Cluster Active Archive:

Interface Control Document for WBD

	Name	Date	Signature
Prepared by:	J. Pickett, C. Perry, K. Sigsbee, J. Soucek	03-11-2015	
Reviewed by:			
Approved by:			
Accepted by:	H. Laakso		

DISTRIBUTION LIST

Affiliation	Name	Number of copies

DOCUMENT CHANGE RECORD

Issue	Date	Details
3.3	2015-11-03	Minor corrections made by J. Soucek based on comments by Harri Laakso from September 2015 PM. Updated information after transfer of processing to IAP. Moved information about instrument issues to UG.
3.2	2012-05-10	Minor corrections and updates to all sections; insertion of CEF metadata in Section 5.2.7, by J Pickett
3.1	2011-04-29	Minor corrections and updates to all sections, by J. Pickett, J. Seeberger, I. Christopher, and R. Mitten
3.0	2010-05-26	Update and add first details of cdf files, by J. Pickett
2.1	2006-11-21	Update of second release
2.0	2006-07-14	Second release by J. Pickett & K. Sigsbee
1.0	2004-08-12	First release (incomplete) by J. Pickett & C. Perry

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 PURPOSE

The purpose of this document is to provide a broad outline of the archiving of the data from the WBD instrument on Cluster in the ESA Cluster Active Archive (CAA) and to define the agreement of the CAA and PI of WBD on this broad outline.

The scientific rationale underpinning the CAA activities is as follows:

- Maximize 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 WBD the main responsibilities will lie with:

- J. Pickett, Cluster WBD Principal Investigator, at University of Iowa

2 POINTS OF CONTACT

For the operation of archiving the high-resolution data from WBD the following contacts have been agreed upon by the University of Iowa, NASA, and the CAA

- Scientific correspondents
  - Dr. C. Philippe Escoubet, ESA/ESTEC (SCI-RSSD), Postbus 299, Keplerlaan, 1, 2200 AG Noordwijk, The Netherlands, Tel: +31-715653454, Fax: +31-715654697, Email: Philippe.Escoubet@esa.int; Dr. Harri Laakso, ESA/ESTEC (SCI-RSSD), Postbus 299, Keplerlaan, 1, 2200 AG Noordwijk, The Netherlands, Tel: +31-715653319, Fax: +31-715654697, Email: harri.laakso@esa.int for the CAA.
  - Melvyn L. Goldstein, Code 692, NASA Goddard Space Flight Center, Greenbelt, MD, 20771, USA, Phone: 001-301-286-7828, Email: melvin.l.goldstein@nasa.gov, for NASA.
  - Jolene S. Pickett, Department of Physics and Astronomy, The University of Iowa, Iowa City, IA, 52242, USA, Phone: 001-319-335-1897, Email: pickett@uiowa.edu, for WBD.
- Technical correspondents
  - Chris Perry, Building R25, Rutherford Appleton Laboratory, Chilton, Didcot, Oxon, OX11 0QX, United Kingdom, Tel: 441235445780, Fax: 441235445848, Email: c.h.perry@rl.ac.uk for the CAA.
  - Jolene S. Pickett, Department of Physics and Astronomy, The University of Iowa, Iowa City, IA, 52242, USA, Phone: 001-319-335-1897, Email: pickett@uiowa.edu for WBD.
- Managerial correspondents
  - Harri Laakso, ESA/ESTEC (SCI-RSSD), Postbus 299, Keplerlaan, 1, 2200 AG Noordwijk, The Netherlands, Tel: +31-715653319, Fax: +31-715654697, Email:

harri.laakso@esa.int for the CAA.

- Jolene S. Pickett, Department of Physics and Astronomy, The University of Iowa, Iowa City, IA, 52242, USA, Phone: 001-319-335-1897, Email: pickett@uiowa.edu, for WBD, and Joanne M. Seeberger, Department of Physics and Astronomy, The University of Iowa, Iowa City, IA, 52242, USA, Phone: 001-319-335-3385, Email: joanne-seeberger@uiowa.edu

3 Instrument Description

3.1 Science Objectives

The eccentric, highly inclined, 4 x 19.5 R_E orbit of the Cluster spacecraft in the first several years of the mission, with evolution to 1.5 x 21 R_E later in the mission, allows the spacecraft to cross through most of the important regions of Earth's magnetosphere which are rich in plasma waves and potential structures for which the Cluster Wideband Data (WBD) Plasma Wave Receiver is ideally suited. These regions include the outer plasmasphere, inner magnetosphere just outside the plasmasphere at perigee, auroral acceleration region and the auroral zones, cusp, plasma mantle, polar cap, plasma sheet, magnetosheath, bow shock, foreshock and near Earth solar wind, as well as numerous boundary layers (magnetopause, plasma sheet, high latitude, low latitude). A sampling of some of the plasma waves and structures that are observed in these regions are whistler-mode chorus, lightning-generated whistlers, auroral hiss, electrostatic ion cyclotron waves, electrostatic electron cyclotron waves, auroral kilometric radiation, continuum radiation, upper hybrid waves, lower hybrid waves, and solitary waves that are interpreted as potential structures, such as electron phase-space holes.

One of the primary purposes of WBD is to support WEC (Wave Experiment Consortium) objectives by providing high time resolution waveforms from one or numerous spacecraft in all of the regions discussed above. The waveforms allow for the study of the microstructure of plasma waves observed by other WEC instruments which send only the spectral components to the ground at frequencies within the WBD frequency range. This allows the investigator in many cases to determine more precisely the character of the waves and in some cases to determine which waves are observed, such as those produced by current-driven instabilities and other mechanisms involving spatial inhomogeneities, since a spectral signature alone can often be indicative of more than one type of wave. In addition simultaneous multi-spacecraft WBD measurements can be used to help resolve space-time ambiguities of complex spatial structures, which is one of the prime objectives of the Cluster mission. WBD can also provide high time resolution density measurements in regions where the upper hybrid or electron plasma frequency can be identified. Multi-point comparisons of electron densities can be used to analyze the motion and evolution of plasma structures in the auroral zone and polar cap.

In addition to supporting WEC science objectives and those of other Cluster investigators, WBD has several science objectives that can only, or best, be carried out by WBD. A few of these are delineated below:

Chorus: Through the use of multi-spacecraft WBD measurements, various characteristics of chorus can be studied for the first time, e.g., the size of individual chorus wave packets, the nonlinear evolution of chorus waves, the motion of chorus waves, and the generation mechanism of chorus waves through joint studies with Cluster particle instruments (PEACE and RAPID). See for example, the initial studies of Santolik and Gurnett (*Geophys. Res. Lett., 30,* No. 2, 1031, doi:10.1029/2002GL016178, 2003) and Inan et al. (*J. Geophys. Res. 109*, No. A5, A05214, doi:10.1029/2003JA010289, 2004).

Generation, Source Location and Beaming of AKR: Through the use of the Very Long Baseline Interferometry technique, applied for the first time from space with Cluster, WBD can study the source location of AKR and how it is beamed. The analyzed data can be compared to images of AKR taken from space by the IMAGE and Polar spacecraft and to ground measurements of AKR activity. For a description of the technique and first results, see Mutel et al. (*J. Geophys. Res., 108*, No. A11, 1398, doi:10.1029/2003JA010011, 2003). WBD data are also being used to study the fine structure of AKR and interpret the findings with respect to processes occurring in the auroral acceleration region. Beginning in 2009, WBD data obtained within the actual auroral acceleration region are being used to better understand the generation and development of AKR, including its fine structure and its various wave modes. Analysis of the wave modes allows for the precise determination of the densities in the auroral density cavity (see Mutel et al. in *Planetary Radio Emissions VII*, Austrian Academy of Sciences Press, Vienna, Austria, pp. 241-252, Oct. 2011).

Characteristics of solitary waves: It is possible to use WBD to determine the characteristics of solitary waves, which are observed in almost all boundary layers and turbulent regions of Cluster's orbit, including the auroral acceleration region. These characteristics can then be used to investigate their nonlinear generation mechanism and their importance in the various processes occurring in these regions, such as reconnection and heating of particles. For an initial statistical study on the characteristics of solitary waves, refer to Pickett et al. (*Ann. Geophys. 22*, p. 2515, 2004).

Electron Foreshock Waves: Since WBD obtains continuous data in the electron foreshock region, it is an ideal instrument from which to carry out studies such as the location of the foreshock boundary, amplitude distributions, and dependence of foreshock wave characteristics on IMF using the waveforms of the Langmuir waves. For an initial electron foreshock study involving WBD, see Sigsbee et al. (*Geophys. Res. Lett., 31*, L07805, doi:10.1029/2004GL019413, April 15, 2004).

Equatorial Emissions: Intense wave emissions at different frequencies are observed in the equatorial region of the inner magnetosphere. An example of an emission below the local lower hybrid frequency is electromagnetic equatorial noise which is often observed very close to the geomagnetic equator. The WBD instrument has sufficient resolution to detect this fine structure which can be indicative of the source mechanism and of the propagation of the waves from the source region. For an initial case study, refer to Santolik et al. (*J. Geophys. Res., 107*(A12), 1495, doi:10.1029/2001JA009159, 2002).

Lion Roar Emissions: "Lion roar" emissions are intense, short-duration, narrow-band packets of whistler-mode waves, which are observed throughout the Earth's magnetosheath. High-resolution data of the WBD instrument can be used to analyze similar wave packets observed on different spacecraft. Timing analysis of these waveforms is expected to contribute to the research on propagation from the source region. For the first Cluster results on these emissions, see Maksimovic et al. (*Ann. Geophys., 19*, p. 1429, 2001.)

3.2 Hardware Overview

3.2.1 General Information

3.2.1.1 Introduction

The Wideband Data (WBD) Plasma Wave Investigation for CLUSTER provides wideband (bandwidths up to 77 kHz) waveform measurements of plasma waves in the Earth's magnetosphere. A Wideband Receiver system which measures electric fields over the frequency rang 100 Hz to 577 kHz and magnetic fields over the frequency range 70 Hz to 4 kHz is provided by the WBD investigation as part of the Wave Experiment Consortium (WEC) instrumentation. The Wideband Data Plasma Wave Receiver provides unique measurement capabilities required for the detailed study of terrestrial plasma waves and radio emissions.

3.2.1.2 Design Heritage

The use of wideband instrumentation was first introduced with the Alouette 1 and Injun 3 satellites, and since that time, wideband measurements have become a standard technique for the study of space plasma waves. Wideband instrumentation has been carried by many spacecraft, including OGO 1 through 6, IMP 6 and 8, S(3), GEOS 1 and 2, S3-3, ISEE 1 and 2, Prognoz 8, Voyager 1 and 2, DE 1, Galileo, Cassini, and Polar. The University of Iowa has constructed wideband instrumentation for many of the above spacecraft, including most recently the Galileo, Cassini and Polar missions. The CLUSTER Wideband Data Plasma Wave Receiver is similar in design to instruments flown on ISEE 1, DE 1, and Polar.

3.2.1.3 Description of the Wideband Technique

The wideband technique involves transmitting band-limited waveform data to a ground station using a high-rate data link. The primary advantage of this approach is that complete, continuous waveforms are available for detailed high resolution frequency-time analysis, which may be performed to a level limited only by the uncertainty principle, $\Delta\omega \times \Delta t \sim 1$. Since the frequency resolution ($\Delta\omega$) and time resolution (Δt) may be selected and modified during data processing on the ground, the wideband technique is an extremely effective and flexible method for resolving features of interest in the plasma wave data. The high resolution nature of the wideband technique is of particular importance for the proper identification and study of plasma emissions which have very complex frequency-time characteristics. The distinctive fine structures of chorus and auroral kilometric radiation, for example, were first identified using wideband measurements.

3.2.1.4 References

Additional sources of information on the Cluster Wideband Data Plasma Wave Receiver instrument and investigation are as follows:

1. Information about the WBD instrument, a list of data received, survey plots, plotting tools, and a full list of publications using data from the WBD instrument, can be found on the home page of the Cluster Wideband Data Investigation on World Wide Web: http://www-pw.physics.uiowa.edu/cluster/

2. “Cluster Wideband Data Products in the Cluster Active Archive”, J. S. Pickett, J. M. Seeberger, I. W. Christopher, O. Santolik and K. M. Sigsbee, in The Cluster Active Archive, Harri Laakso, Matthew Taylor and C. Philippe Escoubet, Eds., Springer, 169, 2010.

3. "The Wideband Plasma Wave Investigation," D. A. Gurnett, R. L. Huff, and D. L. Kirchner, *Space Science Reviews, 79*, pp. 192-208,1997.

4. "First results from the Cluster Wideband Plasma Wave Investigation,” D. A. Gurnett, R. L. Huff, J. S. Pickett, A. M. Persoon, R. L. Mutel, I. W. Christopher, C. A. Kletzing, U. S. Inan, W. M. Martin, J. Bougeret, H. St. C. Alleyne, and K. H. Yearby, *Ann. Geophysicae, 19,* 1259, 2001.

5. "An investigation into instrumental nonlinear effects,” S. N. Walker, M. A. Balikhin, I. Bates, and R. L. Huff*, Adv. Space Res., 30*, 2815, 2002.

6. “Characteristics of Langmuir Electric Field Waveforms and Power Spectra Exhibiting Nonlinear Behavior in Earth's Foreshock”, K. Sigsbee, C. A. Kletzing, J. S. Pickett, D. A. Gurnett, S. J. Schwartz, B. Lefebvre, E. Lucek, A. N. Fazakerley, and H. Kucharek, *J. Geophys. Res., 115,* A10251, doi:10.1029/2009JA014948, Oct. 29, 2010.

7. “Modeling of Cluster’s electric antennas in space: Application to plasma diagnostics,” C. Béghin, P. M. E. Décréau, J. Pickett, D. Sundkvist, and B. Lefebvre, *Radio Science, 40,* RS6008, doi:10.1029/2005RS003264, 2005.

8. “WBD Response to Bipolar and Tripolar Pulses: Bench Tests vs. in Flight Observations, J. M. Swanner, J. S. Pickett, J. R. Phillips, and D. A. Kirchner, Internal Report and Jessica M. Swanner B.S. Thesis, Department of Physics and Astronomy, The University of Iowa, Iowa City, Iowa, USA, May, 2006 (http://www-pw.physics.uiowa.edu/cluster/pulse_tests.pdf).

9. “The Digital Wave Processing Experiment on Cluster,” L. J. C. Woolliscroft, H. Alleyne, C. M. Dunford, A. Sumner, J. A. Thompson, S. N. Walker, K. H. Yearby, A. Buckley, S. Chapman, and M. P. Gough, *Space Sci. Rev., 79*, 209, 1997.

10. “The wave experiment consortium (WEC),” A. Pedersen, N. Cornilleau-Wehrlin, B. De la Porte, A. Roux, A. Bouabdellah, P. M. E. Decreau, F. Lefeuvre, F. X. Sene, D. Gurnett, R. Huff, G. Gustafsson, G. Holmgren, L. Woolliscroft, H. S. Alleyne, J. A. Thompson, P. H. N. Davies, *Space Sci. Rev., 79*, 93-105, 1997.

3.2.2 Instrument Design Description

3.2.2.1 General Information

The Wideband Data (WBD) Plasma Wave Receiver is one experiment in a consortium of five wave and electric field experiments known as the Wave Experiment Consortium (WEC) flown on Cluster. In addition to WBD, the WEC experiment includes an electric field instrument (EFW), a wave magnetic field instrument (STAFF), a relaxation sounder and wave analyzer (WHISPER), a data processing unit (DWP), and a power supply (PWR). The DWP collects data from the WEC instruments and performs instrument control and data management functions. The WEC power supply provides either bus or regulated power to the WEC instruments.

The Wideband Data Receiver is divided into three main subsystems: the Analog Electronics, the Format Generator, and the Power Supply.

The Wideband Data Receiver processes signals from one of four sensors (see Table 3.2.2.2-1) which can be chosen via an antenna selection switch located at the receiver input. The four selectable inputs consist of two electric field signals, and two magnetic field signals. These inputs are provided by the electric (EFW) and magnetic (STAFF) field experiments.

Input bandpass filters limit the incoming signal to one of four possible frequency bands ranging from baseband (0 kHz) to 501.816 kHz (see Table 3.2.2.3-1). The band-limited signal then goes to a single-sideband frequency conversion stage which determines the range of frequencies to be received. The output of the conversion stage then goes to one of a set of three bandpass filters (see Table 3.2.2.5-1) which determines the bandwidth of the output waveform. Under this scheme, the filtered input signal is mixed with conversion frequencies f and f < 90 degrees. The input signals are thereby converted to baseband with upper and lower sidebands superposed and with a phase difference of 180 degrees. A quadrature phase shift network shifts one converted signal by an additional 90 degrees so that when the converted signals are summed, the upper sideband components add and lower sideband components cancel. The output of the conversion stage then goes to one of a set of three bandpass filters which determines the bandwidth of the output waveform.

Because of the large dynamic range of the input signal, and in order to maintain a high signal-to-noise ratio for the processed signal, an incremental automatic gain control (AGC) amplifies the signal to the proper level in steps of 5 dB over a range of 0 dB to 75 dB. The output from the gain select then goes to an analog-to-digital converter which provides 1-bit, 4-bit, or 8-bit resolution for a selection of sample rates.

Finally, a Format Generator organizes the digitized waveform data into a data frame suitable for the spacecraft telemetry system. The digitized wideband data are then transferred to the spacecraft data system in either an ~220 Kbits/sec real-time data mode (TDA-8), which requires direct acquisition by a ground station (NASA DSN or Panska Ves), or an ~73 kbits/sec burst-data mode (TDA-5.2 or BM2), which provides data to the spacecraft solid state recorder via the Wave Experiment Consortium data processing unit (DWP). This latter mode provides the capability for acquiring data when the spacecraft cannot be tracked by a ground station. The disadvantage of the burst-data mode is that all the other instruments receive data at a lesser data rate and, in some cases, possibly no data at all.

Thus, the WBD burst mode has been employed only sparingly throughout the mission. It was first used once to obtain data in the cusp on March 7, 2001. Starting in July 2010, BM2 has been run a few times per year in order to obtain WBD data at very low altitudes (several hundred km to 6000 km), where the spacecraft are prohibited from transmitting directly to the ground due to international regulations governing transmitter power levels, or in the auroral acceleration region where ground station coverage may not be available for WBD transmissions.

The WBD instrument contains an integral power supply which obtains 27 V primary power from the WEC power supply unit. The WEC power supply, in turn, obtains power from a redundant 28 V source supplied by the spacecraft.

Commanding and power switching of the WBD instrument is managed by the DWP.

A summary of WBD instrument parameters, physical dimensions, and mass and power requirements, is given in Table 3.2.2.1-1. Design details of the various WBD subsystems are discussed in the following sections. Please note that in Table 3.2.2.1-1, the lower frequency limits for the electric field measurements are 100 Hz and 700 Hz, not 50 Hz and 1 kHz as described in the WBD instrument paper (Gurnett et al., 1997). These adjustments in the lower frequency limits are due to changes in the implementation of the electric field boom buffer. Please also note that in Table 3.2.2.1-1, the conversion frequencies are 0 kHz, 125.454 kHz, 250.908 kHz, and 501.816 kHz. The nominal conversion frequencies of the WBD receiver were intended to be 0 kHz, 125 kHz, 250 kHz, and 500 kHz, as described in the WBD instrument paper (Gurnett et al.,1997). However, conversion frequencies of 125 kHz, 250 kHz, and 500 kHz were not realizable due to the way in which the clocks were implemented in the onboard data handling system. Joint operations between the Cluster WBD receiver and the RPI transmitter on board the IMAGE spacecraft verified that the actual Cluster WBD receiver conversion frequencies are the values given in Table 3.2.2.1-1.

Table 3.2.2.1-1. Wideband Instrument Parameters

Sensors	Two electronic dipole antennas; two search coil magnetometers
Conversion Frequencies	0 (Baseband, default mode), 125.454 kHz, 250.908 kHz, 501.816 kHz
Bandpass Filter Ranges	700 Hz to 77 kHz (electric) 100 Hz to 19 kHz (electric) 100 Hz to 9.5 kHz (default mode) (electric) 70 Hz to 4 kHz (magnetic) (upper limit driven by STAFF search coils)
Sampling Frequency	27.4 to 219.5 kHz (depending on mode)
Time Resolution	4.55 to 36.4 μsec (depending on mode)
Frequency Resolution	Determined by FFT or other spectral analysis program; maximum 2048 point FFT in noncontinuous modes
Gain Select	5 dB steps, 16 levels, dynamic range 75 dB, automatic ranging or set by command
A/D Converter	1-, 4-, or 8-bit resolution for a selection of sample rates
Dimensions	19.0 x 15.8 x 14.3 cm
Mass	Approx. 1800 grams
Power (primary)	Approx. 1.6 W

3.2.2.2 Sensors and Sensor Interfaces

On Cluster, the plasma wave sensors consist of two orthogonal spherical-probe electric antennas located in the spin plane of the spacecraft, and a triaxial search coil magnetometer oriented with two measurement axes in the spin plane and the third measurement axis oriented parallel to the spacecraft spin axis.

The electric antennas, which are provided by the Electric Fields and Waves (EFW) investigation, have sphere-to-sphere separations of about 88 m. The spheres each contain a high-impedance preamplifier which provides signals to the EFW main electronics, and to the WBD instrument and the other wave instruments via buffer amplifiers. The EFW/WBD buffer amplifier is a low-noise, low power design which meets WBD frequency/amplitude response requirements, particularly the need to maintain a nearly flat response up to about 600 kHz.

The three orthogonal search coils are part of the STAFF instrumentation, and provide magnetic field signals up to 4 kHz.

The WBD instrument has the capability of processing signals from one of four sensors which may be selected by spacecraft command. Under the control of the DWP, WBD may be switched to either of the electric sensors, to a spin-plane search coil, or to the spin-axis search coil. Four dedicated differential amplifiers are provided as part of the Wideband Data Receiver electronics, two amplifiers for the electric sensor interface, and two for the magnetic sensor interface.

The WBD antenna select combinations are summarized in Table 3.2.2.2-1. The Ez electric antenna was chosen as the default because the WHISPER sounder always uses the electric Ey antenna as its active sounding antenna and thus introduces intense interference to the input of WBD if using this antenna. The user of WBD data is being referred to the WBD Caveats document, as well as the WBD User Guide, both archived at the CAA for information about the WBD measurements after failures of EFW probes on Ez and Ey. WBD data are occasionally received on the Ez antenna for short periods of time (< 10 s) prior to the command to switch to Ey fully executing on those spacecraft using the Ey antenna due to failures on Ez.

Table 3.2.2.2-1. WBD Antenna Select

Mode	Cmd/Status	Antenna	Comments
0	00	Ez (electric)/spheres 1 and 2	Default Mode
1	01	Bx (search coil)	
2	10	By (search coil)	
3	11	Ey (electric)/spheres 3 and 4	

3.2.2.3 Frequency Bands

The input frequency range of the WBD instrument can be shifted by the frequency converter to any one of four frequency ranges, where the conversion frequency f determines the lower edge of the frequency range to be received. The conversion frequency is obtained by dividing down a reference oscillator with a frequency of 14.0508 MHz. To maintain phase stability in the entire system, the 14.0508 MHz oscillator is synchronized to a spacecraft high frequency clock signal of 220.752 kHz, which is the frequency of the spacecraft's Ultra Stable Oscillator (USO) divided by 38.

A spacecraft command to select a particular frequency band causes the DWP to switch the WBD instrument to the appropriate input bandpass filter and to select the appropriate conversion frequency. If baseband (f = 0) is selected, the mixing stage is bypassed so that the signal is routed directly to the output bandpass stage with no frequency conversion. The WBD frequency bands are summarized in Table 3.2.2.3-1. The bandwidth of the WBD output waveform is determined by one of three bandpass filters selected in combination with a given WBD output mode. Output modes are discussed further in Section 3.2.2.5.

Table 3.2.2.3-1. WBD Frequency Band Select

Mode	Cmd/Status	Conversion Frequency	Comments

0	00	0 kHz/Baseband (no conversion)	Default Mode
1	01	125.454 kHz	
2	10	250.908 kHz	
3	11	501.816 kHz	

3.2.2.4 Gain Control

The gain select stage of the WBD receiver employs multi-gain amplifiers which may be programmed to provide gain control in increments of 5 dB. This programmable amplifier stage consists of amplifiers having gains of 0/5 dB, 0/10/20/30 dB, and 0/40 dB gain. The gain combinations used are listed in Table 3.2.2.4-1. In manual gain select mode, the total receiver gain can be set to one of the sixteen levels by the appropriate spacecraft command processed through the DWP.

Table 3.2.2.4-1. WBD Gain Select

Gain Step	Cmd/Status	Amplifier Combination	Total Gain (dB)
0	0000	0 + 0 + 0	0
1	0001	0 + 0 + 5	5
2	0010	0 + 10 + 0	10
3	0011	0 + 10 + 5	15
4	0100	0 + 20 + 0	20
5	0101	0 + 20 + 5	25
6	0110	0 + 30 + 0	30
7	0111	0 + 30 + 5	35
8	1000	40 + 0 + 0	40 *
9	1001	40 + 0 + 5	45 *
10	1010	40 + 10 + 0	50 *
11	1011	40 + 10 + 5	55
12	1100	40 + 20 + 0	60
13	1101	40 + 20 + 5	65
14	1110	40 + 30 + 0	70
15	1111	40 + 30 + 5	75

* The 35 dB to 40 dB, 50 dB to 45 dB, and 45 dB to 50 dB gain transitions produce ringing. See the “WBD Interpretation Issues” document or the WBD user guide for details.

Additionally, the Wideband Data Receiver has the capability of auto-ranging through the gain steps. The auto-ranging mode is enabled by command and allows WBD to automatically manage large changes in signal intensity. In this operational mode, the output from the programmable amplifier is compared to a pair of reference amplitudes. If the criteria for changing the gain are met, the gain state is either increased by one step (5 dB) or decreased by one step, accordingly. In order to avoid excessive toggling between gain steps, and to provide proper gain control for both 4- and 8-bit sample modes, a threshold must be exceeded in either direction. These are the Upper and Lower AGC threshold parameters, both of which have remained at their default values (UV0 and LV0, respectively) for the mission thus far because they provide the most stable state for the system.

3.2.2.5 A/D Converter and Format Generator

The output analog waveform is sampled by an analog-to-digital converter which provides sampling resolution and data output rates which are listed in Table 3.2.2.5-1.

For sample rates where the bit rate exceeds the allowable WBD telemetry rate (220 kbits/sec), the digitized wideband data are buffered by the Format Generator and read out at the allowed bit rate. The Format Generator organizes the digitized waveform data into an output frame, along with appropriate timing and status information, and makes the frame available to the spacecraft OBDH (On Board Data Handling) system. Alternatively, the WBD data stream is read out through the DWP to the OBDH solid state recorder.

Table 3.2.2.5-1. WBD Output Modes

Mode	Cmd/Status	Bandwidth	Sample Rate	Bits/ Sample	Duty Cycle	Comments
0	000	100 Hz-9.5 kHz	27.443 kHz	8	100%	Default Mode
1	001	100 Hz-9.5 kHz	27.443 kHz	8	100%	
2	010	100 Hz-19 kHz	54.886 kHz	4	100%	
3	011	100 Hz-19 kHz	54.886 kHz	8	50%	Note a
4	100	700 Hz-77 kHz	219.544 kHz	8	12.5%	Note b
5	101	700 Hz-77 kHz	219.544 kHz	1	100%	
6	110	700 Hz-77 kHz	219.544 kHz	4	25%	Note c
7	111	700 Hz-77 kHz	219.544 kHz	8	12.5%	Notes b,d

Notes:
(a) 2180 samples (contained in two adjacent 1090 bit minor frames) equal to 39.719 msec of data followed by 39.719 msec of data gap.
(b) 2180 samples (contained in two adjacent 1090 bit minor frames) equal to 9.9297 msec of data followed by 69.508 msec of data gap.
(c) 2180 samples (contained in two adjacent 1090 bit minor frames) equal to 19.859 msec of data followed by 59.578 msec of data gap.
(d) This mode is a repeat of output Mode 4, but also toggles the primary and redundant OBDH (On Board Data Handling System) interfaces.

3.2.2.6 WBD Data Interfaces

The Wideband Data Plasma Wave Receiver has two different output modes for providing digitized data to the spacecraft data handling system. These modes consist of a real-time data mode (TDA-8) which provides data at about 220 kbits/sec and a burst-data mode (TDA-5.2 or BM2) which provides data at about 73 kbits/sec. These two output modes require separate data interfaces as discussed in the following sections.

3.2.2.6.1 OBDH Interface

The WBD/OBDH serial data interface is a direct connection between the WEC (originating at WBD) and the spacecraft's OBDH system. The interface supplies the primary path for data from the WBD instrument, allowing real-time acquisition of WBD data at a ground receiving station. The WBD data go directly to the Central Terminal Unit (CTU) of the OBDH bypassing the Remote Terminal Unit (RTU). The data appear on virtual channel VC5 as described in the Cluster EID Part A, embedded in the 1096 byte Data Field of the standard 1279-byte transfer frame.

The OBDH supplies the sampling clock, a synchronizing pulse, and access to a high-rate data port.

The WBD/OBDH interface functions are described below.

> WBD Clock - A special clock is provided continuously by the spacecraft at a rate of 220.753 kHz. The clock is used to shift telemetry out of WBD, and is also used to phase-lock the WBD VCXO (Voltage Controlled Crystal Oscillator). The clock signal is obtained by dividing the frequency of the Ultra Stable Oscillator by 38.
>
> WBD Data Out - Serial data are transferred from WBD to the OBDH via the WBD Data Out line most significant bit first at a rate determined by the WBD Clock described above. Data will be present on this line whenever WBD is powered.

VCO Reset Pulse - This pulse is correlated with the first bit of the housekeeping transfer frame (Virtual Channel 0, sampled at the rate of only once every 132 WBD frames) and is used to gate the contents of the 7-byte onboard time counter into the Onboard Time Field of the housekeeping frame. The pulse is also distributed continuously to WBD to determine the timing of the WBD data frame.

It is assumed that the VCO Reset interval is 5.15222168 seconds, and that this interval corresponds to a fixed number of cycles of a counter operating at an integer fraction of the USO frequency. It is also assumed that the Reset Pulse has an associated time jitter of less than a microsecond. WBD will achieve microsecond sample timing by maintaining an internal counter, the contents of which will be gated out for each WBD minor frame and stored within a special field of the minor frame as a time offset. The counter will be zeroed by the VCO Reset Pulse.

3.2.2.6.2 WBD Data Frame Format

The high-rate WBD data are transmitted in a Minor-Frame/Major-Frame format. A WBD major frame consists of four minor frames, with overall format as shown in Table 3.2.2.6.2-1. Each minor frame contains 1096 bytes of data, of which the first six bytes supply frame and byte synchronization, status information, and time information.

Table 3.2.2.6.2-1. WBD Frame Format

Frame #	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Bytes 6-1095
0=00B	FA	F3	34	Frame	COUNT2	COUNT1	Data
1=01B	FA	F3	34	Frame	COUNT0	STAT3	Data
2=10B	FA	F3	34	Frame	STAT2	STAT1	Data
3=11B	FA	F3	34	Frame	STAT0	STAT3	Data

The four fields in a minor frame are listed below:

1. Frame Sync - 3 bytes (FA, F3, 34 Hex)

2. Frame count - 1 byte. Sequential count of each minor frame. Allows the data system to assemble the received frames in order, and allows the data system to determine if any frames have been lost. The two least significant bits of the frame count byte give the minor frame number.

3. Status/Clock - 2 bytes. These two bytes provide different functions in each minor frame of the major frame. The use of the two status bytes as a function of the two least significant frame count bits are as follows:

Minor Frame #	Function
00	Two most significant bytes of the three byte VCO time offset counter.
01	Least significant byte of VCO time offset counter and status byte 3.
10	Status bytes 1 and 2.
11	Status byte 0 and status byte 3 repeated

.

The format of the four status bytes is given in Table 3.2.2.6.2-2.

4. Data - 1090 bytes. Data is presented most-significant-bit first. When either a 4- bit or 1-bit mode (see Table 3.2.2.5-1) is enabled, the samples are packed into each byte in reverse time order.

Table 3.2.2.6.2-2. WBD/OBDH Status Word Format

Byte	Bit	Description
STAT3	7	VCXO Lock (1=Not Working; 0=Lock)
	6	OBDH Interface (0=Primary; 1=Redundant)
	5	Command Status (0=No cmds; 1=Cmds received)
	4	A/D Converter Power
	3,2,1,0	Gain Level/Select
STAT2	7,6	11
	5	Gain Mode (Manual=1; Auto=0)
	4,3,2,1	Gain Level/Select
	0	OBDH Interface (0=Primary; 1=Redundant)
STAT1	7,6	01
	5,4	Antenna Select
	3,2	Frequency Select
	1,0	Upper AGC Threshold
STAT0	7,6,5	WBD Model (000=EM; 100=PFM; 101=F2; 110=F3; 111=F4)
	4,3,2	Output Mode
	1,0	Lower AGC Threshold

3.2.2.6.3 DWP Interface

The DWP/WBD interface provides three main functions: a second path for WBD data (to the solid state recorder), a means for controlling WBD via serial command, and a means for acquiring housekeeping and status information from WBD. These functions are discussed in the following sections.

3.2.2.6.4 Burst Data Mode

The burst mode (TDA-5.2 or BM2) provides high-rate data to the spacecraft solid state recorder via the DWP. This data mode uses a high-rate serial interface between WBD and the DWP. Data is transferred to the DWP through this serial interface at 220 kbits/sec, and the DWP, in turn, reduces the wideband data by a factor of three (73 kbits/sec) via either digital filtering or duty cycling (which is command selectable) and transfers the wideband data to the spacecraft data system for recording and subsequent playback.

3.2.2.6.5 Serial Command

The DWP controls the Wideband Data Receiver through a 16-bit command word. The bit assignments for the command word are given in Table 3.2.2.6.5-1.

Table 3.2.2.6.5-1. WBD/DWP Command Word Format

Bit	Description
15, 14, 13, 12	Gain Select
11, 10	Upper AGC Threshold
9, 8	Lower AGC Threshold
7	Gain Mode, manual(=1)/auto(=0)
6, 5	Frequency Select
4, 3, 2	Output Mode
1, 0	Antenna Select

3.2.2.6.6 Instrument Status and Housekeeping Data

The WBD gain status, along with all other status information (auto/fixed gain, gain select, frequency select, output bandwidth select, and antenna select) are sampled by the DWP via a 3-byte status polling sequence and provided as housekeeping parameters. The format of these three bytes is shown in Table 3.2.2.6.6-1. The unique status bit combinations for all of the WBD instrument states are listed in Table 3.2.2.6.6-2.

Table 3.2.2.6.6-1. WBD/DWP Status Word Format

Byte	Bit	Description
0	7, 6	11
0	5	Gain Mode, manual (=1) / auto (=0)
0	4, 3, 2, 1	Gain Select
0	0	1 = Redundant Interface
1	7, 6	01
1	5, 4	Frequency Select
1	3, 2	Lower AGC Threshold
1	1, 0	Upper AGC Threshold
2	7, 6	00
2	5	VCXO Lock (1=not working, 0=Lock)
2	4, 3, 2	Output Mode
2	1, 0	Antenna Select

Table 3.2.2.6.6-2. WBD Status Bit Combinations

Byte 1 (MSB)	Byte 2	Byte 3 (LSB)	Instrument State
110xxxxx	01xxxxxx	00xxxxxx	auto gain select
111xxxxx	01xxxxxx	00xxxxxx	manual gain select
11x0000x	01xxxxxx	00xxxxxx	gain set to 0 dB
11x0001x	01xxxxxx	00xxxxxx	gain set to 5 dB
11x0010x	01xxxxxx	00xxxxxx	gain set to 10 dB
11x0011x	01xxxxxx	00xxxxxx	gain set to 15 dB
11x0100x	01xxxxxx	00xxxxxx	gain set to 20 dB
11x0101x	01xxxxxx	00xxxxxx	gain set to 25 dB
11x0110x	01xxxxxx	00xxxxxx	gain set to 30 dB
11x0111x	01xxxxxx	00xxxxxx	gain set to 35 dB
11x1000x	01xxxxxx	00xxxxxx	gain set to 40 dB

11x1001x	01xxxxxx	00xxxxxx	gain set to 45 dB
11x1010x	01xxxxxx	00xxxxxx	gain set to 50 dB
11x1011x	01xxxxxx	00xxxxxx	gain set to 55 dB
11x1100x	01xxxxxx	00xxxxxx	gain set to 60 dB
11x1101x	01xxxxxx	00xxxxxx	gain set to 65 dB
11x1110x	01xxxxxx	00xxxxxx	gain set to 70 dB
11x1111x	01xxxxxx	00xxxxxx	gain set to 75 dB
11xxxxx0	01xxxxxx	00xxxxxx	primary OBDH interface
11xxxxx1	01xxxxxx	00xxxxxx	redundant OBDH interface
11xxxxxx	0100xxxx	00xxxxxx	conv. freq. = 0 Hz
11xxxxxx	0101xxxx	00xxxxxx	conv. freq. = 125.454 kHz
11xxxxxx	0110xxxx	00xxxxxx	conv. freq. = 250.908 kHz
11xxxxxx	0111xxxx	00xxxxxx	conv. freq. = 501.816 kHz
11xxxxxx	01xx00xx	00xxxxxx	lower agc = LV0
11xxxxxx	01xx01xx	00xxxxxx	lower agc = LV2
11xxxxxx	01xx10xx	00xxxxxx	lower agc = LV1
11xxxxxx	01xx11xx	00xxxxxx	lower agc = LV3
11xxxxxx	01xxxx00	00xxxxxx	upper agc = UV0
11xxxxxx	01xxxx01	00xxxxxx	upper agc = UV2
11xxxxxx	01xxxx10	00xxxxxx	upper agc = UV1
11xxxxxx	01xxxx11	00xxxxxx	upper agc = UV3
11xxxxxx	01xxxxxx	000xxxxx	VCXO locked
11xxxxxx	01xxxxxx	001xxxxx	VCXO not locked
11xxxxxx	01xxxxxx	00x000xx	BW = 9.5 kHz; 8-bits
11xxxxxx	01xxxxxx	00x001xx	BW = 9.5 kHz; 8-bits
11xxxxxx	01xxxxxx	00x010xx	BW = 19 kHz; 4-bits
11xxxxxx	01xxxxxx	00x011xx	BW = 19 kHz; 8-bits
11xxxxxx	01xxxxxx	00x100xx	BW = 77 kHz; 8-bits
11xxxxxx	01xxxxxx	00x101xx	BW = 77 kHz; 1-bit
11xxxxxx	01xxxxxx	00x110xx	BW = 77 kHz; 4-bits
11xxxxxx	01xxxxxx	00x111xx	BW = 77 kHz; 8-bits
11xxxxxx	01xxxxxx	00xxxx00	antenna = Ez
11xxxxxx	01xxxxxx	00xxxx01	antenna = By
11xxxxxx	01xxxxxx	00xxxx10	antenna = Bx
11xxxxxx	01xxxxxx	00xxxx11	antenna = Ey

3.2.2.7 Instrument Power Supply

The WBD Power Supply is a simple PWM system which supplies ±12, ±6 and +5 V regulated voltages for the various WBD subsystems. The WBD Power Supply receives a 27V bus supply and a converter synchronization signal through the WEC Power Supply. Power to WBD is managed by the WEC DWP, which controls a latching relay in the WEC Power Supply.

The WBD unit on Cluster 3 developed an overheating problem at about 22:05 UT on December 13, 2003, tentatively attributed to a degraded capacitor on the power supply board. The degraded component has been deemed to be non-critical, with the WBD unit on Cluster 3 still providing good science data as long as it is powered ON for no more than 10 minutes approximately once every 60-70 minutes. Consequently, after January 13, 2004, most Cluster 3 operations were limited to high priority science campaigns with 10-minute data periods.

3.2.2.8 Mechanical Design

The WBD instrument consists of a single physical unit, about the size of a toaster. The electronics housing is milled from a single block of aluminum with walls approximately .040 inches thick, and is supported by six feet attached to the experiment platform. Total weight is approximately 1800 grams.

Inside the housing, the box is divided into two compartments, one for analog electronics, and one for digital/power supply. The circuit boards are .0625 polyamide and are stacked together via aluminum standoffs, and fastened to the housing via stainless steel screws. Electrical parts are placed on the boards by a combination of vapor phase reflow and hand soldering by a NASA certified assembly technician. Some of the digital electronics are constructed on multilayer boards.

3.3 Data Processing Chain

3.3.1 Onboard Processing

WBD performs no onboard processing. However, when WBD is in BM2 mode (see section 3.2.2.6.4), the DWP reduces the WBD data by a factor of 3 through either digital filtering or duty cycling in order to fit within the telemetry assignments for this mode. As stated above, BM2 mode has been sparingly invoked during the lifetime of the mission.

3.3.2 Ground Processing

In TDA-8 mode, which is the mode used to obtain almost all WBD data, a total of 1,090 bytes of WBD data and 6 status bytes are presented to the spacecraft OBDH during each minor frame. The OBDH adds headers and trailers consisting of identification codes, synchronization patterns, onboard counter stamps, Reed-Solomon encoding etc., ending up with a 1279 byte transfer frame which is telemetered to the ground. These transfer frames are picked up by NASA’s Deep Space Network (DSN) ground stations in Madrid, Goldstone or Canberra, or the Czech Republic ground station at Panska Ves, depending on which station has view of the spacecraft. Within 2 hours of the end of a WBD transmission period (typically 2 hours long), DSN and Panska Ves perform Reed-Solomon decoding to check for transmission problems, add headers and trailers to the transfer frame, consisting of various identification codes and more importantly the Ground Receive Time (GRT) stamp of the receipt of the transfer frame on the ground (accurate to within 50 μsec), and finally push the raw file by ftp to the Physics Department at the University of Iowa (starting from 2015, data are only uploaded to a server at the Institute of Atmospheric Physics in Prague). Panska Ves ground station also stores all WBD files indefinitely as a backup.

At this point IAP Prague carries out a processing routine, called Level 1, which takes these raw data files and

1. checks the file for problems,
2. looks for the synchronization patterns,
3. determines the time of WBD measurement using both
   a) the onboard (OBT) time counters, according to ESOC algorithm using the ESOC-provided “tcal” files, and
   b) the ground receive (GRT) stamps taking into account the time of flight of the spacecraft telemetry as well as onboard delays from measurement to transmission,
4. unpacks the status bits, and
5. writes “Level 1” data files.

These files are a maximum of 10 minutes long, always starting on the first whole minute, and consist of all of the ground station supplied header and trailer information, the original 1279 byte transfer frames from the spacecraft, which includes the WBD measurements and status bytes, unpacked status byte data, and the Iowa-determined time of WBD measurement based on GRT stamps provided by the ground stations and OBT counters contained in the transfer frames. The OBT-derived times are accurate up to 2 msec. Time corrections to obtain accuracy of at least 50 μsec for the OBT stamps are provided in separate WEC TCOR files that are archived in the CAA. The exact format of the WBD Level 1 files, the naming conventions for the files and the makeup of the transfer frames are described in other WBD documents located on the WBD web site at Iowa.

In addition to creating the Level 1 data files, a log of all data received is created. This log provides the start and stop times of the data periods, the spacecraft that obtained the data, and the mode of the WBD instrument for these data periods (antenna, base frequency, and resolution). These logs are provided to the CAA for public release in machine readable form (as "Coverage" files), as well as in html form with expanded information on the region of Earth where the data were expected to have been taken, the level of EDI interference, and whether ASPOC was operating or not (as "Summary Science" files).

Once the data have been validated as good through the use of various output files and plots, all of the Level 1 files for any given month are then assembled at the end of the month and written onto DVDs. From the start of the mission through December 31, 2011, two copies of these DVDs have been kept at Iowa, one copy each going to the French, Swedish and UK Cluster Data Centres, Stanford University, and Southwest Research Center (SwRI). As of January 1, 2012, WBD no longer distributes DVDs, but rather provides access to the Level 1 data files and all documentation previously included on a DVD through a special web site at Iowa, preserving the file structure of the original DVDs.

Regarding the determination of the time stamps contained in the Level 1 files, Iowa cannot stress strongly enough that this is a nontrivial task given the complexities and idiosyncrasies of the OBDH as well as various problems that arise through ground station retrieval and processing. Iowa has made every attempt to ensure that these time stamps are as accurate as possible, but there is no way to guarantee that the time stamps written into the Level 1 files are accurate to the levels stated above. However, the time stamps obtained via GRT are always cross compared with those obtained via OBT. If these time stamps agree to within 2 msec, this is considered a sufficient check. At certain times, ESOC has allowed the drift of the OBT stamps to be less accurate than 2 msec by 1-2 msec before performing a time correlation to bring these OBT stamps back into the allowed range. Under these circumstances, Iowa has allowed these OBT stamps to be validated, with the assumption that the time corrections for these OBT stamps, contained in the WEC TCOR files discussed above, when applied to the OBT stamps in the Level 1 files, will provide at least 50 μsec accuracy that is desirable for doing certain types of cross-spacecraft correlations. We note that there are times when the GRT stamps have been determined to be wrong, and it is not possible to obtain the 50 μsec accuracy required for these time stamps. In this case, fill data is written into the Level 1 files in place of the GRT-derived time stamps.

3.3.3 Science Processing

Once the Level 1 data files have been produced (see Section 3.3.2), routine graphical science products are created. The measured time series can be calibrated on the ground using calibration factors obtained during pre-launch testing and applied to the "raw counts" (0 to 255) contained in the WBD Level 1 data files. Spectrograms can be created from the Level 1 data via the standard Fast Fourier Transform (FFT) using a 1024 point windowed FFT. A Hann window is typically used to create the standard WBD spectrograms provided to the CAA. If the FFT is performed on calibrated data, the spectral density units will be $V^2m^{-2}Hz^{-1}$ for electric field measurements and nT/Hz for magnetic field measurements. If the FFT is performed on uncalibrated data, a normalization factor for the gain state in which the measurements were taken is applied before calculating the FFT. In any gain state, the dynamic range is only a 48 dB portion of the WBD instrument's full dynamic range. Applying the gain state normalization ensures that the uncalibrated data are scaled into the correct portion of the WBD instrument's full dynamic range. Then the FFT is performed, the electric or magnetic spectral density is calculated and divided by the instrument's noise bandwidth, and the result is converted into relative units of dB. See the WBD Calibration Report archived at the CAA for a full description of the calibration procedure. The graphical science products created in this manner consist of overview spectrograms of the WBD data periods from all spacecraft transmitting data during any specific data interval, in postscript format, and two types of high resolution spectrograms (30-second and 10-minute durations) for each spacecraft individually, in gif format. Only the postscript overview spectrograms, plus the png versions of them, and the high resolution 30-second gif spectrograms are being provided to the CAA. The 10 min duration gif spectrograms are available through the University of Iowa web site (http://www-pw.physics.uiowa.edu/cluster/). Further details of the WBD graphical science products that have been provided to the CAA are available in Section 4.

3.4 Instrument Data Products

WBD makes only one measurement, that being the high time resolution AC electric or magnetic field along only one axis for a chosen filter bandwidth appropriate to the region or science objective being carried out for any given operation. The measured time series is calibrated on the ground using calibrations obtained during pre-launch testing and applied to the "raw counts" (0 to 255) contained in the WBD Level 1 data files, as described previously. The primary benefit of the WBD instrument lies in the fact that it obtains the high resolution time series and transmits this to the ground. This provides the most flexibility in that it allows the user to apply whatever analysis method best fits their scientific use of the data. This method can be an FFT, as described above in Section 3.3.3, or it can be another technique, such as wavelet analysis. In addition to permitting flexibility in the choice of data analysis methods, the high time resolution AC electric and magnetic field measurements provided by the WBD Receiver are not affected by temporal and spatial averaging, as measurements from instruments that only provide spectral densities can be.

The overview and high resolution 30-second spectrograms described above are archived at the CAA, along with the calibrated waveform (time series) (see section 4). A WBD Calibration Report and WBD User Guide are also available through the CAA. Example software programs to read the Level 1 files and apply the calibrations can currently be found at http://www-pw.physics.uiowa.edu/cluster/dvd/. In the main directory of this web site, the text files called ERRATA.TXT, INSTDESC.TXT, README.TXT, TIMETAGS.TXT, and WBFORMAT.TXT provide information about the WBD instrument, how to determine timing, and the structure of the Level 1 files. Various example programs can be found in subdirectories of the SOFTWARE directory on the above web site, including a program called CALIBRATE.C, written in the C language, which shows how to calibrate the data. There is also a program called FIX_SC2.C which corrects the WBD waveforms for errors created by problems with the OBDH on spacecraft 2. The program called R_WBD_WF.C is an example of how to read a WBD Level 1 file.

Currently, to obtain access to the WBD Level 1 data for download, an investigator can direct that request to the WBD Principal Investigator, Jolene S. Pickett (pickett@uiowa.edu), or to one of the data centres mentioned above in Section 3.3.2. Iowa encourages users, however, to download the CEF or CDF files directly from the CAA since those data are fully calibrated and Iowa has cleaned up the data as much as is possible. If Iowa has not yet created a CDF.CEF file for download from the CAA for a time period needed by any CAA user, that user can request the WBD Principal Investigator to preferentially process his/her time interval. Iowa will then deliver the CDF files to the CAA as soon as possible so that the CAA can convert them to CEF for the user to download.

4 Data Provision – General Conventions

The Wideband Data Plasma Wave Receiver team is not funded by ESA for the provision of digital data to the ESA Cluster Active Archive. For the CAA, the WBD team is marginally funded by NASA to provide pre-generated survey plots that can be used to identify periods of interest, as well as CDF files of the calibrated WBD waveform data and associated parameters needed for analyzing the data. Further details of the routine graphical science products and digital CDF files being provided to the CAA and the delivery process follow in Sections 4.1-4.5.

4.1 Formats

Postscript and png overview spectrograms and the high resolution 30-second gif spectrograms mentioned in Section 3.3.3 are being provided to the CAA.

The postscript and png overview spectrograms show the WBD data from all spacecraft transmitting WBD data during a WBD data interval, with up to 4 panels, one for each spacecraft. Each panel has the frequency plotted on the vertical axis, the increasing time plotted on the horizontal axis, with color indicating spectral density, either electric field or magnetic field, of the waves. The antenna that is used is indicated to the left of the panel, while the spacecraft number, 1 through 4, is indicated to the right of each panel. At the bottom of the overview spectrograms is a columnar listing of the following ephemeris data: Distance from center of Earth in RE, Magnetic Latitude in degrees, Magnetic Local Time in decimal hours, and L-shell. This listing is only relevant to the spacecraft whose data are plotted just above it, or in other words, the bottom-most panel of a multi-panel plot. These plots are typically around 2 hours in length, but can vary from anywhere around a few minutes to up to 5 hours. The spectrograms are created via use of the standard Fast Fourier Transform (FFT) using a 1024 point FFT. Since these are overview plots containing more data than available pixels, data averaging occurs.

The high resolution 30-second spectrograms, in gif format, contain full resolution data with no averaging. The spectrograms are created by 1024 point FFTs with frequency on the vertical axis, increasing time on the horizontal, and color indicating spectral density, in dB. Above the spectrogram are a line plot panel and four status lines. The line plot panel at the top provides the gain state of the instrument. The four status lines provide the following information according to the color code in the upper right-hand corner: data mode (whether from Deep Space Network or Panska Ves Observatory ground stations (DSN, PAN80, PAN81) or from BM2 mode as digitally filtered or duty cycled (DC)), the antenna used, the resolution, and the translation from base frequency of 0 kHz. Instead of using the exact conversion frequencies in Table 3.2.2.1-1, the translations from the base frequency given on the 30-second spectrograms have been rounded to 125, 250, and 500 kHz. In the lower right-hand corner are the ephemeris values (same as those contained at the bottom of the overview plots discussed above) applicable to the start time of the plot. At the middle right-hand side are given the date and start time of the plot, as well as the spacecraft number.

The WBD digital data files are being delivered to the CAA as standard CDF files for conversion to standard CEF format. These files contain two types of data. The first are the global attributes which provide all of the usual information about when the file was produced, general information about the WBD investigation and data, which Cluster spacecraft has provided the data, etc. The second type are the variables consisting of time tags, WBD status parameters, time series of calibrated electric or magnetic field amplitudes, angles for orienting the measurement into two reference frames, the DC Offset used in carrying out the calibration, and a data quality flag.

4.2 Standards

The file level metadata for the survey plots and cdf files shall be generated by the CAA on ingestion based on a supplied file naming convention, which is discussed further in Section 5.

4.3 Production Procedures

The postscript and png overview spectrograms and the high resolution 30-second gif spectrograms provided to the CAA were generated from the latest version of the WBD Level 1 files by the WBD Team at the University of Iowa. The plots use a standard 1024 point FFT with a Hann window. The details of the science data processing required to generate these plots were discussed in Section 3.3.3. The digital data files were produced using standard CDF processing routines available from NASA in the U.S. adapted for processing WBD data.

4.4 Quality Control Procedures

The data shown in the postscript and png overview spectrograms and the high resolution 30-second gif spectrograms provided to the CAA have been validated by the WBD Principal Investigator, Jolene Pickett. The data shown in the overview spectrograms and high resolution 30-second gif spectrograms are generally believed to be correct and suitable for publication and presentation, unless otherwise noted.

When switching between instrument modes occurs during the time span of an overview plot, each plot will show the data for only one mode. When this occurs, it is noted on the left-hand side of the plot that it is not for suitable publication since the data in one instrument mode have been dilated across the data gaps created when the instrument is in the other mode(s). For example, during operations in magnetospheric regions where electromagnetic waves may be found, the WBD Plasma Wave Receiver sometimes switches between the electric and magnetic field antennas in a regular cycle. In these cases, two overview plots are available, one showing the electric field data and the one showing the magnetic field data. For the electric field mode plot, the color bar on the overview will be in units of $V^2m^{-2}Hz^{-1}$. Intervals when the WBD receiver was in a magnetic field mode will be treated as a data gap (typically about 10 seconds long) and the intervals when the receiver was in an electric field mode (typically about 42 seconds long) will be dilated across the gap. For the magnetic field overview plot, the color bar is given in relative dB and 10 second data intervals are dilated across a 42 second gap. The lengths of the cyclic data intervals and gaps are noted on the overview plot.

The other main example is during operations targeting auroral kilometric radiation, or other high-frequency waves, where the WBD Plasma Wave Receiver is cycled between translation frequencies of 125.454 kHz, 250.908 kHz, and 501.816 kHz. During this type of operation, the WBD Plasma Wave Receiver records 52 seconds of data for the 125.454 kHz conversion frequency, 104 seconds of data for the 250.908 kHz conversion frequency, and 52 seconds of data for the 501.816 kHz conversion frequency. Variable bandwidths have been used for the different conversion frequencies, usually 9.5 kHz and 77 kHz. For time periods with data from this type of operation, three separate overview plots are produced. One overview plot will show the data from the 125.454 kHz conversion frequency intervals, dilated across the 156 second gap when the receiver was recording data for the 250.908 kHz and 501.816 kHz conversion frequencies. A second overview plot will show the data from the 250.908 kHz conversion frequency intervals dilated across the 104 second gap when the receiver was recording data in the 501.816 kHz and 125.454 kHz modes. The third plot shows the data from the 501.816 kHz conversion frequency intervals, dilated across the 156 second gap when data were taken for the 125.454 kHz and 250.908 kHz conversion frequencies. The lengths of the cyclic data intervals and gaps are noted on the overview plot.

Please note once again that overview plots from time periods when the WBD Plasma Wave Receiver cycled between different antennas or cycled through different conversion frequencies are not suitable for publication. Users of WBD receiver overview spectrograms are advised to contact the WBD Principal Investigator if they wish to publish data from time periods containing data from multiple instrument modes.

The Level 1 files, as well as the CDF files being provided to the CAA, used to generate the plots provided to the CAA have been corrected to account for problems with the OBDH on spacecraft 2. However, the OBDH problems on spacecraft 2 occasionally resulted in corrupt parameters in the status bits that determine the WBD gain state. When this happens, there is no way to know what the correct gain value should have been. This may result in incorrect calibrated spectral density in the 30-second spectrogram plots, which appear as sudden jumps in the intensity indicated by the color bar. This data interpretation issue has been documented in the instrument level metadata specification for spacecraft 2, as described in Section 5.

There are other data interpretation issues which have been described in a WBD Interpretation Issues document, such as spacecraft and other interference lines, spin modulations, ringing due to gain changes, instrumental harmonics, and the misidentification of tripolar and bipolar pulses. This WBD Interpretations Issues document is available at the CAA and on the Iowa WBD web site. All users of the WBD survey plots are advised to be aware of these data interpretation issues, to use their common sense when interpreting these data, and to contact the WBD PI if they find data they believe to be questionable or are uncertain of the proper data interpretation. In addition, the WBD Caveats Document available at the CAA and on the Iowa WBD web site should always be consulted for cautions on the use of the data and for a description of other known problems associated with the use of the WBD dataset.

4.5 Delivery Procedures

Before January 2014, pre-generated spectrograms and CDF files were placed on the CAA server by the WBD Plasma Wave Receiver team at the University of Iowa and CDF files were converted to CEF by CAA. Starting from 2014, Institute of Atmospheric Physics in Prague creates the CDF files for TDA8 mode and converts them to CEF. An analogous procedure is performed by University of Sheffield for BM2 data. The final CEF files are uploaded to CAA. Spectrograms are also generated by IAP (and University of Sheffield for BM2) and uploaded to CAA in the same format as before.

4.6 Data Available Through US Archive Sites

The WBD CDF files are currently being archived at NASA's CDAWeb web site, as well as at the CAA with all of the other Cluster data. In addition, various WBD plotting and data analysis tools are currently available through the University of Iowa WBD web site http://www-pw.physics.uiowa.edu/cluster/. A Digital Data Download Tool on the University of Iowa web site allows WBD waveform data to be downloaded for a specific time interval and spacecraft number into an ASCII file. The ASCII files contain the time in seconds after the input start time, the calibrated WBD electric field in mV/m or magnetic field in nT, a flag that indicates whether or not each data value is clipped, the WBD bandwidth setting and conversion frequency, the gain value in dB, the antenna used, and the resolution (1-bit, 4-bit, or 8-bit). Because of the high-time resolution of the WBD data, the files created by this tool can be very large. It is recommended that only data for time spans of less than 30 seconds be downloaded using this tool. Other tools available at the University of Iowa web site include a Line Plotting Tool, which allows the user to plot a single electric or magnetic waveform snapshot or spectrum, a Wavelet Plotting Tool, a Spectrogram Plotting Tool, and tools to plot the Cluster location and trajectory. Although these data tools do not require a password, investigators who wish to download or plot data though the University of Iowa web site should contact the WBD Principal Investigator, Jolene S. Pickett (pickett@uiowa.edu).

5 DATA PROVISION – SPECIFIC DESCRIPTIONS

5.1 Survey Plots

Overview spectrograms (frequency vs. time with color indicating spectral density, either electric field or magnetic field, as described in Section 4.1) in postscript and png format will be provided by Iowa to the CAA. The purpose of providing the overview spectrograms and the 30-second gif spectrograms to the CAA is to provide requestors of data a convenient method of surveying the WBD data

5.1.1 Format

The overview spectrograms (provided in both ps and png formats) show the data from all Cluster spacecraft on which the WBD instrument was active, and for which the data could be successfully processed during the indicated time interval. WBD passes can be as short as 10 minutes and as long as 5 hours. Typical passes are around 2 hours long. Due to problems with the power supply on spacecraft 3, WBD intervals are limited to only 10 minutes in length on this spacecraft starting January 14, 2004.

In addition to the overview spectrograms, 30-second high resolution plots will be provided to the CAA for each entire pass shown in the overview spectrograms. Although the postscript overview spectrograms may contain data from multiple spacecraft, the 30-second plots contain data from only one spacecraft. If more than one spacecraft was transmitting WBD Plasma Wave Receiver data at any one time, there will be a separate set of 30-second plots for each spacecraft.

For further information about the format of the overview spectrograms and the 30-second high resolution gif plots see Section 4.1 and the examples shown below in Section 5.1.6.

5.1.2 Standards

See section 4.2.

5.1.3 Production Procedure

The survey plots were produced at the University of Iowa using existing data processing and visualization tools. The details of the science data processing required to generate these plots were discussed in Section 3.3.3.

5.1.4 Quality Control Procedure

The quality control procedures taken to ensure that the data are correct were described in Section 4.4.

5.1.5 Delivery Procedure

Plots are transferred to the CAA as described in Section 4.5

5.1.6 Product Specification

Examples of the two types of WBD spectrogram plots provided to the CAA are shown in Figures 5.1 and 5.2.

Figure 5.1 shows an example of an overview of WBD data from a time period when chorus emissions were observed. Due to the nature of the WBD real-time operations at the ground stations, data from all four spacecraft are not always available. Panels are included in the overview plots for all of the spacecraft for which WBD data are available at any given time. During the example shown, data were available from spacecraft 1, 2, 3 and 4 for different parts of the plot time interval. The spectrograms are created by 1024 point FFTs and plotted with frequency on the vertical axis, increasing time on the horizontal, and color indicating either electric field or magnetic field spectral density, in units of $V^2m^2Hz^{-1}$ for the electric field and in relative dB for the magnetic. This example shows the electric plot

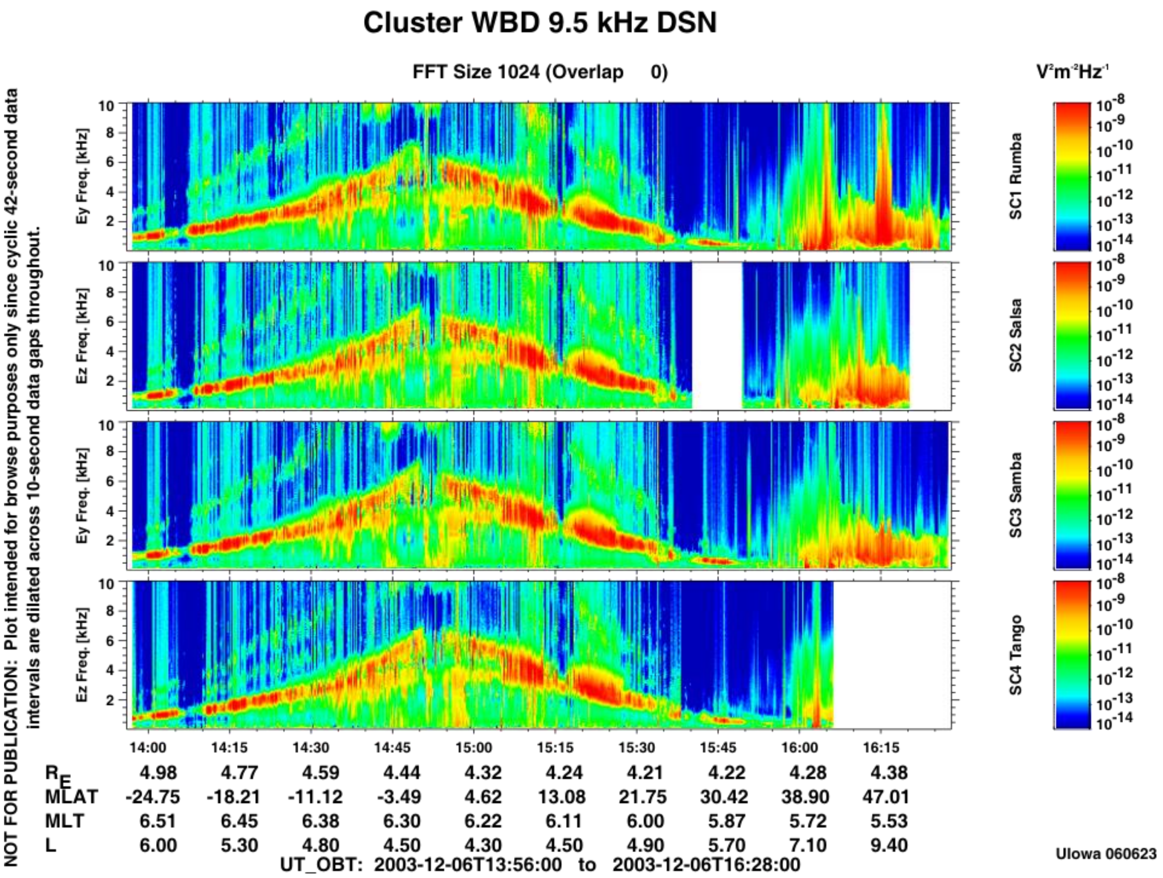

Figure 5.1. Example postscript overview of WBD interval. A detailed specification of these plots is provided in Section 4.1.

from a time period when the WBD receiver switched between the electric and magnetic field antennas, as described in Section 4.4. Text stating that this plot is not suitable for publication due to the mode changes appears on the left hand side. Below the time labels on the horizontal axis, are the ephemeris values applicable to the times marked on the horizontal axis. The ephemeris values are provided for the spacecraft whose data are shown in the bottom panel of the plot, just above the time axis labels (spacecraft 4, in the example shown in Figure 5.1). These ephemeris values are provided only as an indication of the general location of the Cluster quartet within the magnetosphere. Due to varying spacecraft separations, the ephemeris values for the spacecraft shown in the other plot panels may be considerably different from the values given for the spacecraft in the bottom panel. At the middle right-hand side are given the date and start time of the plot as well as the spacecraft number. The total time span of the overview plots depends on the length of WBD operations scheduled at the ground stations. When data from multiple spacecraft are shown in the overview plots, the time span in which WBD data are available for each spacecraft may be different. The plot production date is given in the lower right hand corner.

The 30-second duration survey spectrogram plots from the WBD instrument, such as the example shown in Figure 5.2, are created by 1024 point FFTs and plotted with frequency on the vertical axis increasing time on the horizontal, and color indicating electric field or magnetic field spectral density, in relative dB. Above the spectrogram is a line plot panel, followed by four status lines. The line plot panel at the top provides the gain state (0 to 75 dB, in 5 dB steps) of the instrument. The four status lines provide the following information according to the color code in the upper right corner:

> Data mode - whether from DSN or Panska Ves (PAN80 or PAN81), or from BM2 mode as digitally filtered or duty cycled.
> Antenna - the electric field (Ey or Ez) or the magnetic field (Bx or By) antenna used.
> Resolution - the data digitization level, which can be 1 bit, 4 bit or 8 bit.
> Translation - the translation from base frequency of 0 kHz.

In the lower right-hand corner are the ephemeris values applicable to the start time of the plot. At the middle right-hand side are given the date and start time of the plot as well as the spacecraft number.

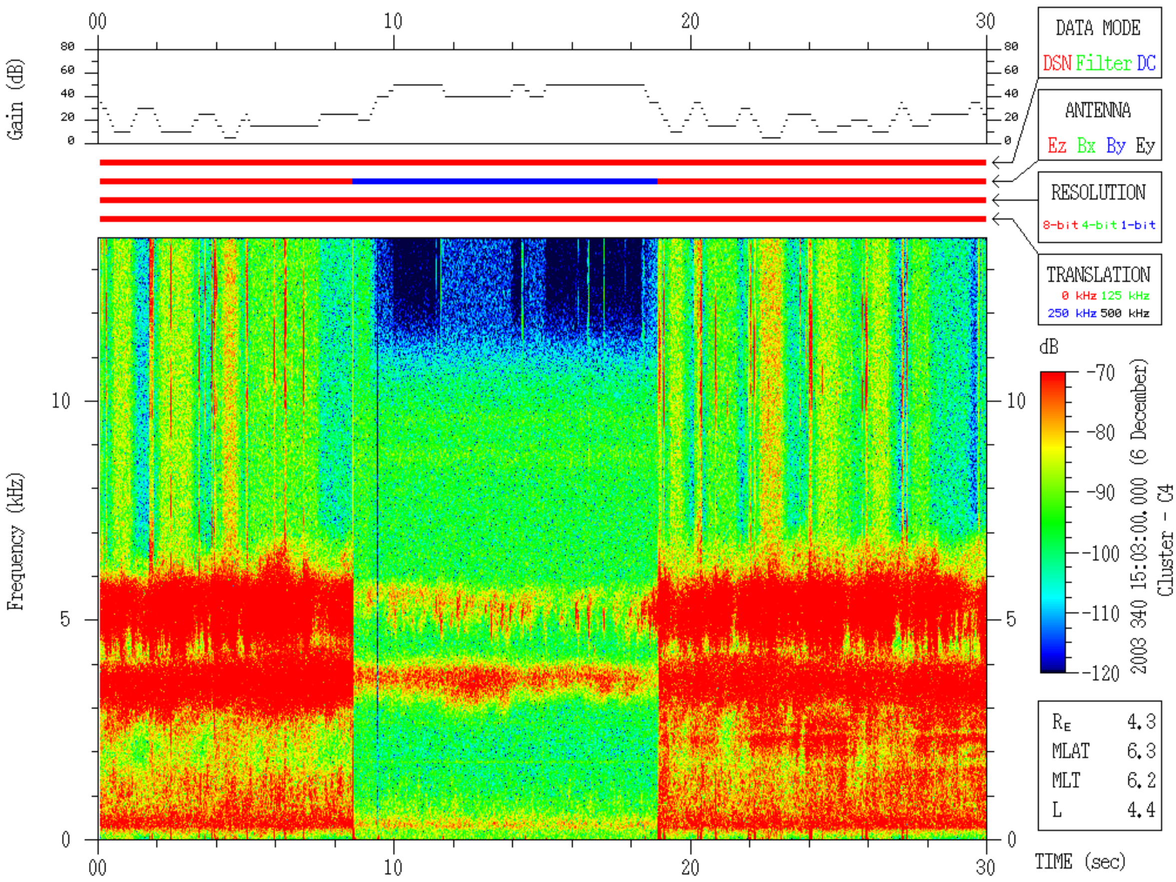

Figure 5.2: Example of the high resolution gif spectrogram plots each covering 30-second intervals. A detailed specification of these plots is provided in Section 4.1.

5.1.7 Metadata Specification

The metadata specification for the WBD graphical science data products agreed upon between the CAA and University of Iowa uses the CEF header syntax to specify the static metadata descriptions for the plots. This format simplifies ingestion of the plots into the CAA. Two types of datasets shall be defined, one for the interval level survey plots and the other for the high resolution 30-second spectrogram data. A separate dataset of each type shall be generated for each spacecraft. For plot files there is no equivalent of the digital data parameter level metadata. The metadata specifications therefore consist of the file level metadata, the metadata specifications for the 30-second and overview plots, the instrument level metadata for each spacecraft, and the WBD experiment level metadata for the entire Cluster quartet.

The file level metadata that specifies the individual product ID, filename and time interval of the observation shall be determined from the filename. The general filename syntax for the interval level postscript survey plots is YYMMDDhhmmss*.ps, where YY is the 2 digit year specification, MM is the month number, DD is the day of month, hh is hour of day, mm is minutes of hour, and ss is seconds of minute. For many WBD intervals, only a single overview plot was created. In these cases, the file names shall be in the format YYMMDDhhmmss.ps. However, if the WBD Plasma Wave Receiver cycled between different antennas or conversion frequencies, as described in Section 4.4, multiple postscript overview plots may have been generated. If all of the plots generated for the various instrument modes begin at the same time, the additional filenames will be the date and time, followed by “x of n”, where there are n plots with the same start time, and x is a number from 1 to n. If the plots generated for the various instrument modes do not begin at the same time, they will be named only with the date and time. Note that the CAA changes the names of these overview plots consistent with their naming convention. These file names will include both a start and an end time, among other things.

The filename syntax for the 30-second spectrogram plots is c*/YYYYDDDhhmmss.nn.gif, where ”cx/” is a subdirectory name and * is the spacecraft number 1 through 4, YYYY is the 4 digit year, DDD is the day of year, hh is the hour of day, mm is minutes of hour, ss is seconds of minute, and nn is a sequence number indicating the number of the high resolution 30-second plot within a 10 minute interval. The subdirectory name is included with the file name since these plots do not incorporate the spacecraft designator in the actual file name. Note that the CAA also changes the names of these plots to include a start and end time, among other things.

The experiment level metadata have been provided to the CAA in a file called CL_CH_WBD_EXP.CEH. This file contains spacecraft-independent information about the WBD experiment such as the key personnel for the WBD Receiver, the general experiment caveats for WBD as a whole that apply to all spacecraft, references for the experiment, and a brief experiment description.

In addition to the experiment level metadata, four files with names in the format C[1234]_CH_WBD_INST.CEH have been provided to the CAA to specify the instrument level metadata for each spacecraft. These files contain several standard Cluster Metadata Dictionary keywords defining the instrument type (Antenna, Double_Sphere, Search_Coil, Waveform_Receiver) and the measurement type (Electric_Field, Magnetic_Field, Radio_and_Plasma_Waves). The instrument level metadata file for each spacecraft also contains a brief description of the instrument caveats for the WBD Receiver which applies only to that spacecraft.

The metadata specifications for the 30-second spectrogram plots can be found in files called C[1,2,3,4]_CH_WBD_SPECPLOT_30S.CEH. These files include references to the Cluster mission level metadata file CL_CH_MISSION.ceh, the observatory level metadata files C[1234]_CH_OBS.ceh, the WBD experiment level metadata file CL_CH_WBD_EXP.ceh, and WBD instrument level metadata files C[1234]_CH_WBD_INST.ceh for each spacecraft in the Cluster quartet. They also include the dataset ID (C[1,2,3,4]_CG_WBD_SPECPLOT_30S), the dataset title (Survey spectrograms), the data type (CG), a description of the format of the 30-second plots, contact information and acknowledgments. Similar information for the postscript overview plots can be found in series of files called C[1,2,3,4]_CH_WBD_SPECPLOT_OVERVIEW.CEH for each spacecraft.

5.2 WBD digital waveform files

5.2.1 Format

Starting from 2014, The WBD digital waveform files are delivered to the CAA as CEF files produced at IAP from the source CDF files. Before 2014, Univesity of Iowa delivered CDF files that can also be downloaded from CAA. An excerpt from one of the CDF files delivered to the CAA is shown below:

```
Epoch, Bandwidth, Translation, Resolution, ANTENNA, Gain, Ant_B_Field_Angle, Ant_Xgse_Angle,
Ant_YZgse_Plane_Angle, DC_Offset, WBD_Elec, WBD_Mag, DATA_QUALITY

2001-04-15T18:30:00.000.024.441.888z, 9.5, 0.0, 8, 0, 75, 25.7, 87.2, 184.5, 127.54, -1.2267e-03, -
1.0000e+31, 0
2001-04-15T18:30:00.000.060.880.993z, 9.5, 0.0, 8, 0, 75, 25.7, 87.2, 184.5, 127.54, -1.8255e-03, -
1.0000e+31, 0
2001-04-15T18:30:00.000.097.320.097z, 9.5, 0.0, 8, 0, 75, 25.7, 87.2, 184.5, 127.54, -1.2267e-03, -
1.0000e+31, 0
2001-04-15T18:30:00.000.133.759.201z, 9.5, 0.0, 8, 0, 75, 25.7, 87.2, 184.5, 127.54, -1.1723e-03, -
1.0000e+31, 0
2001-04-15T18:30:00.000.170.198.306z, 9.5, 0.0, 8, 0, 75, 25.7, 87.2, 184.5, 127.54, -1.3900e-03, -
1.0000e+31, 0
```

The column headings which are shown separated by commas, are provided for reference and represent the 13 variables contained in the CDF files. The data shown below the column headings are also separated by commas and associated with the column headings. These variables are as follows:

1. Epoch: This is the time tag to picoseconds of each data point, given as an Epoch-16 variable. Note that the accuracy of the WBD time tags is on the order of 50 microseconds or better, but processed to the picosecond level to avoid rounding errors.
2. Bandwidth: Three possible values, in kHz. See Section 3.2.2.5 and Table 3.2.2.5-1.
3. Translation: Four possible values, in kHz. See section 3.2.2.3 and Table 3.2.2.3-1.
4. Resolution: 3 possible values, in bits/sample. See section 3.2.2.5 and Table 3.2.2.5-1.
5. Antenna: 4 possible values (0 through 3). See section 3.2.2.2 and Table 3.2.2.2-1.
6. Gain: 16 possible values, used in calibrating the data, in dB. See section 3.2.2.4 and Table 3.2.2.4-1. See also the WBD Calibration Report available on the CAA and at the WBD web site.
7. Ant_B_Field_Angle: Orientation of active antenna (variable 5) to ambient magnetic field, in degrees ranging from 0 to 180. i.e., total angle between antenna used for WBD measurement (variable 5) and FGM-measured B field direction. See Figure 5.3.
8. Ant_Xgse_Angle: Orientation of active antenna (variable 5) within a geocentric coordinate system, specifically the total angle between antenna used for WBD measurement (variable 5) and the Xgse axis in degrees ranging from 0 to 180. See Figure 5.3.
9. Ant_YZgse_Plane_Angle: Orientation of active antenna (variable 5) within a geocentric coordinate system, specifically the total angle between Ygse axis and the projection of the antenna direction (variable 5) in the Ygse-Zgse plane in degrees ranging from 0 to 360. See Figure 5.3.
10. DC_Offset: the average value of the zero point of the electric or magnetic field in each 1090 point sample, which is the sample size of a minor frame as mentioned above in Section 3.2.2.6.2, provided as a floating point number (should be close to 127 in normal 8 bit mode since raw data values range from 0 to 255). This number is used in calibrating the data to remove residual DC field effects, and can be used to convert calibrated data points back to original raw data values of 0 to 255 (see WBD Calibration Report).
11. WBD_Elec: This is the calibrated value of the electric field, in mV/m. Note that if an electric antenna is active (variable 5), there were will be a fill value for the calibrated magnetic field (variable 12) since WBD samples only one antenna at any one time. See also the WBD Calibration Report.
12. WBD_Mag: This is the calibrated value of the magnetic field, in nT. Note that if a magnetic

antenna is active (variable 5), there were will be a fill value for the calibrated electric field (variable 11) since WBD samples only one antenna at any one time. See also the WBD Calibration Report.

13. DATA_QUALITY: three possible values: 0 (data ok), 1 (data clipped or questionable), 2 (bad data value). A clipped data point is one in which the measurement was equal to raw data value maximum (255) or minimum (0). This does not necessarily mean the receiver was saturated, but the user should use caution. A bad data value means it was possible to determine through known receiver and data handler behavior that a data point was corrupted. In this case the data value will contain fill.

The above CEF excerpt is thus from 15 April 2001, starting at UT 18:30:00.000024441888. The WBD mode is bandwidth 9.5 kHz, translation of 0 kHz, 8 bits, Ez antenna (value of 0). The gain was 75 dB, which meant that only weak emissions were being detected since 75 dB of gain was being added to the system. The electric field for the first data point was -0.0012267 mV/m and the data quality was good. The three measured angles for this data point were 25.7, 87.2 and 184.5 degrees corresponding to variables 7, 8 and 9, respectively. The DC offset was 127.54. The data came from Cluster spacecraft 1, as would be apparent from the file name from which the data were taken, as well as information contained in the global attributes contained at the beginning of the file.

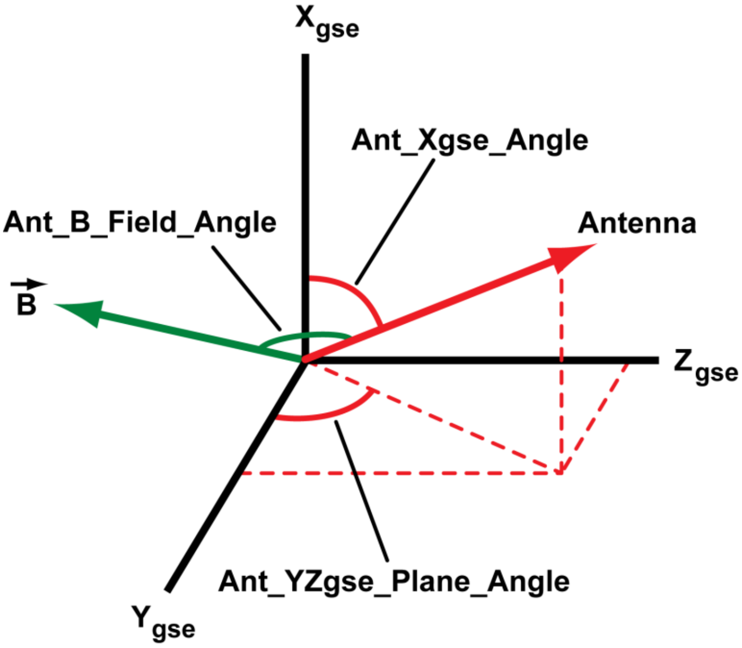

Figure 5.3: Orientation angles related to the WBD measurements (see variables 7-9 above)

5.2.2 Standards

See section 4.2.

5.2.3 Production Procedure

The CDF files were produced at the University of Iowa using existing data processing and visualization tools. Starting from January 2014, the conversion is performed at IAP and CEF files are delivered.

5.2.4 Quality Control Procedure

The quality control procedures taken to ensure that the data are correct were described in Section 4.4.

5.2.5 Delivery Procedure

The CEF files are transferred to the CAA as described in Section 4.5 .

5.2.6 Product Specification

The CDF data files which contain the actual digital calibrated waveform data cover at most 10 minutes of time and are on the order of a few hundred Mbytes each. The files are provided on even 10-minute boundaries, e.g., for UT hour 07 to 08, there could be at most six files spanning the following time ranges: 0700-0710, 0710-0720, … 0750-0800. They are delivered to the CAA as compressed CDF files with filenames of the format c*_waveform_wbd_YYYYMMDDhhmm_v01, where the * corresponds to the Cluster spacecraft number, 1 through 4, YYYY for the year, MM for the month, hh for the hour, and mm for the start minute. The "v" denotes that it is a compressed CDF file, and the numbers following the "v" are the version number. After ingestion of these files at the CAA, the CAA converts these files to CEF for distribution upon request by users.

5.2.7 Metadata Specification

Once the WBD CDF files have been converted to CEF format, the WBD data contained in these files are made available through the CAA interface in both CDF and CEF format. The metadata contained in the original CDF files will be retained as submitted and augmented by metadata supplied by the CAA when a user requests a CDF data download from the CAA. If a user requests CEF files, the various separate spacecraft and mission specific metadata files described in Section 5.1.7 are merged with the metadata contained in the WBD CDF files. The metadata contained in the CEF file for the example presented in Section 5.2.1 for spacecraft 1 on April 15, 2001 is provided below.

```
!-------------------- CEF ASCII FILE ----------------
FILE_NAME             = "C1_CP_WBD_WAVEFORM__20010415_183000_20010415_183100_V100614.cef"
FILE_FORMAT_VERSION       = "CEF-2.0"
END_OF_RECORD_MARKER      = "$"
!----------------------------------------------------
! START_CEFMERGE_INCLUDE = "C1_CH_WBD_WAVEFORM.ceh"

! Include mission header
! This header is provided by the CAA
!-----------------------------------
! START_CEFMERGE_INCLUDE = "CL_CH_MISSION.ceh"
!
!  CL_CH_MISSION.ceh
!  Global mission metadata provided by the CAA.
!
!  Save to your own hard drive so this file can be
!  included as CL_CH_MISSION.ceh in other cef files.
!

START_META = MISSION
    ENTRY  = "Cluster"
END_META   = MISSION

START_META      = MISSION_TIME_SPAN
    VALUE_TYPE = ISO_TIME_RANGE
    ENTRY      = 2000-08-16T12:39:00Z/2009-12-31T23:59:59Z
END_META        = MISSION_TIME_SPAN

START_META = MISSION_AGENCY
    ENTRY  = "ESA"
END_META   = MISSION_AGENCY

START_META = MISSION_DESCRIPTION
    ENTRY  = "The aim of the Cluster mission is to study small-scale structures of the magnetosphere "
    ENTRY  = "and its environment in three dimensions. To achieve this, Cluster is constituted of four "
    ENTRY   =  "identical  spacecraft  that  will  flight  in  a  tetrahedral  configuration.  The  separation
distances "
```

```
    ENTRY   = "between the spacecraft will be varied between ~40 km and 10 000 km, according to the "
    ENTRY   = "key scientific regions."
END_META    = MISSION_DESCRIPTION

START_META = MISSION_KEY_PERSONNEL
    ENTRY   = "Philippe Escoubet>Philippe.Escoubet@esa.int >Cluster Project Scientist"
END_META    = MISSION_KEY_PERSONNEL

START_META = MISSION_REFERENCES
    ENTRY    = "The Cluster and Phoenix Missions>Cluster project and instrument teams>Space Sci. Rev. 79,
Nos. 1-2, 1997"
END_META    =  MISSION_REFERENCES

START_META = MISSION_REGION
    ENTRY   = "Solar_Wind"
    ENTRY   = "Bow_Shock"
    ENTRY   = "Magnetosheath"
    ENTRY   = "Magnetopause"
    ENTRY   = "Magnetosphere"
    ENTRY   = "Magnetotail"
    ENTRY   = "Polar_Cap"
    ENTRY   = "Auroral_Region"
    ENTRY   = "Cusp"
    ENTRY   = "Radiation_Belt"
    ENTRY   = "Plasmasphere"
END_META    = MISSION_REGION

START_META = MISSION_CAVEATS
 ENTRY = "*CL"
END_META = MISSION_CAVEATS

! END_CEFMERGE_INCLUDE = "CL_CH_MISSION.ceh"

! Include observatory header
! This header is provided by the CAA
!-----------------------------------
! START_CEFMERGE_INCLUDE = "C1_CH_OBS.ceh"
!
!  C1_CH_OBS.ceh
!  Global Cluster1 metadata provided by the CAA.
!
! Save to your own hard drive so this file can be
! included as C1_CH_OBS.ceh in other cef files.
!

START_META      =   OBSERVATORY
    ENTRY       =   "Cluster-1"
END_META        =   OBSERVATORY

START_META      =   OBSERVATORY_CAVEATS
    ENTRY       =   "*C1_CQ"
END_META        =   OBSERVATORY_CAVEATS

START_META      = OBSERVATORY_DESCRIPTION
    ENTRY       = "Cluster-1 (Rumba)"
    ENTRY       = "Launched: 09 Aug 2000"
    ENTRY       = "ESA Number: 1"
    ENTRY       = "COSPAR ID: 2000-045A"
    ENTRY       = "USSPACECOM catalogue number 26463"
    ENTRY       = "CSDS Code: C1"
    ENTRY       = "ESOC FD code: S1"
    ENTRY       = "ESA Flight Model Number: FM5"
END_META        = OBSERVATORY_DESCRIPTION

START_META      = OBSERVATORY_TIME_SPAN
    VALUE_TYPE = ISO_TIME_RANGE
    ENTRY       = 2000-07-16T12:39:00Z/2009-12-31T23:59:59Z
END_META        = OBSERVATORY_TIME_SPAN

START_META = OBSERVATORY_REGION
    ENTRY   = "Solar_Wind"
    ENTRY   = "Bow_Shock"
    ENTRY   = "Magnetosheath"
    ENTRY   = "Magnetopause"
    ENTRY   = "Magnetosphere"
    ENTRY   = "Magnetotail"
    ENTRY   = "Polar_Cap"
    ENTRY   = "Auroral_Region"
    ENTRY   = "Cusp"
    ENTRY   = "Radiation_Belt"
    ENTRY   = "Plasmasphere"
END_META    = OBSERVATORY_REGION

! END_CEFMERGE_INCLUDE = "C1_CH_OBS.ceh"
```

```
! Include experiment header
!--------------------------
! START_CEFMERGE_INCLUDE = "CL_CH_WBD_EXP.ceh"
!
START_META     =   EXPERIMENT
   ENTRY       =   "WBD"
END_META       =   EXPERIMENT
!
START_META     =   EXPERIMENT_DESCRIPTION
   ENTRY       =   "The Wideband Data (WBD) Plasma Wave Investigation for Cluster provides wideband"
   ENTRY       =   "waveform measurements (up to 577 kHz) of plasma waves in the Earth's magnetosphere."
   ENTRY       =   "The Wideband Receiver measures electric and magnetic fields over the frequency"
   ENTRY       =   "range 100 Hz to 577 kHz as part of the Wave Experiment Consortium (WEC)"
   ENTRY       =   "instrumentation. The Wideband Data Plasma Wave Receiver provides unique high time "
   ENTRY        =   "and frequency resolution measurement capabilities required for the detailed study of
terrestrial "
   ENTRY       =   "plasma waves and radio emissions."
END_META       =   EXPERIMENT_DESCRIPTION
!
START_META     =   INVESTIGATOR_COORDINATES
   ENTRY       =   "Jolene Pickett>PI>pickett@uiowa.edu"
END_META       =   INVESTIGATOR_COORDINATES
!
START_META     =   EXPERIMENT_REFERENCES
   ENTRY       =   "Walker, S. N., M. A. Balikhin, I. Bates, and R. L. Huff, An investigation into"
   ENTRY       =   "instrumental nonlinear effects, Adv. Space Res., 30, 2815, 2002."
   ENTRY       =   "Gurnett, D. A., R. L. Huff, J. S. Pickett, A. M. Persoon, R. L. Mutel,"
   ENTRY       =   "I. W. Christopher, C. A. Kletzing, U. S. Inan, W. M. Martin, J. Bougeret,"
   ENTRY       =   "H. St. C. Alleyne, and K. H. Yearby, First results from the Cluster Wideband Plasma"
   ENTRY       =   "Wave Investigation, Ann. Geophysicae, 19, 1259, 2001."
   ENTRY       =   "Gurnett, D. A., R. L. Huff, and D. L. Kirchner, The Wide-Band Plasma Wave"
   ENTRY       =   "Investigation, Space Sci.Rev.,79,157,1997."
   ENTRY              =      "Cluster   II   Wideband   (WBD)   Plasma   Wave   Investigation,   http://www-
pw.physics.uiowa.edu/cluster/"
END_META       =   EXPERIMENT_REFERENCES
!
START_META     =   EXPERIMENT_KEY_PERSONNEL
   ENTRY       =   "Jolene Pickett>PI>pickett@uiowa.edu"
   ENTRY       =   "Donald Gurnett>Former PI>donald-gurnett@uiowa.edu"
   ENTRY       =   "Larry Granroth>WBD Systems Manager>larry-granroth@uiowa.edu"
   ENTRY       =   "Melvyn L. Goldstein>U.S. Cluster Project Scientist>melvyn.l.goldstein@nasa.gov"
END_META       =   EXPERIMENT_KEY_PERSONNEL
!
START_META     =   EXPERIMENT_CAVEATS
   ENTRY       =   "Data from the Cluster Wideband Data (WBD) Plasma Wave Receiver are not available"
   ENTRY       =   "continuously throughout the mission as the WBD data are directly received by a"
   ENTRY       =   "NASA Deep Space Network (DSN) station in real-time.  For a complete list of the"
   ENTRY       =   "science data availability beginning February 2001, please obtain this listing from "
   ENTRY              =      "Cluster   Active   Archive   documentation   or   refer   to:   http://www-
pw.physics.uiowa.edu/cluster/science/sds.html"
   ENTRY       =   "Users of the WBD Receiver data should be aware there are issues regarding"
   ENTRY         =    "the proper interpretation of impulses in the waveform data, such as bipolar and
tripolar pulses, "
   ENTRY       =   "as well as the generation of instrumental harmonics.  "
   ENTRY           =    "Please contact the PI or refer to the WBD website (provided below under
EXPERIMENT_REFERENCES) for further information."
   ENTRY        =   "For other general Cluster WBD Plasma Wave Receiver data interpretation issues, obtain
the document entitled Cl"
   ENTRY       =   "uster WBD Interpretation Issues from the Cluster Active Archive documentation or see:"
   ENTRY       =   "http://www-pw.physics.uiowa.edu/cluster/interpretation_issues/interpretation.html"
   ENTRY       =   "*CQ_WBD"
END_META       =   EXPERIMENT_CAVEATS
!
! END_CEFMERGE_INCLUDE = "CL_CH_WBD_EXP.ceh"

! Include instrument header
!--------------------------
! START_CEFMERGE_INCLUDE = "C1_CH_WBD_INST.ceh"
!
START_META     =   INSTRUMENT_NAME
   ENTRY       =   "WBD1"
END_META       =   INSTRUMENT_NAME
!
START_META     =   INSTRUMENT_DESCRIPTION
   ENTRY       =   "WBD Experiment on Cluster C1"
END_META       =   INSTRUMENT_DESCRIPTION
!
START_META     =   INSTRUMENT_TYPE
   ENTRY       =   "Antenna"
   ENTRY       =   "Double_Sphere"
   ENTRY       =   "Search_Coil"
   ENTRY       =   "Waveform_Receiver"
END_META       =   INSTRUMENT_TYPE
```

```
!
START_META     =   MEASUREMENT_TYPE
   ENTRY       =   "Magnetic_Field"
   ENTRY       =   "Electric_Field"
   ENTRY       =   "Radio_and_Plasma_Waves"
END_META       =   MEASUREMENT_TYPE
!
! END_CEFMERGE_INCLUDE = "C1_CH_WBD_INST.ceh"


START_META     =   DATASET_ID
   ENTRY       =   "C1_CP_WBD_WAVEFORM"
END_META       =   DATASET_ID
!
START_META     =   DATA_TYPE
   ENTRY       =   "CP>CAA_Parameter"
END_META       =   DATA_TYPE
!
START_META     =   DATASET_TITLE
   ENTRY       =   "High time resolution electric and magnetic waveform data (CEF)"
END_META       =   DATASET_TITLE
!
START_META     =   DATASET_DESCRIPTION
   ENTRY       =   "High time resolution calibrated waveform data sampled in one of 3 frequency"
   ENTRY       =   "bands in the range 0-577 kHz along one axis using either an electric field"
   ENTRY       =   "antenna or a magnetic search coil sensor.  The dataset also includes instrument"
   ENTRY       =   "mode, data quality and the angles required to orient the measurement with"
   ENTRY       =   "respect to the magnetic field and to the GSE coordinate system."
   ENTRY       =   "..."
   ENTRY       =   "CALIBRATION:"
   ENTRY       =   "..."
   ENTRY       =   "The procedure used in computing the calibrated Electric Field and Magnetic "
   ENTRY       =   "Field values found in this file can be obtained from the document "
   ENTRY       =   "'cluster_wbd_calibration.pdf'. Because the calibration was applied in the time"
   ENTRY       =   "domain using a simple equation the raw counts actually measured by the WBD"
   ENTRY       =   " instrument can be obtained by using these equat ions and solving for "
   ENTRY       =   "'Raw Counts', keeping in mind that this number is an Integer ranging "
   ENTRY       =   "from 0 to 255.  Since DC offset is a real number, the resultant when solving "
   ENTRY       =   "for raw counts will need to be converted to the nearest whole number."
   ENTRY       =   "..."
   ENTRY       =   "CONVERSION TO FREQUENCY DOMAIN:"
   ENTRY       =   "..."
   ENTRY       =   "In order to convert the WBD data to the frequency domain via an FFT, the "
   ENTRY       =   "following steps need to be carried out:"
   ENTRY       =   "  1) If Electric Field, first divide calibrated data values by 1000 to get V/m;"
   ENTRY       =   "  2) Apply window of preference, if any (such as Hanning, etc.);"
   ENTRY       =   "  3) Divide data values by sqrt(2) to get back to the rms domain;"
   ENTRY       =   "  4) perform FFT (see Bandwidth variable notes for non-continuous modes);"
   ENTRY       =   "  5) divide by the noise bandwidth, which is equal to the sampling frequency"
   ENTRY       =   "     divided by the FFT size (see table below for appropriate sampling frequency);"
   ENTRY       =   "  6) multiply by the appropriate constant for the window used, if any."
   ENTRY       =   "..."
   ENTRY       =   "Bandwidth   Sample Rate"
   ENTRY       =   "---------   ------------"
   ENTRY       =   "9.5 kHz      27.443 kHz "
   ENTRY       =   "19 kHz       54.886 kHz "
   ENTRY       =   "77 kHz      219.544 kHz "
   ENTRY       =   "..."
   ENTRY       =   "COORDINATE SYSTEM USED:"
   ENTRY       =   "..."
   ENTRY       =   "One axis measurements made in the Antenna Coordinate System, i.e., if electric"
   ENTRY       =   "field measurement, it will either be Ey or Ez, both of which are in the spin"
   ENTRY       =   "plane of the spacecraft, and if magnetic field measurement, it will either be "
   ENTRY       =   "Bx, along the spin axis, or By, in spin plane."
END_META       =   DATASET_DESCRIPTION
!
START_META     =   CONTACT_COORDINATES
   ENTRY       =   "Jolene Pickett>PI>pickett@uiowa.edu"
END_META       =   CONTACT_COORDINATES
!
START_META     =   TIME_RESOLUTION
   ENTRY       =   0.000035
END_META       =   TIME_RESOLUTION
!
START_META     =   MIN_TIME_RESOLUTION
   ENTRY       =   0.000035
END_META       =   MIN_TIME_RESOLUTION
!
START_META     =   MAX_TIME_RESOLUTION
   ENTRY       =   0.000035
END_META       =   MAX_TIME_RESOLUTION
!
START_META     =   PROCESSING_LEVEL
   ENTRY       =   "Calibrated"
```

```
END_META       =   PROCESSING_LEVEL
!
START_META     =   DATASET_CAVEATS
   ENTRY       =   "DATASET VERSION HISTORY"
   ENTRY       =   "======================="
   ENTRY       =   "V01/02 - Initial delivery and conversion of WBD waveform data"
   ENTRY       =   "Created Mar 2008. Revised Dec 2008, Jan 2010"
   ENTRY       =   "..."
   ENTRY       =   "(the ISTP global metadata included in the source CDF is given below)"
   ENTRY       =   "..."
   ENTRY       =   "TITLE[0]:           CLUSTER WBD"
   ENTRY       =   "Project[0]:         ISTP>International Solar-Terrestrial Physics"
   ENTRY       =   "Discipline[0]:      Space Physics>Magnetospheric Science"
   ENTRY       =   "Source_name[0]:     C1>Cluster spacecraft 1"
   ENTRY       =   "Data_type[0]:       waveform"
   ENTRY       =   "Descriptor[0]:      WBD>Wide Band Data Plasma Wave Receiver"
   ENTRY       =   "ADID_ref[0]:        NSSD0171"
   ENTRY       =   "Logical_source[0]:  c1_waveform_wbd"
   ENTRY         =   "Logical_source_description[0]: Cluster Wideband Data Plasma Wave Receiver/High Time
Resolution Waveform Data"
   ENTRY       =   "PI_name[0]:         2006 - Current:  J. S. Pickett; 1988 - 2006:  D. A. Gurnett"
   ENTRY       =   "PI_affiliation[0]:  The University of  Iowa"
   ENTRY       =   "Mission_group[0]:   Cluster"
   ENTRY       =   "Instrument_type[0]: Radio and Plasma Waves (space)"
   ENTRY       =   "HTTP_LinearK[0]:       http://www-pw.physics.uiowa.edu/cluster/"
   ENTRY       =   "HTTP_LinearK[1]:       http://caa.estec.esa.int/caa/"
   ENTRY       =   "LinearK_TITLE[0]:      Cluster Wideband Plasma Wave Investigation"
   ENTRY       =   "LinearK_TITLE[1]:      Cluster Active Archive"
   ENTRY        =   "Acknowledgement[0]: Users of the Cluster WBD data are encouraged to acknowledge NASA
Goddard Space Flight Center and The University of Iowa as the source of the data in any publication."
   ENTRY        =   "Rules_of_use[0]:     Cluster WBD data are open to everyone.  However, users of these
data are encouraged to contact the PI Institute should questions arise."
   ENTRY       =   "Time_resolution[0]: 1.0/Sample_rate"
   ENTRY        =   "LinearK_TEXT[0]:        Overview and high time resolution spectrograms, documentation,
and data coverage files"
   ENTRY         =   "LinearK_TEXT[1]:         High time resolution spectrograms, documentation, and data
coverage files"
   ENTRY       =   "File_naming_convention[0]: source_datatype_descriptor"
END_META       =   DATASET_CAVEATS
!
START_META     =   ACKNOWLEDGEMENT
   ENTRY       =   "Please acknowledge the WBD team, NASA and ESA Cluster Active Archive in any publication
based upon use of this data "
END_META       =   ACKNOWLEDGEMENT
!
!
!
START_VARIABLE   =  time_tags__C1_CP_WBD_WAVEFORM
    PARAMETER_TYPE      = "Support_Data"
    CATDESC             = "UT Time, time of WBD data point"
    UNITS               = "s"
    SI_CONVERSION       = "1.0>s"
    SIZES               = 1
    VALUE_TYPE          = ISO_TIME
    SIGNIFICANT_DIGITS  = 29
    FILLVAL             = 9999-12-31T23:59:59Z
    FIELDNAM            = "Universal Time"
    LABLAXIS            = "UT"
    DELTA_PLUS          = 0.0000002
    DELTA_MINUS         = 0.0000002
    PARAMETER_CAVEATS   = "On-board time is corrected to a precision of order 50 microseconds when compared
to UTC. The applied time correction comes from the DWP TCOR time correction files located at the Cluster
Active Archive (CAA)."
END_VARIABLE     =  time_tags__C1_CP_WBD_WAVEFORM
!
!
START_VARIABLE   =  Bandwidth__C1_CP_WBD_WAVEFORM
    PARAMETER_TYPE      = "Data"
    ENTITY              = "Instrument"
    PROPERTY            = "Status"
    FLUCTUATIONS        = "Waveform"
    CATDESC             = "Frequency Bandwidth: 9.5 kHz, 19 kHz, 77 kHz"
    UNITS               = "kHz"
    SI_CONVERSION       = "1.0E3>Hz"
    SIZES               = 1
    VALUE_TYPE          = FLOAT
    SIGNIFICANT_DIGITS  = 5
    FILLVAL             = -1.0e+31
    FIELDNAM            = "Frequency Bandwidth"
    SCALEMIN            = 0.0
    SCALEMAX            = 80.0
    SCALETYP            = "Linear"
    LABLAXIS            = "Bandwidth"
    DEPEND_0            = time_tags__C1_CP_WBD_WAVEFORM
```

```
    PARAMETER_CAVEATS    = "WARNING:  19 and 77 kHz Bandwidth modes with 8-bit resolution, and 77 kHz
Bandwidth mode with 4-bit resolution (see Resolution__ variable) are not continuous data modes. Always
check for periodic time jumps for these modes."
    QUALITY             = "0"
END_VARIABLE     =  Bandwidth__C1_CP_WBD_WAVEFORM
!
!
START_VARIABLE  =  Translation__C1_CP_WBD_WAVEFORM
    PARAMETER_TYPE      = "Data"
    ENTITY              = "Instrument"
    PROPERTY            = "Status"
    FLUCTUATIONS        = "Waveform"
    CATDESC             = "Base freq. of freq. bandwidth (0.0, 125.454, 250.908, and 501.816 kHz)"
    UNITS               = "kHz"
    SI_CONVERSION       = "1.0E3>Hz"
    SIZES               = 1
    VALUE_TYPE          = FLOAT
    SIGNIFICANT_DIGITS  = 6
    FILLVAL             = -1.0e+31
    FIELDNAM            = "Frequency Shift"
    SCALEMIN            = 0.0
    SCALEMAX            = 510.0
    SCALETYP            = "Linear"
    LABLAXIS            = "Freq.Shift"
    DEPEND_0            = time_tags__C1_CP_WBD_WAVEFORM
    PARAMETER_CAVEATS   = "Also known as Conversion Frequency."
    QUALITY             = "0"
END_VARIABLE     =  Translation__C1_CP_WBD_WAVEFORM
!
!
START_VARIABLE  =  Resolution__C1_CP_WBD_WAVEFORM
    PARAMETER_TYPE      = "Data"
    ENTITY              = "Instrument"
    PROPERTY            = "Status"
    FLUCTUATIONS        = "Waveform"
    CATDESC             = "Number of bits used when digitizing waveform (8-bit, 4-bit, or 1-bit)"
    UNITS               = "bits"
    SI_CONVERSION       = "1>(bits)"
    SIZES               = 1
    VALUE_TYPE          = INT
    SIGNIFICANT_DIGITS  = 3
    FILLVAL             = -128
    FIELDNAM            = "Digital Resolution"
    SCALEMIN            = 1
    SCALEMAX            = 8
    SCALETYP            = "Linear"
    LABLAXIS            = "Dig. Res."
    DEPEND_0            = time_tags__C1_CP_WBD_WAVEFORM
    QUALITY             = "0"
END_VARIABLE     =  Resolution__C1_CP_WBD_WAVEFORM
!
!
START_VARIABLE  =  Antenna__C1_CP_WBD_WAVEFORM
    PARAMETER_TYPE      = "Data"
    ENTITY              = "Instrument"
    PROPERTY            = "Status"
    FLUCTUATIONS        = "Waveform"
    CATDESC             = "Antenna (0=Ez, 1=Bx, 2=By, 3=Ey)"
    UNITS                 = "unitless"
    SI_CONVERSION       = "1.0>(ordinal 0=Ez, 1=Bx, 2=By, 3=Ey)"
    SIZES               = 1
    VALUE_TYPE          = INT
    SIGNIFICANT_DIGITS  = 3
    FILLVAL             = -128
    FIELDNAM            = "Antenna"
    SCALEMIN            = 0
    SCALEMAX            = 3
    SCALETYP            = "Linear"
    LABLAXIS            = "Antenna"
    DEPEND_0            = time_tags__C1_CP_WBD_WAVEFORM
    QUALITY             = "0"
END_VARIABLE     =  Antenna__C1_CP_WBD_WAVEFORM
!
!
START_VARIABLE  =  Gain__C1_CP_WBD_WAVEFORM
    PARAMETER_TYPE      = "Data"
    ENTITY              = "Instrument"
    PROPERTY            = "Status"
    FLUCTUATIONS        = "Waveform"
    CATDESC             = "Gain state of WBD instrument"
    UNITS               = "dB"
    SI_CONVERSION       = "1.0>(dB)"
    SIZES               = 1
    VALUE_TYPE          = INT
```

```
    SIGNIFICANT_DIGITS  = 3
    FILLVAL             = -128
    FIELDNAM            = "Gain"
    SCALEMIN            = 0
    SCALEMAX            = 80
    SCALETYP            = "Linear"
    LABLAXIS            = "WBD Gain"
    DEPEND_0            = time_tags__C1_CP_WBD_WAVEFORM
    PARAMETER_CAVEATS   = "Steps of 5 dB from 0 to 75."
    QUALITY             = "0"
END_VARIABLE     =  Gain__C1_CP_WBD_WAVEFORM
!
!
START_VARIABLE   =  Ant_B_Field_Angle__C1_CP_WBD_WAVEFORM
    PARAMETER_TYPE      = "Data"
    ENTITY              = "Instrument"
    PROPERTY            = "Status"
    FLUCTUATIONS        = "Waveform"
    CATDESC                 = "Total angle between antenna used for WBD measurement and measured B field
direction"
    UNITS               = "degrees"
    SI_CONVERSION       = "1.0>degrees"
    SIZES               = 1
    VALUE_TYPE          = FLOAT
    SIGNIFICANT_DIGITS  = 5
    FILLVAL             = -1.0E+31
    FIELDNAM            = "Antenna-B Field Total Angle"
    SCALEMIN            = 0.0
    SCALEMAX            = 180.0
    SCALETYP            = "Linear"
    LABLAXIS            = "Ant-B Ang"
    DEPEND_0            = time_tags__C1_CP_WBD_WAVEFORM
    PARAMETER_CAVEATS   = "Antenna refers to the antenna in use, either E or B.  See Antenna__ variable."
    QUALITY             = "0"
END_VARIABLE     =  Ant_B_Field_Angle__C1_CP_WBD_WAVEFORM
!
!
START_VARIABLE   =  Ant_Xgse_Angle__C1_CP_WBD_WAVEFORM
    PARAMETER_TYPE      = "Data"
    ENTITY              = "Instrument"
    PROPERTY            = "Status"
    FLUCTUATIONS        = "Waveform"
    CATDESC             = "Total angle between the Xgse axis and the antenna direction"
    UNITS               = "degrees"
    SI_CONVERSION       = "1.0>degrees"
    SIZES               = 1
    VALUE_TYPE          = FLOAT
    SIGNIFICANT_DIGITS  = 5
    FILLVAL             = -1.0E+31
    FIELDNAM            = "Antenna Xgse Angle"
    SCALEMIN            = 0.0
    SCALEMAX            = 180.0
    SCALETYP            = "Linear"
    LABLAXIS            = "Ant_Xgse"
    DEPEND_0            = time_tags__C1_CP_WBD_WAVEFORM
    PARAMETER_CAVEATS    = "Total angle between the Xgse axis and the antenna direction. Antenna refers to
the antenna in use, either E or B.  See ANTENNA variable."
    QUALITY             = "0"
END_VARIABLE     =  Ant_Xgse_Angle__C1_CP_WBD_WAVEFORM
!
!
START_VARIABLE   =  Ant_YZgse_Plane_Angle__C1_CP_WBD_WAVEFORM
    PARAMETER_TYPE      = "Data"
    ENTITY              = "Instrument"
    PROPERTY            = "Status"
    FLUCTUATIONS        = "Waveform"
    CATDESC              = "Total angle between Ygse axis and the projection of the antenna direction in the
Ygse-Zgse plane"
    UNITS               = "degrees"
    SI_CONVERSION       = "1.0>degrees"
    SIZES               = 1
    VALUE_TYPE          = FLOAT
    SIGNIFICANT_DIGITS  = 5
    FILLVAL             = -1.0e31
    FIELDNAM            = "Antenna YZgse-Plane Angle"
    SCALEMIN            = 0.0
    SCALEMAX            = 360.0
    SCALETYP            = "Linear"
    LABLAXIS            = "Ant_YZgse"
    DEPEND_0            = time_tags__C1_CP_WBD_WAVEFORM
    PARAMETER_CAVEATS    = "Total angle between Ygse axis and the projection of the antenna direction in the
Ygse-Zgse plane, measured counter-clockwise from +Ygse (angle=0 deg) to +Zgse (angle=90 deg), -Ygse
(angle=180 deg) and -Zgse (angle=270 deg).  Antenna refers to the antenna in use, either E or B.  See
ANTENNA variable."
```

```
    QUALITY              = "0"
END_VARIABLE    =  Ant_YZgse_Plane_Angle__C1_CP_WBD_WAVEFORM
!
!
START_VARIABLE  =  DC_Offset__C1_CP_WBD_WAVEFORM
    PARAMETER_TYPE       = "Data"
    ENTITY               = "Instrument"
    PROPERTY             = "Status"
    FLUCTUATIONS         = "Waveform"
    CATDESC              = "DC Offset used when converting from raw digital values to calibrated data"
    UNITS                  = "unitless"
    SI_CONVERSION        = "1.0>unitless"
    SIZES                = 1
    VALUE_TYPE           = FLOAT
    SIGNIFICANT_DIGITS   = 5
    FILLVAL              = -1.0e31
    FIELDNAM             = "DC Offset"
    SCALEMIN             = 0.0
    SCALEMAX             = 255.0
    SCALETYP             = "Linear"
    LABLAXIS             = "DC Offset"
    DEPEND_0             = time_tags__C1_CP_WBD_WAVEFORM
    PARAMETER_CAVEATS     = "DC Offset values may be used to reverse calibrate the data to the original raw
counts and to determine the boundaries of the original transport packets. A description of the procedure
may be found in the 'cluster_wbd_calibration.pdf' document (see Global attributes section of this file).
In addition, sample code for reverse calibration may be found in the above mentioned document."
    QUALITY              = "0"
END_VARIABLE    =  DC_Offset__C1_CP_WBD_WAVEFORM
!
!
START_VARIABLE  =  E__C1_CP_WBD_WAVEFORM
    PARAMETER_TYPE       = "Data"
    ENTITY               = "Electric_Field"
    PROPERTY             = "Magnitude"
    FLUCTUATIONS         = "Waveform"
    CATDESC              = "Calibrated AC WBD Electric Field"
    UNITS                = "mV/m"
    SI_CONVERSION        = "1.0e-3>V m^-3"
    SIZES                = 1
    VALUE_TYPE           = FLOAT
    SIGNIFICANT_DIGITS   = 7
    FILLVAL              = -1.0e31
    FIELDNAM             = "WBD AC Electric Field"
    SCALEMIN             = -50.0
    SCALEMAX             = 50.0
    SCALETYP             = "Linear"
    LABLAXIS             = "E-field"
    DEPEND_0             = time_tags__C1_CP_WBD_WAVEFORM
    PARAMETER_CAVEATS    = "For non-CAA quality information see parameter Quality__ parameter"
    QUALITY              = "3"
END_VARIABLE    =  E__C1_CP_WBD_WAVEFORM
!
!
START_VARIABLE  =  B__C1_CP_WBD_WAVEFORM
    PARAMETER_TYPE       = "Data"
    ENTITY               = "Magnetic_Field"
    PROPERTY             = "Magnitude"
    FLUCTUATIONS         = "Waveform"
    CATDESC              = "Calibrated AC WBD Magnetic Field"
    UNITS                = "nT"
    SI_CONVERSION        = "1.0e-9>T"
    SIZES                = 1
    VALUE_TYPE           = FLOAT
    SIGNIFICANT_DIGITS   = 7
    FILLVAL              = -1.0e31
    FIELDNAM             = "WBD AC Magnetic Field"
    SCALEMIN             = -10.0
    SCALEMAX             = 10.0
    SCALETYP             = "Linear"
    LABLAXIS             = "B-field"
    DEPEND_0             = time_tags__C1_CP_WBD_WAVEFORM
    PARAMETER_CAVEATS    = "For non-CAA quality information see parameter Quality__ parameter"
    QUALITY              = "3"
END_VARIABLE    =  B__C1_CP_WBD_WAVEFORM
!
!
START_VARIABLE  =  Quality__C1_CP_WBD_WAVEFORM
    PARAMETER_TYPE       = "Data"
    ENTITY               = "Instrument"
    PROPERTY             = "Status"
    FLUCTUATIONS         = "Waveform"
    CATDESC              = "Data Quality: 0 = OK, 1 = clipped or questionable, 2 = bad data point."
    UNITS                  = "unitless"
    SI_CONVERSION        = "1.0>unitless"
```

```
    SIZES               = 1
    VALUE_TYPE          = INT
    SIGNIFICANT_DIGITS  = 3
    FILLVAL             = -128
    FIELDNAM            = "Data Quality"
    SCALEMIN            = 0
    SCALEMAX            = 3
    SCALETYP            = "Linear"
    LABLAXIS            = "Data Qual"
    DEPEND_0            = time_tags__C1_CP_WBD_WAVEFORM
    PARAMETER_CAVEATS    = "Clipped data:  Measurement was equal to raw data value maximum (255) or minimum
(0).  This does not necessarily mean the receiver was in saturation, which would be accompanied by non-
linear effects. "
    QUALITY             = "0"
END_VARIABLE    =  Quality__C1_CP_WBD_WAVEFORM
!
! END_CEFMERGE_INCLUDE = "C1_CH_WBD_WAVEFORM.ceh"
!----------------------------------------------------
!
START_META               = FILE_TYPE
ENTRY                    = "cef"
END_META                 = FILE_TYPE
!
START_META               = LOGICAL_FILE_ID
  ENTRY      = "C1_CP_WBD_WAVEFORM__20010415_183000_20010415_183100_V100614"
END_META                 = LOGICAL_FILE_ID
!
!
START_META               = VERSION_NUMBERs
  ENTRY      = 100614
END_META                 = VERSION_NUMBER
!
START_META   = DATASET_VERSION
    ENTRY    = "Merged file, the dataset version for each segment follows:-"
    ENTRY    = "2001-04-15T18:30:00Z/2001-04-15T18:31:00Z , C1_CP_WBD_WAVEFORM__20010415_1830_V01"
    ENTRY    = "  V1.0 Jan 2010"
END_META     = DATASET_VERSION
!
START_META   = FILE_CAVEATS
    ENTRY    = "CAA Merged File - $Id: cefmerge.c,v 1.27 2009/04/09 09:40:06 cperry Exp cperry $"
    ENTRY    = "The file caveats for each segment follows:-"
    ENTRY    = "2001-04-15T18:30:00Z/2001-04-15T18:31:00Z , C1_CP_WBD_WAVEFORM__20010415_1830_V01"
    ENTRY    = "  File converted by CAA Fri May 28 19:07:05 2010"
    ENTRY    = "  Source File: C1_CE_WBD_WAVEFORM_CDF__20010415_1830_V01.cdf"
    ENTRY    = "  Application name: cdf2cef_64_20100527"
END_META     = FILE_CAVEATS
!
START_META               = FILE_TIME_SPAN
VALUE_TYPE               = ISO_TIME_RANGE
  ENTRY      = 2001-04-15T18:30:00.000Z/2001-04-15T18:31:00.000Z
END_META                 = FILE_TIME_SPAN
!
START_META               = GENERATION_DATE
VALUE_TYPE               = ISO_TIME
  ENTRY      = 2012-05-05T14:50:25Z
END_META                 = GENERATION_DATE
!
!----------------------------------------------------
```