 24 h	CEF
2	Calibrated WaveForm (CWF)⋆⋆	STAFF-SC	NBR	1 file / 1 sat. / 24 h	CEF
2	Calibrated WaveForm (CWF)⋆⋆	STAFF-SC	HBR	1 file / 1 sat. / 24 h	CEF
3	Dynamic Spectra plots⋆	STAFF-SC	NBR	1 file / 4 sat. / 3 h	PS/PNG
3	Dynamic Spectra plots⋆	STAFF-SC	HBR	1 file / 4 sat. / 3 h	PS/PNG
2	Automatied Gain Control (AGC)⋆	STAFF-SA	all	1 file / 1 sat. / 24 h	CEF
2	Power Spectral Density (PSD)⋆	STAFF-SA	all	1 file / 1 sat. / 24 h	CEF
2	Spectral Matrix (SM)⋆	STAFF-SA	all	1 file / 1 sat. / 24 h	CEF
3	Plots⋆⋆⋆	STAFF-SA	TBD	TBD	PS
3	Polarisation Parameters⋆⋆⋆	STAFF-SA	TBD	TBD	CEF

is as clear and simple as possible and may be read quite easily with any usual scientific software.
To keep as much information as possible, it has also been decided to store data in the satellite reference frame (so called SR2). This minimizes information loss (in fact, no loss at all) as data records are as close to raw data as possible except that they are nice-looking and time tagged.
Level 0 (N0) data are raw data. None is stored in the CAA.
Level 1 (N1) data are only decommutated and time-tagged. This is the case of STAFF-SC Decommutated WaveForm (DWF) which is provided uncalibrated. The present waveform calibration method, imposed by the non-linear frequency response of the instrument, is an $FFT-$spectrum-calibration$-FFT^{-1}$ which is only suitable for on-demand calibration (i.e. user-defined resolution) but not for continuous calibration of the waveform because of the FFT windowing. We are looking for a better way of calibrating these data (see 5.2).
Level 2 (N2) data are calibrated. At the time of writing, STAFF-SA data are the only STAFF data in the CAA to be given in physical units.
Level 3 (N3) data are value-added products. The only type of N3 products delivered to CAA yet, are graphical plots of dynamic spectra.
The reader will find a summary of CAA-STAFF products main characteristics in Tab. 1.

4.1. STAFF-SC Dynamic Spectra

These N3 files are graphical plots showing dynamic spectra and integrated power for the 4 satellites. At the bottom the amplitude of the DC field perpendicular to the spin axis, computed from the search-coil spin signal, is also plotted for the 4 spacecraft. Plots are delivered in time series of 3 hours for HBR or NBR (e.g. Fig.2). They are provided either in good quality PostScript (PS) files and Portable Network Graphics (PNG) format for preview.

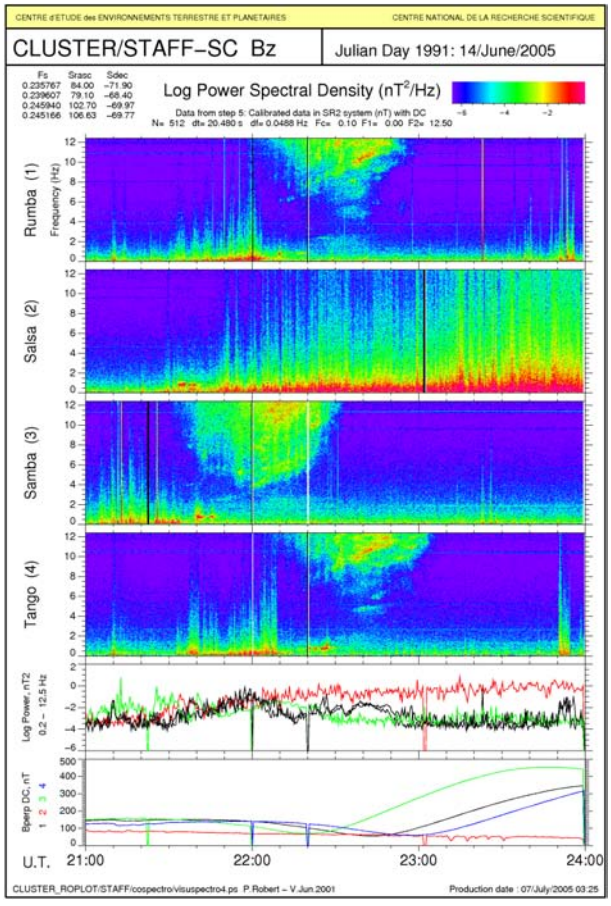

Figure 2. Example of STAFF-SC NBR dynamic spectra.

4.2. STAFF-SC Decommutated WaveForm

These N1 CEF files contain the Decommutated Waveform (DWF) of the Magnetic Field (uncalibrated) sampled at 25 Hz for the Normal BitRate (NBR) mode and 450 Hz for the High BitRate (HBR) mode. Other variables or constant data (constant for one given file) are also stored here. B_x, B_y and B_z are given in SR2 coordinate system and in telemetry counts units.

4.3. STAFF-SA Automatic Gain Control

These N2 CEF files contain the 3 measured values of the Automatic Gain Control (AGC) for B_x, B_y+B_z and E_y+E_z $\times$ the 3 frequency bands (A,B and C). The AGC data are not subject to direct scientific use. However they represent a measure of the total wave power for the corresponding sensor and frequency band.

4.4. STAFF-SA Power Spectral Density and Spectral Matrix

These N2 CEF files store the records of the 5$\times$5 complex Spectral Matrix (SM) which is the cross-product of the magnetic and electric fields values computed on-board the spacecraft[1]:

$$\begin{pmatrix} B_x^2 & B_x.B_y^* & B_x.B_z^* & B_x.E_x^* & B_x.E_y^* \\ B_y.B_x^* & B_y^2 & B_y.B_z^* & B_y.E_x^* & B_y.E_y^* \\ B_z.B_x^* & B_z.B_y^* & B_z^2 & B_z.E_x^* & B_z.E_y^* \\ E_x.B_x^* & E_x.B_y^* & E_x.B_z^* & E_x^2 & E_x.E_y^* \\ E_y.B_x^* & E_y.B_y^* & E_y.B_z^* & E_y.E_x^* & E_y^2 \end{pmatrix}$$

As this matrix is complex, the real and imaginary parts have been separated in the SM CEF file.
It has also been decided to cut it in three pieces to be unit consistent, the first being the magnetic elements $B\times B$, the second the electric ones $E\times E$ and the third the cross-product $B\times E$. As the matrix is also non-hermitian, that is $S_i.S_j^* = S_j.S_i^*$ (where $S = B$ or E, and $i, j = x, y, z$), only half of the non-diagonal elements are stored.
The Power Spectral Density (PSD) file is a record of the SM diagonal values. PSD are sampled at higher cadency than the SM elements, that is why they are stored in a separated CEF file.
All of these values are given for each of the 27 frequency channels (3 bands $\times$ 9 sub-bands logarithmically spaced).

[1] E_y and E_z became E_x and E_y because of the definition of the ISR2 coordinate system.

5. PROSPECTS

5.1. CAA STAFF Data Status

At the time of writing, the full data for years 2001 and 2002 are stored in the CAA for DWF, AGC, SM and PSD products, and also for the STAFF-SC dynamic spectra plots.
The rhythm of delivery will now be of 2 new years of data per year plus eventually improved quality data or calibration (Calibrated WaveForm - CWF) for the already delivered data.
STAFF data that will be available at CAA will also be delivered by STAFF to the french data centre Centre de Données de la Physique des Plasmas (CDPP).

5.2. STAFF-SC Data Prospects

The uncalibrated data products DWF have to be reprocessed in order to include a compression quality factor and to improve the time accuracy (new version of the TED software and microsecond correction files to be provided by DWP).
Calibrated WaveForm (CWF) data can't be delivered at present time because of FFT windowing that prevents continuous calibration. Two solutions are under study. The preferred one would be to find a global method for calibration, but reaching this aim might be long because of heavy testing phases.
Another solution could be to deliver software to perform on-line calibration that would allow the end-user to tune the time resolution settings to his/her needs (this software already exists but cannot handle the CEF format yet).
In the case the delay is too long to provide calibrated waveform data, there is still the possibility to produce spectra continuously in physical units, with a time resolution that still has to be defined.

5.3. STAFF-SA Data Prospects

In the year to come, we may start to deliver dynamic spectra : one with the total magnetic field and total electric field for the four spacecraft and two with the propagation and polarization characteristics.

REFERENCES

1. Allen, A. *et al.* . Cluster Exchange Format : Data File Syntax. Technical Report DS-QMW-TN-0010, issue 2, rev. 0.3, ESA, September 2004.

2. Cornilleau-Wehrlin, N. *et al.* . Cluster Active Archive : Interface Control Document for STAFF. Technical Report CAA-STA-ICD-0001, issue 1, ESA, May 2005.

3. Cornilleau-Wehrlin, N. *et al.* . First results obtained by the Cluster STAFF experiment. *Annales Geophysicae*, 21:437–456, February 2003.

4. Cornilleau-Wehrlin, N. *et al.* . The Cluster Spatio-Temporal Analysis of Field Fluctuations (STAFF) Experiment. *Space Science Reviews*, 79:107–136, January 1997.

5. Harvey, C. C. *et al.* STAFF Spectrum Analyzer, Conversion of the Science Data to Physical Units. Technical Report OBSPM-TN-0001, issue 7, rev. 5, Observatoire de Paris-Meudon, September 2004.

6. Robert, P. Roproc Command Language V.2 *unpublished*. Technical report, CETP-IPSL, November 2004.

7. Santolik, O. PRopagation Analysis of STAFF-SA Data with COherency tests (PRASSADCO). http://terezka.ufa.cas.cz/santolik/PRASSADCO/.