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The  $N1 \rightarrow N2$  Software Module  
for the  
STAFF Spectrum Analyser

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## Appendix

1. Definition of a logical instrument

## 1 Documentation

### 1.1 Applicable Documents

1. **Calibration of the STAFF Spectrum Analyser**, by C.C. Harvey, M. Belkacemi, R. Manning, F. Wouters and Y. de Conchy, DS-MEU-TN0001, issue 0, rev. 4, 1994 May 9.
2. **Description of CLUSTER/STAFF\_SA data received from the Sussex EGSE**, by Y. de Conchy, e-mail message du 7-JAN-1994, CCH ref. CFCWE44N.026.

### 1.2 Reference Documents

1. **Report of the WEC Data Working Group**, by Holmgren et. al., May 1993, available from the WECdata server.
2. **WEC Logical Instruments**, note presented at WECdata meeting, ESTEC, 1993 December 16; attachment to WECdata minutes circulated 21-DEC-1993; CCH ref. CFCWE44N.011

## 2 Introduction

This document describes the software object which converts from Level 1 to Level 2 the data from the Spectral Analyser of the experiment to perform Spatio-Temporal Analysis of Field Fluctuations (STAFF-SA). This software object performs two essential tasks:

1. It converts the data from 8-bit telemetry words to physical units. It is thus an implementation of the procedure which is fully described in reference 1.
2. It completes the ordering of the STAFF data set by logical instrument. This ordering has been initiated at Level 1, where the STAFF-SA data stream was separated from the STAFF-SC data stream.

For data analysis, the logical instruments may be divided into three broad categories:

- auxiliary instruments;
- physical instruments;
- calibration instruments.

This document deals with the physical instruments and the calibration instruments associated with the STAFF Spectrum Analyser.

*Peut-être vaut-il mieux faire un second document pour les instruments d'étalonnage ?*

This document treats the problem as generally as possible. The specific interfaces required

- to integrate the module into the CTM software, and
- to integrate it into ISDAT

are treated in section 7.

There are four Cluster spacecraft. This implies four independent set of calibration coefficients, four examples of every logical instrument, each of which must be uniquely identifiable by its logical name. It may also imply four sets of processing software. Hopefully this will not be the case, but this possibility must be foreseen by the architecture so that it can be implemented, for example, in the event of an engineering failure on one of the spacecraft.

### 2.1 Science Monitoring using the WEC Housekeeping Data

The STAFF-SA AGC data words are also telemetered in the WEC housekeeping packets (thus they appear twice in the spacecraft telemetry stream). These words from the housekeeping packets will be used for science progress monitoring, notably within JSOC. This document does not discuss the processing of these words.

The Level 1 data (both the SA digital output and also AGC words) required for the processing described in this document is obtained from the WEC science packets.

## 3 Application of the Transfer Function

This section summarises the procedure which will apply the equations and coefficients described in the preceding sections to the conversion of the data from level 1 (telemetry units) to level 2 (physical units). It is a straight copy (without equation numbers) from section 9 of applicable document 1.

1. Acquire one packet of STAFF-SA data.
2. Decompress the elements of the leading diagonal of the cross-spectral matrix or, equivalently, use a 256-point look-up table.
3. Decompress the off-diagonal elements of the cross-spectral matrix, then assemble the complex value; alternatively (and probably better), a look-up table can be used to determine the corresponding 256 complex values.
4. Compute the average values of the diagonal elements of the cross-spectral matrix during the period of acquisition of the off-diagonal elements.
5. Renormalize the off-diagonal elements, using average values just calculated.

Mode name	Duration of packet	Sampling period			AGC		Sensors		Packet size
		auto A	auto B&C	cross	A	B&C	magn.	elec.	
Normal Mode 1	4	1	1	4	1	1	3	2	846
Normal Mode 1'b	4	1	1	4	1	1	3	0	430
Normal Mode 1'e	4	1	1	4	1	1	1	2	430
Normal Mode 2b	1	1	.5	1	1	.5	3	0	228
Normal Mode 2e	1	1	.5	1	1	.5	1	2	228
Special Mode	2	1	.5	2	1	.5	3	2	756
Fast Mode 1	1	-	.125	1	-	.125	3	2	948
Fast Mode 2	1	-	.25	1	-	.25	3	2	564
Fast Mode 3b	1	-	.125	1	-	.125	3	0	518
Fast Mode 3e	1	-	.125	1	-	.125	1	2	518
Emergency Mode	4	2	2	4	2	2	3	2	558
Calibration 1									
Calibration 2									

Table 1: STAFF-SA Modes of Operation

We now have the numerical output from the digital analyser as it was before being compressed for the telemetry. In addition, we have the diagonal elements (the power spectra) which are telemetered at higher time resolution.

- Assemble the data into the different logical instruments. Note that the diagonal elements of the cross-spectral matrix are the average values calculated at step 4 above; the telemetered of the diagonal elements are sampled more rapidly, and form a separate logical instrument.

We now convert the data in each of these logical instruments into physical units.

- Identify which of the elements of  $S_{ij}$  and  $S'_{ij}$  are involved (*i.e.*, whether all the elements or only the diagonal elements are involved for the particular logical instrument being processed).
- Obtain the required elements  $S_{ij}$  and  $S'_{ij}$  using the tables of the calibration coefficients. These tables give  $F_i^m(f_n, A_i^m)$ , that is,  $F_i$  as a function of the frequency  $f$  as specified by  $m, n$  and the AGC telemetry value  $A_i^m$ .
- Compute the matrices  $T_{ij}$  and  $T'_{ij}$ .
- For all the elements of the logical instrument being processed, derive in physical units in the inertial (non-spinning) reference system,
- Output the results as one record for the logical instruments being processed.

## 4 Interfaces

### 4.1 Input: the Level 1 Data

The data from STAFF-SA are produced in packets. The packet is the smallest element of data which can be handled; anything smaller would contain either

- an incomplete logical instrument data record, or
- inadequate information to process the data.

There are eleven different types of data packet (??), and two types of calibration packet:



HEADER  
#####

Word	Data Item
0	0082 hex
1	DWP Model Tag (HK word 0)
2	S/C Time (Year minus 1900)
3	S/C Time (Month 1..12)
4	S/C Time (Day of Month 1..31)
5	S/C Time (Hour 0..23)
6	S/C Time (Minutes 0..59)
7	S/C Time (Seconds 0..59)
8	S/C Time (Milliseconds 0..999)
9	Length of Science Data (number of words)
10	DWP Master Clock Pulse Count (from Science Packet Time Tag)
11	OBDH Acquisition Mode (HK byte 23)
12	(Bits 0..3) STAFF SA analysis mode (HK byte 112 masked with 0F hex) (Bit 15) 1 if HK byte 112 masked with 80 hex is non-zero (ie 1 iff STAFF MWF is in calibration mode)
13	STAFF SA voltage monitor 0 ( HK byte 93)
14	STAFF SA voltage monitor 1 ( HK byte 92)
15	STAFF SA voltage monitor 2 ( HK byte 95)
16	EGSE Decommutation Diagnostics Word
17	0000 hex
18	0000 hex
19	Staff SA temperature monitor (HK byte 101)
20	0000 hex
21	STAFF mWF calibration step (HK byte 113)
22	User Word (default is FFFF hex)

#### 4.1.2 The flow of data

The data is ingested packet by packet.

#### 4.1.3 Open questions

How is data ingestion managed ?

- by client-server protocols;
- by pipelining (which is much the same thing);
- using the product elaboration driver (possible only at CTM);
- by subroutine call.

How is the start of a new data file to be identified ? This information is needed so as to be able to load a new set of calibration coefficients.

## 4.2 Output: the Level 2 Data

The output from STAFF-SA will be arranged into logical instruments. This is a decision taken at the WEC level [Ref. ?], although its implementation still has numerous associated open questions (or answers which are presently unknown to the authors of this technical note) 4.2.3.

It may be noted that parameters of the Summary Parameter and Prime Parameter data sets are already in the form of logical instruments; their nature and characteristics are well-defined, and they have logical names which are agreed Cluster-wide.

#### 4.2.1 Implementation for STAFF-SA

All the logical instruments of the Summary Parameter and Prime Parameter data sets will be available in the WEC data analysis environment.

The proposed logical instruments corresponding to the STAFF physical data are shown in Table 2, and are shown schematically in Figures 1 and 2. Successive columns of the table show:

1. a succinct description of the logical instrument;
2. the coordinate system used;
3. a proposed logical name (is more imagination needed ?)
4. the type of logical instrument (using terminology of Appendix 1);
5. comments

All the STAFF logical instruments have been split into two, A and B& C, because there are several modes in which band A (the lowest nine frequencies) is sampled less frequently than bands B and C.

A more detailed description of the logical instruments is supplied in Table 3.

Note that the logical instruments **acE**, **cEB**, **aB**, and **aE** are non-standard (in the sense of not being "complete" physical observables), but are nevertheless recognised ISDAT (version 2) structures.

Note that when the STAFF spectrum analyser is in one of the  $3 \times 3$  e-modes, the Bx, Ey and Ez sensors are used; this could yield the following logical instruments (*c.f.*, Table 3):

<b>cEB'</b>	complex	The two elements $B_x E_y$ and $B_x E_z$ .
<b>aB'</b>	real	The auto-spectrum of $ B_x $ .

Alternatively, these two can be considered as degenerate cases (2/3 of the data missing) of **cEB** and **aB**; this is the solution presently adopted.

Not all logical instruments are available in all modes of operation of the experiment. Table 4 shows, for each logical instrument, its repetition period in each of the different instrument modes.

#### 4.2.2 The flow of data

#### 4.2.3 Open questions

Is there a metafile with all characteristics of the logical instrument point by a logical name? Or is there VIDF? This is a question for ISDAT.

## 5 The Calibration Coefficients

### 5.1 Structure of the Calibration Coefficient Files

The problem here is

- to know when to load the calibration coefficients. It should be loaded once, before processing the first record of the data file. The transfer function should be re-loaded every time a new Level 1 file is opened on input, because the functions to be used are data-dependent.
- to know which calibration coefficients to load (*i.e.*, spacecraft 1, 2, 3 or 4).

It is assumed that only one spacecraft is being processed at a time. If two or more spacecraft are being handled simultaneously (*e.g.*, by ISDAT), then all four sets of calibration coefficients need to be loaded into memory, and some pointer is required to know which set (*i.e.*, which spacecraft) is to be used. Alternatively, four separate programmes need to be executing at the same time.

Description	Coords	Name	Type	Comments
<b>SPACECRAFT Auxiliary Logical Instruments</b>				
Spacecraft position	GSE		1	from SPDB
Spacecraft orientation	GSE		2	from ???
<b>STAFF Auxiliary Logical Instruments</b>				
One logical instrument TBD	n/a	TBD	X	from WEC h/k
<b>STAFF-SC Standard Logical Instruments</b>				
<b>B</b> -field waveform with 10 Hz filter	GSE	B10	1	
<b>B</b> -field waveform with 180 Hz filter	GSE	B180	1	
<b>STAFF-SA Standard Logical Instruments</b>				
$3 \times 3$ <b>B</b> -field cross-correlation tensor A	GSE	acB_A	2a	
$3 \times 3$ <b>B</b> -field cross-correlation tensor B&C	GSE	acB_BC	2a	
<b>STAFF-SA Recognised Non-Standard Logical Instruments</b>				
$2 \times 3$ E/B cross-correlation matrix A	GSE	cEB_A	X	NOT a tensor
$2 \times 3$ E/B cross-correlation matrix B&C	GSE	cEB_BC	X	NOT a tensor
$2 \times 2$ E/E cross-correlation matrix A	GSE	acE_A	X	NOT a tensor
$2 \times 2$ E/E cross-correlation matrix B&C	GSE	acE_BC	X	NOT a tensor
Diagonal elements of acB_A	GSE	aB_A	X	NOT a vector
Diagonal elements of acB_BC	GSE	aB_BC	X	NOT a vector
Diagonal elements of acE_A	GSE	aE_A	X	NOT a vector
Diagonal elements of acE_BC	GSE	aE_BC	X	NOT a vector
The AGC values in band A	n/a	agc_A	X	telemetry counts
The AGC values in bands B&C	n/a	agc_BC	X	telemetry counts
<b>Special Logical Instruments for <math>3 \times 3</math> e-modes</b> (are obtained as a subset of the corresponding unprimed instruments)				
The two elements $B_x E_y$ and $B_x E_z$ , A	GSE	cEB'_A	X	NOT a vector
The two elements $B_x E_y$ and $B_x E_z$ , B&C	GSE	cEB'_BC	X	NOT a vector
The auto-spectrum of $ B_x $ , A	GSE	aB'_A	X	NOT a scalar
The auto-spectrum of $ B_x $ , B&C	GSE	aB'_BC	X	NOT a scalar

Table 2: Proposed WEC Logical Instruments

Name	Type	Description
<b>B10</b>	real	The B-field waveform obtained using the 10 Hz filter.
<b>B180</b>	real	The B-field waveform obtained using the 180 Hz filter.
<b>acB</b>	complex	The complete ( <i>i.e.</i> , auto and cross) $3 \times 3$ B-field cross-spectral matrix has been chosen because <ul style="list-style-type: none"> <li>• it is a true tensor quantity</li> <li>• item it is always <math>3 \times 3</math>.</li> </ul> Note that the diagonal elements will be the mean value of instrument aB below, averaged over the integration period of the off-diagonal elements. The instrument type is 2a, because it is a true tensor which is a function of a scalar (frequency).
<b>acE</b>	complex	The “complete” ( <i>i.e.</i> , auto and cross) $2 \times 2$ E-field cross-spectral matrix has been separated from the preceding logical instrument because <ul style="list-style-type: none"> <li>• it is not a true tensor quantity (one component is missing), and</li> <li>• it is present independently of <b>acE</b>.</li> </ul>
<b>cEB</b>	complex	These are the remaining six off-diagonal elements of the $5 \times 5$ cross-spectral matrix.
<b>aB</b>	real	The diagonal elements of acB (which are sampled more frequently than complete matrix acB).
<b>aE</b>	real	The diagonal elements of acE.
<b>agc</b>	real	The three AGC values, $A_{Bx}$ , $A_{Bs}$ , $A_{Es}$ . Note that $A_{Es}$ will be missing (replaced by the “fill” value) in $3 \times 3$ b-modes, and that $A_{Bs}$ will be missing in $3 \times 3$ e-modes.

Table 3: Descriptions of the STAFF Logical Instruments

Field Instrument Mode	Magnetic		Electric		Cross	Special e-mode	
	acB A BC	aB A BC	acE A BC	aE A BC	cEB A BC	cEB' A BC	aB' A BC
Normal Mode 1	4 4	1 1	4 4	1 1	4 4	(4) (4)	(1) (1)
Normal Mode 1'b	4 4	1 1	- -	- -	- -	- -	(1) (1)
Normal Mode 1'e	- -	- -	4 4	1 1	- -	4 4	1 1
Normal Mode 2b	1 1	1 .5	- -	- -	- -	- -	- -
Normal Mode 2e	- -	- -	1 1	1 .5	- -	1 .5	1 .5
Special Mode	2 2	1 .5	2 2	1 .5	2 2	- -	- -
Fast Mode 1	- 1	- .125	- 1	- .125	- 1	- (1)	- (.125)
Fast Mode 2	- 1	- .25	- 1	- .25	- 1	- (1)	- (.25)
Fast Mode 3b	- 1	- .125	- -	- -	- -	- -	- -
Fast Mode 3e	- -	- -	- -	- .125	- -	- 1	- .125
Emergency Mode	4 4	2 2	4 4	2 2	4 4	- -	- -

N.B., the values of **cEB'** and **aB'** in parentheses are merely the corresponding elements of **cEB** or **aB**.

Table 4: The periodicity of each logical instrument as a function of instrument mode

## **5.2 Application of the transfer data**

### **5.3 Naming of the files**

#### **5.3.1 The four spacecraft**

#### **5.3.2 Open questions**

Who decides when a new calibration data set is to be loaded:

- this module itself, or
- the module which is calling it ?

Granularity of the sets of calibration coefficients. The solution proposed here is to load a new transfer function every time a new Level 1 file is processed.

- Is this either inadequate, or
- extravagant ?

## **6 Timing**

### **6.1 Open questions**

## **7 Integration into the Ground Data Segment**

### **7.1 CTM**

#### **7.1.1 Input**

#### **7.1.2 Calibration coefficients**

#### **7.1.3 Output**

#### **7.1.4 Open questions**

### **7.2 ISDAT**

#### **7.2.1 Input**

#### **7.2.2 Output**

#### **7.2.3 Calibration coefficients**

#### **7.2.4 Open questions**

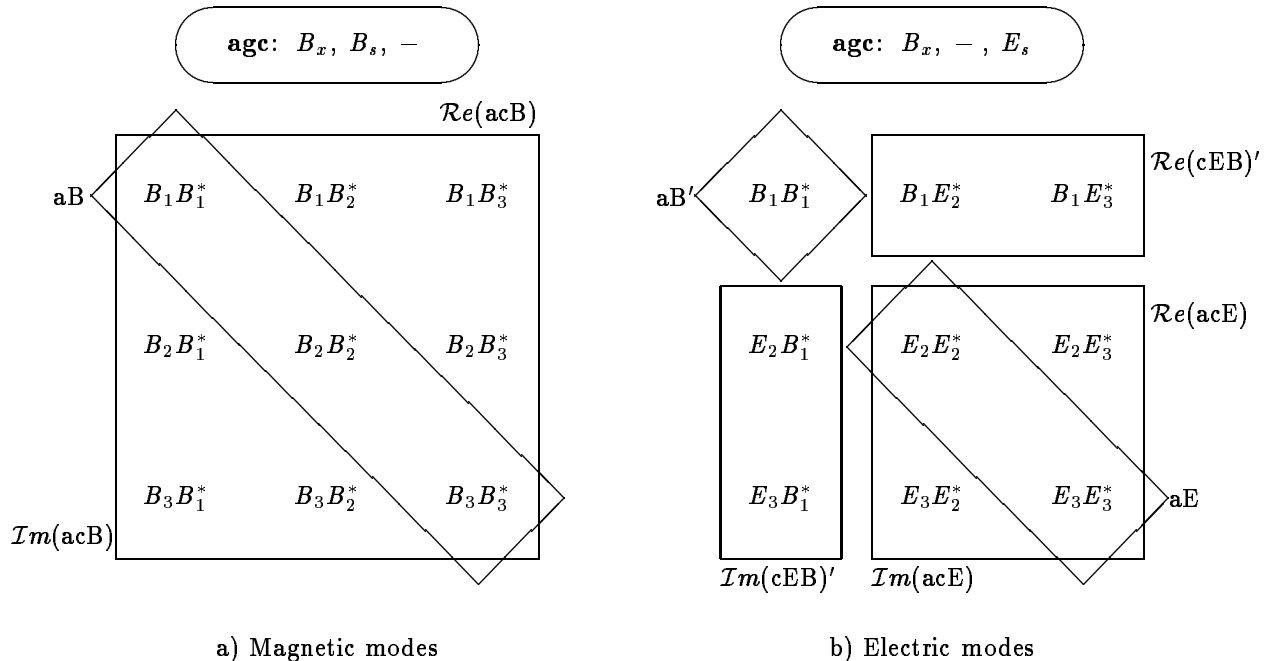
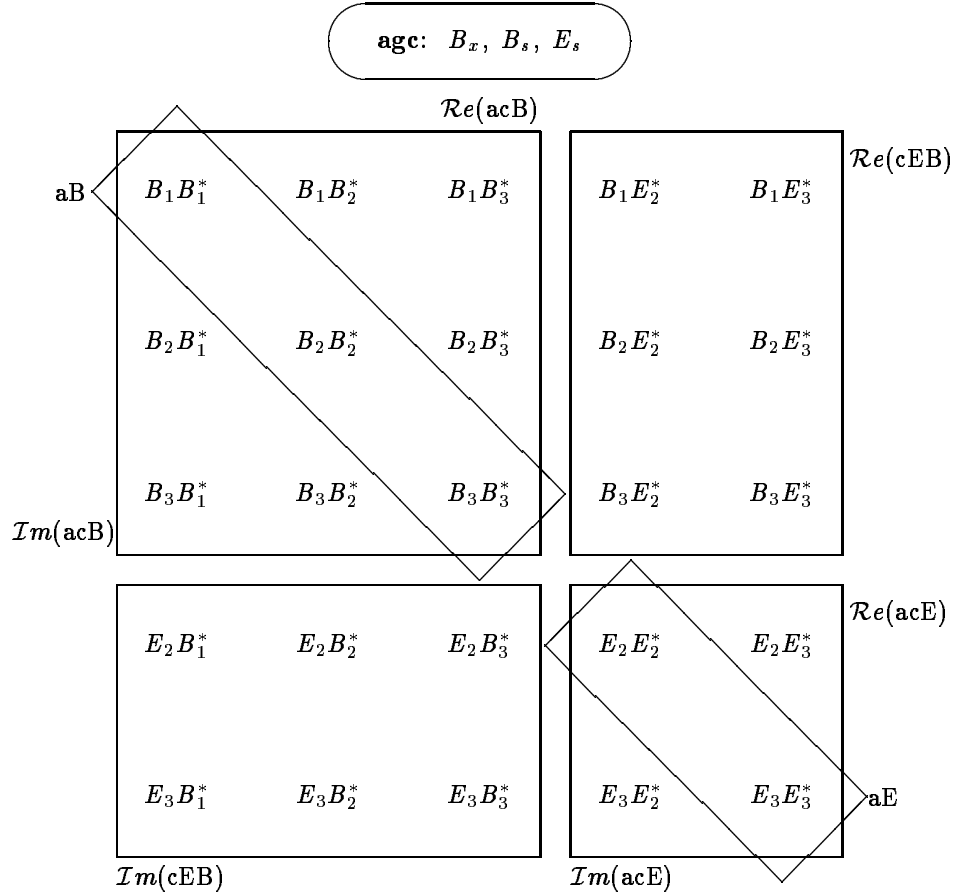


Figure 2: STAFF-SA Logical Instruments for  $3 \times 3$  modes

## 8 Work Breakdown Structure

The following workpackages have been identified:

### 8.1 Provision of an Interface Testing Package

**Task description:** produce a software module to perform the following tasks:

- Acquire the Level 1 data
- Split the Level 1 data into logical instruments.
- Output the Level 1 data words in the Level 2 output interface (without any further processing, so the output is scientifically meaningless as Level 2 data).

The purpose of this workpackage is to produce a module that can be integrated into the WEC and CTM data processing chain for testing purposes. This is felt to be necessary at an early stage, because these interface problems cannot be left until all the other workpackages have been completed. The remaining workpackages require time and effort, but do not present the same technical challenge as this work package.

First delivery: after the Uppsala meeting

Final delivery:

### 8.2 Acquire the Calibration Coefficients

**Task description:** produce software to perform the following tasks:

- Define the structure of the calibration coefficient file.
- Determine when the calibration coefficients must be loaded.
- Determine which calibration coefficients must be loaded.
- Load the calibration coefficients.
- Integrate this into the software from workpackage 1.

First delivery:

Final delivery:

### 8.3 Apply the Calibration coefficients

**Task description:**

Produce software to perform the following tasks:

- Apply the transfer function to the data arranged in logical instruments by workpackage 1, so that that workpackage outputs the data in physical units.
- Integrate this into the software from workpackage 2.

First delivery:

Final delivery:

## 8.4 Generate the Launch Transfer Function Coefficients

### Task description:

- Determine the first four (*i.e.*, one for each spacecraft) sets of STAFF-SA Transfer Functions to be used at the time of launch.

First delivery:

Final delivery: before launch

## 8.5 Beta-test the STAFF-SA Software

### Task description:

- Perform an end-to-end test of the STAFF-SA N1 → N2 software module.

First delivery:

Final delivery:

## 8.6 Handle the In-Flight Calibration Cycle

### Task description:

- Produce and test software to analyse data from the in-flight calibration cycle, and use the results to update the table of calibration coefficients.

First delivery:

Final delivery:

# 9 Calibration

*Voulons-nous traiter ces données dans ce document ?*

## APPENDIX 1 - Definition of a logical instrument

A logical instrument is a software object with the following characteristics:

1. it is uniquely identified by a logical name;
2. it supplies a flux of time-tagged data corresponding to a physical observable;
3. associated with the data are the attributes of the data stream.

The motivation for such a definition is twofold:

1. The nature of a physical variable determines what can be done to it: coordinate transformations, graphical displays, spectral analysis, or other analytical procedures.
2. A client-server protocol between applications requires the definition of a structure for the data; to simplify the system, it is highly desirable to have only a small number of such structures.

These two seemingly different reasons are, in fact, essentially the same. This definition allows the development of standard applications, which can be used without any need for intervention at the programming level on the part of the scientist user.

The attributes of a logical instrument contain the information required to analyse the physical data. In particular, it includes all the information necessary to create a CDF. Sometimes this is termed metadata (data about data). For further details, see the Reference Document 1, and the associated appendices.

The following are examples of different types of logical instrument:

- |    |                     |               |                |
|----|---------------------|---------------|----------------|
| 0) | a scalar,           | <i>e.g.</i> , | density        |
| 1) | a vector,           |               | magnetic field |
| 2) | a tensor of rank 2, |               | pressure       |
| 3) | or higher rank      |               | heat flux.     |

In addition to being a function of time, an observable may be a function of some other variable, which may itself be a scalar or vector (perhaps even a tensor, although there is no obvious example). Examples are :

- |    |          |               |                         |
|----|----------|---------------|-------------------------|
| a) | a scalar | <i>e.g.</i> , | a spectrum              |
| b) | a vector |               | a distribution function |

There are inevitably some

- |    |                           |               |                    |
|----|---------------------------|---------------|--------------------|
| X) | non-standard instruments, | <i>e.g.</i> , | the electric field |
|----|---------------------------|---------------|--------------------|

when only two components are measured. Non-standard logical instruments cannot profit from standard applications without some intervention of the part of the scientist; there is no way of avoiding this problem. The nature of any non-standard logical instruments must be documented in its attributes.

We may note that many of the WEC logical instruments fall into the category of "special instruments", so that their analysis requires special applications. This is an unfortunate consequence of the electric field not being a "complete" physical observable, in the sense that one of its components is not measured. This is unfortunate; but the vast majority of the Summary and Prime Parameters are "complete" logical instruments.

Logical instruments can supply the same data at different rates depending, for example, upon the instrument bit-rate.

Equivalent data, that is, coming from both the same part of the STAFF instrument and having undergone the same data processing, but originating from different Cluster spacecraft, will be associated with different logical instruments, which must be identified by different logical names.