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Cluster Active Archive:
Interface Control Document for RAPID

Max-Planck-Institut für Sonnensystemforschung

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For 1st Operations Review May 2006

Document Status Sheet

1. Document Title: **CAA ICD for RAPID**

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3. Issue	4. Revision	5. Date	6. Reason for Change
Draft	0	2004 Jun 28	Preliminary, incomplete
	0.5	2004 Nov 26	With products listed
	0.6	2004 Dec 7	For CAA internal review
	0.7	2005 Jan 28	Change variable names (e.g., Ion_He → Helium)
	0.7	2005 Feb 9	Change 'L2' in the L3DD variable naming to 'L' (e.g., Electron_L2_Dif_flux_3D → Electron_L_Dif_flux_3D)
	0.7	2005 Feb 14	Add IPITCH and EPITCH to the list of products, ensure consistency of variable order in product descriptions between written descriptions and array order, e.g., [8,12,16] means 8 channels, 12 polar directions and 16 azimuthal sectors.
	0.8	2005 Feb 17	Add graphical products to product list and thus add some sentences about plots in chapters 4 and 5 + some minor corrections.
	0.9	2005 Apr 7	E3DD_NM changed to E2DD.
1	0	2005 Apr 21	Rework parts, which needed updating because of calibration revision and the introduction of `sci2caa` software. Paragraphs on calibration were shortened. Finalize the document for the CAA implementation review.
1	1	2006 Apr 10	Add short description of IDL RAPID visualization software. Add product description of EPADEX, IPADEX, DE, PED, HK, caveats, instrument settings. Correct descriptions of omnidirectional electron products and all helium and hydrogen products due to changes in energy levels and introduction of fill values for several channels.
1	2	2006 Apr 26	Update description of calibration files; revise instrument settings, caveats; add PEDPOS.
2	0	2006 May 4	Update delivery schedule and summary plot description. Finalize the document for the 1st CAA operations review.

Contents

List of Acronyms

BM	Burst Mode, Cluster high telemetry rate
CAA	Cluster Active Archive
CDF	Common Data Format (NASA format)
CEF	Cluster Exchange Format (CAA format)
CF	Conversion Factor
DPU	Digital Processing Unit
ENA	Energetic Neutral Atoms
ESA	European Space Agency
GF	Geometry Factor
IEL	Inter-Experimental Link
IES	Imaging Electron Spectrometer (part of RAPID)
IIMS	Imaging Ion Mass Spectrometer (part of RAPID)
LUT	Look-Up Table (for IES)
MCP	Multichannel Plate
MPS	Max-Planck-Institut für Sonnensystemforschung, Lindau, Germany
MSF	Merged Science File (RAPID raw data)
NM	Nominal Mode, Cluster low telemetry rate
PI	Principal Investigator
RAPID	Research with Adaptive Particle Imaging Detectors (Cluster Experiment)
SCENIC	Spectroscopic Camera for Electrons, Neutral, and Ion Composition (part of RAPID)
SCI	SCIence file, RAPID-specific format for processed data
SCU	Signal Conditioning Unit
TOF	Time-Of-Flight

Reference Documents

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2. RAPID Flight Operations User Manual. Version 3.0, Max-Planck-Institut für Aeronomie, Katlenburg-Lindau, Germany, June 2000. URL `http://mps.mpg.de/dokumente/projekte/cluster/rapid/Rapid_flight_man30.pdf`.

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12. Müllers, A., Rathje, R., and Dierker, C. RAPID: Instrument User's Guide. Version 2.8, Institut für Datenverarbeitungsanlagen, Technische Universität Braunschweig, May 2001. URL `http://mps.mpg.de/dokumente/projekte/cluster/rapid/guide28.pdf`, annex 1 of [Ref. 2].

13. Mühlbachler, S. and Daly, P. W. Userguide to the RAPID Data Visualization Software. Report CAA–RAP–UM–0022, Issue 0.3, Max-Planck-Institut für Sonnensystemforschung, Katlenburg-Lindau, Germany, April 2006. URL `http://mps.mpg.de/dokumente/projekte/cluster/rapid/rap_vis_sw.pdf`.

1 Purpose

The CAA has the objective of archiving all the relevant scientific data, metadata, documentation, support files from the Cluster Mission (launched July-August 2000, see Escoubet et al. [Ref. 1] for payload description) while the Mission is still operating and the experiment teams still functioning. This project is defined by the Systems Specification Document [Ref. 3] User Requirements Document [Ref. 4], and the Management Plan [Ref. 5].

As one of the Cluster experiments, RAPID is contributing to this effort as layed out in the RAPID Archiving Plan [Ref. 6].

The purpose of this document is to specify the interfaces between the

Cluster Active Archive (CAA) as operated by the European Space Agency (ESA)

and the

RAPID Archiving Team at the Max-Planck-Institut für Sonnensystemforschung (MPS)

In addition, it is expected that this document may also be helpful to the users of CAA, in that much detail is given about the RAPID instrument and the data sets that are generated.

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The RAPID Archiving Team at MPS consists of

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3 Instrument Description

3.1 Science Objectives

Over many years of intense research the Earth magnetosphere has emerged as a highly structured and dynamic, magnetically contained body of plasma. At times or permanently parts of the magnetosphere seem to be connected with interplanetary field lines. The field topology in the outer regions of the magnetosphere and its time dependence are largely a result of currents carried by the thermal plasma. The suprathermal component, on the other hand, may be less important for most of the macroscopic plasma quantities but it plays an important role in its own right due to peculiarities in the physics of energetic particles. Acceleration processes in the magnetosphere of still unknown nature energize particles elsewhere in the magnetosphere to hundreds of keV. The relatively fast motion of these particles can carry information about the energization process over significant distances to an observing platform. Studies of the intensity profile, the energy distribution, and the ionic mass and charge composition can provide important clues on the nature of the process. Furthermore, the kinetic properties of these particles can be used as a tool to trace out plasma structures over distances as large as an Earth radius by utilizing the particle's gyroradius. Information can even be transmitted over global distances by the rapid drift of energetic particles in field gradients or, even more important, by field-aligned swift electrons travelling with speeds comparable with the speed of light. In tail-like field configurations these particles can transmit near instantaneous information on changes in the field topology over very large distances.

The Cluster polar orbit (4×19 R_E), provides excellent opportunities for energetic particle studies. The physics at the magnetopause, the bow shock, and the near-earth magnetotail are key regions of interest for the RAPID investigation. The state-of-the-art detection techniques, the large energy range for nuclei and electrons, and the complete coverage of the unit sphere in velocity space lead to the following capabilities:

- Remote sensing of local density gradients over distances comparable with particle gyroradii. Species dependent structures in gradients can be studied, gradient motions can be resolved to one spin period (T $\approx$ 4 sec).
- Determination of major ion species (H, He, CNO) in the energetic plasma component. A special operational mode allows the identification and analysis of energetic neutral atoms (ENA).
- Characterization of magnetic field line topologies using the fast motion of energetic electrons.

These observational features allow detailed studies in all regions of geospace visited by Cluster. The RAPID instrument uses two different and independent detector systems for the detection of nuclei and electrons, i.e., The **I**maging **I**on **M**ass **S**pectrometer (IIMS) and the **I**maging **E**lectron **S**pectrometer (IES).

3.2 Hardware Overview

The RAPID experiment is described by Wilken et al. [Ref. 7], and also in the Flight Operational Manual [Ref. 2]. The instrument is physically a single structure which contains all major elements like the IIMS and IES sensor systems, the front-end electronics (called SCU), and the digital processing unit (DPU) with the low-voltage power-supply (LVPS) and the spacecraft interface.

3.2.1 The IIMS Instrument

The centerpiece of the IIMS sensor system is the so-called SCENIC (Spectroscopic Camera for Electrons, Neutral, and Ion Composition) detector head, shown in Figure 1. In essence, this is a miniature telescope composed of a time-of-flight and an energy detection system. The particle identifying function of the SCENIC spectrometer is obtained from a two-parameter measurement: the particle's velocity V and its energy E are measured as independent quantities; the particle's mass A is then uniquely determined either by computation ($A \sim E/2$) or by statistical analysis in two-dimensional (V, E) space with the mass A as the sorting parameter. Actually the velocity detector measures the flight time T take by the particle to travel a known distance in the detector geometry.

Each SCENIC head has a field-of-view that is 6° wide (in the direction of the spacecraft spin) and 60° in the other direction (in the plane containing the spin axis). By means of the imaging features of this instrument, the particle's incident direction is assigned to one of 4 subdivisions of this field-of-view, each of 15° height. With three detector heads in all, the full range of 0–180° is covered by 12 polar angular segments (left side of Figure 3).

There are two sampling modes for IIMS heads:

serial mode: only one of the three SCENIC heads is active at any one time, each being turned on for a fixed time; after all three have had their accumulation time, they wait until the next sector starts before accumulating once more, one after another.

parallel mode: all three heads are active at the same time, for a fixed time, after which they are turned off until the start of the next sector.

See Section 3.2.3 for more information.

3.2.2 The IES Instrument

Electrons with energies from 20 keV to 400 keV are measured with the IES (Imaging Electron Spectrometer). Advanced microstrip solid state detectors having a 0.5 cm $\times$ 1.5 cm planar format with three individual elements form the image plane for three acceptance "pin-hole" systems. Each system divides a 60° segment into 3 angular intervals, Figure 2. Three of these detectors provide electron measurements over a 180° fan (middle of Figure 3).

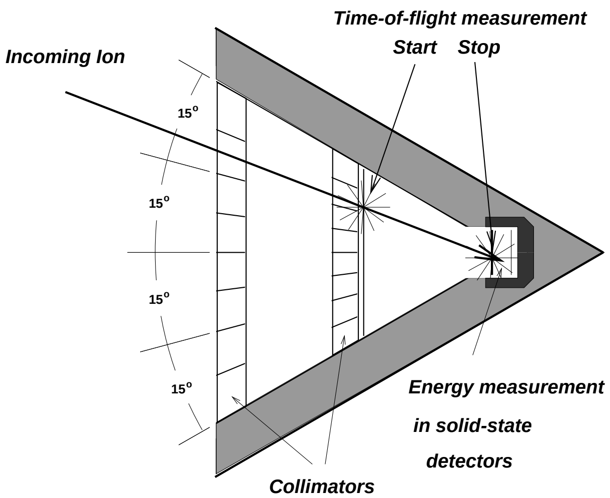

Figure 1: One of the three SCENIC heads making up the IIMS part of RAPID. Shown is an incoming ion that triggers a start signal at a foil, which also serves to determine the fine direction, and a stop signal when it enters the solid state detector, where its energy is measured.

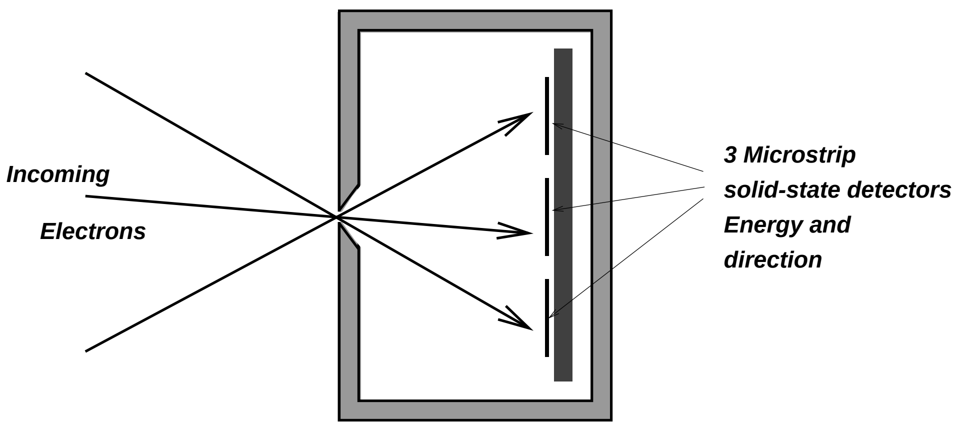

Figure 2: One of the three IES heads, containing three solid state detectors to determine the direction of the incoming detected electron to within 20°.

	IIMS	IES
Protons	$28 - 1500$ keV	—
Helium	$138 - 1500$ keV	—
CNO	$90 - 1500$ keV	—
Electrons	—	$35 - 400$ keV
Mass Resolution (A/dA)	4 (oxygen)	—
Field–of–view	$\pm 3° \times 180°$	$\pm 17.5° \times 180°$
Angular coverage		
Polar (Range/intervals)	180°/12	180°/9
Azimuthal (Range/intervals)	360°/16	360°/16
Geometric Factor(per segment)	2.2×10^{-3} cm$^2 \cdot$ sr	2.2×10^{-3} cm$^2 \cdot$ sr

Table 1: Characteristics of the IIMS and IES sensors.

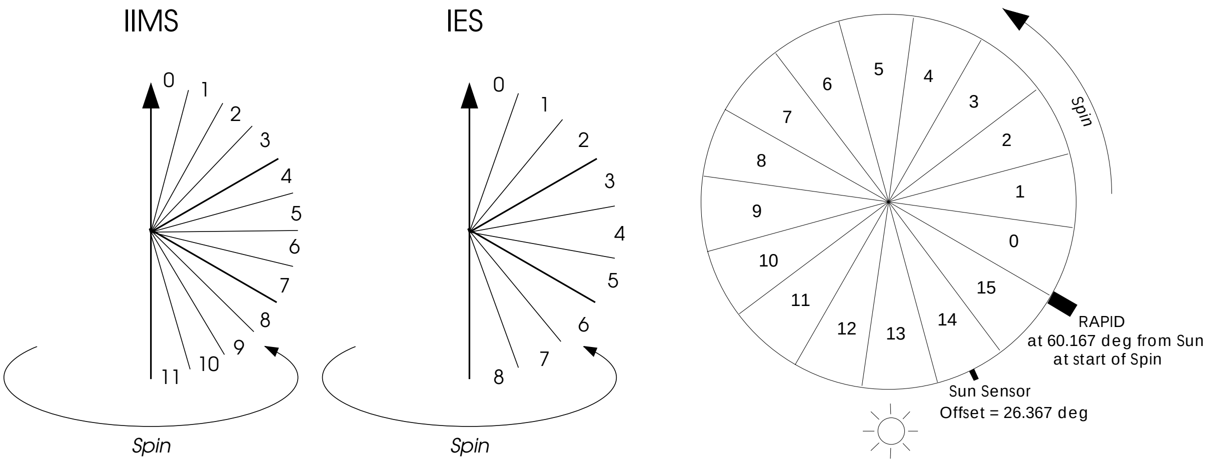

Figure 3: The IIMS and IES polar segments relative to the spin axis (left and center) and the RAPID sectorization relative to the sun (right). Note that the spin axis actually points towards the $-Z$ GSE axis (southward).

The 800 micron thick ion-implant solid state devices are covered with a 450 μg/cm^2 (Si eq) absorbing window which eliminates ions up to 350 keV through the mass dependent range-energy relationship.

The 9 individual strips on the three focal plane detectors are interrogated by a multichannel switched-charge/ voltage-converter (SCVC) in monolithic technology. The SCVC provides for each particle coded information on the strip number and particle energy. This primary information is transferred to the DPU for further evaluation, as explained in Section 3.3.2.

The characteristics of the IIMS and IES sensors are listed in Table 1.

3.2.3 Spin Sectorization

For both IIMS and IES, the azimuthal distribution of particle fluxes is obtained by sorting the counts into 16 sectors during one rotation of the spacecraft (right side of Figure 3).

The DPU measures the rotation period as indicated by the spacecraft sun reference pulses, and takes 1/16 of this as the sector time.

At the start of each sector, there is a preset *dead time* of 55 ms during which the accumulations from the previous sector, or spin, are written to the EDB buffer, and during which other tasks are carried out. When these tasks are finished, or when the preset dead time is over, whichever is longer, the DPU begins to accumulate IIMS events. In serial mode, it addresses the 3 SCENIC heads one after the other, accumulating for 60 ms in each. In parallel mode, all 3 are active simultaneously for 180 ms. At the end of this time, it stop accumulating IIMS events, and waits for the start of the next sector.

Electrons are accumulated during the entire sector.

The times given above can be adjusted by command from the ground. The values of 60 and 180 ms are those in effect since the major patch upload in May, 2001.

If the DPU tasks at the start of the sector take longer than the predetermined time, the IIMS accumulation is delayed accordingly, and if the next sector then starts before the accumulation time is finished, a *dead time flag* is set (housekeeping word) to indicate that the IIMS accumulation has been truncated in that spin. This normally occurs when a new LUT for IES is loaded during sector 0, causing a reduction in accumulation time for IIMS in that sector.

3.2.4 The Digital Processing Unit

Each of the two sensor systems (IIMS and IES) is followed by dedicated circuitries called the **S**ignal **C**onditioning **U**nit (SCU). The primary task of the SCU is to provide proper analogue amplification and signal shaping, event-definition logic, control functions for configuring the detector system and to interface with the **D**igital **P**rocessing **U**nit (DPU).

The internal RAPID-DPU serves the SCUs and sensor systems, evaluates and compresses the primary event data rate to a level which is compatible with the telemetry capacity and arranges the output data in the format of an **E**xperiment **D**ata **B**lock (EDB). A more detailed description of the onboard data processing is given in Sections 3.3.1 and 3.3.2.

3.3 On Board Data Processing Chain

3.3.1 IIMS Onboard Data Processing

The main task of the DPU is to distill the large amount of input information from the detectors to a small set of numbers for output to the EDB.

In incoming ion (an *event*, Figure 1) creates a burst of electrons when it passes through the start foil, losing some of its energy as it does so. The electrons are collected on multi-channel plate detectors, initiating the *start* signal, and also determining the incoming direction to within 15°. (It is possible that the direction is not uniquely determined, in which case only the coarse direction is known, i.e., in which head the event occurred.) The ion traverses the remaining distance (34 mm) to the solid state detector, where it is absorbed, emitting further electrons on the surface (leading to the *stop* signal). The ion energy is deposited in the solid state detector, producing an analog signal proportional to that energy, less an amount loss in the dead layer. If the ion is very energetic, over 4 MeV, it passes completely through the front detector, and triggers an *overflow* signal in the back detector. The start and stop signals generate an analog TOF (time-of-flight) pulse.

The DPU processes the various digital signals generated by the event. The analog energy and TOF pulses are digitized as integers from 0 to 255 for 0 to 1500 keV, and 0 to 80 ns. There are 4 possible situations:

Valid E and TOF the mass of the ion is determined by matching the E and TOF to one of 32 mass curves in $E - T$ space; the energy per mass, E/A is found directly from the time-of-flight (essentially V^2 or T^{-2}. E/A is a number from 0 to 63.

Valid TOF, no E the underrange region, E is less than the minimum 30 keV needed for an E signal. Mass and E/A are found from T alone with the knowledge that $E < 30$ keV.

Valid TOF, max E, no overflow the overrange region, mass and E/A are determined from T alone with the knowledge that $4000 > E > 1500$ keV.

Max E, overflow the event is rejected.

The mass and E/A numbers are then used to classify the event, to sort it into one of 57 bins. For each of 4 ion groups (H, He, C-N-O, Si-Fe) there are 8 bins of different energies. Figure 4 shows how the $E-T$ space is divided into these bins. Note that the lowest energy bins are (mainly) from the underrange region, where no energy signal has been detected.

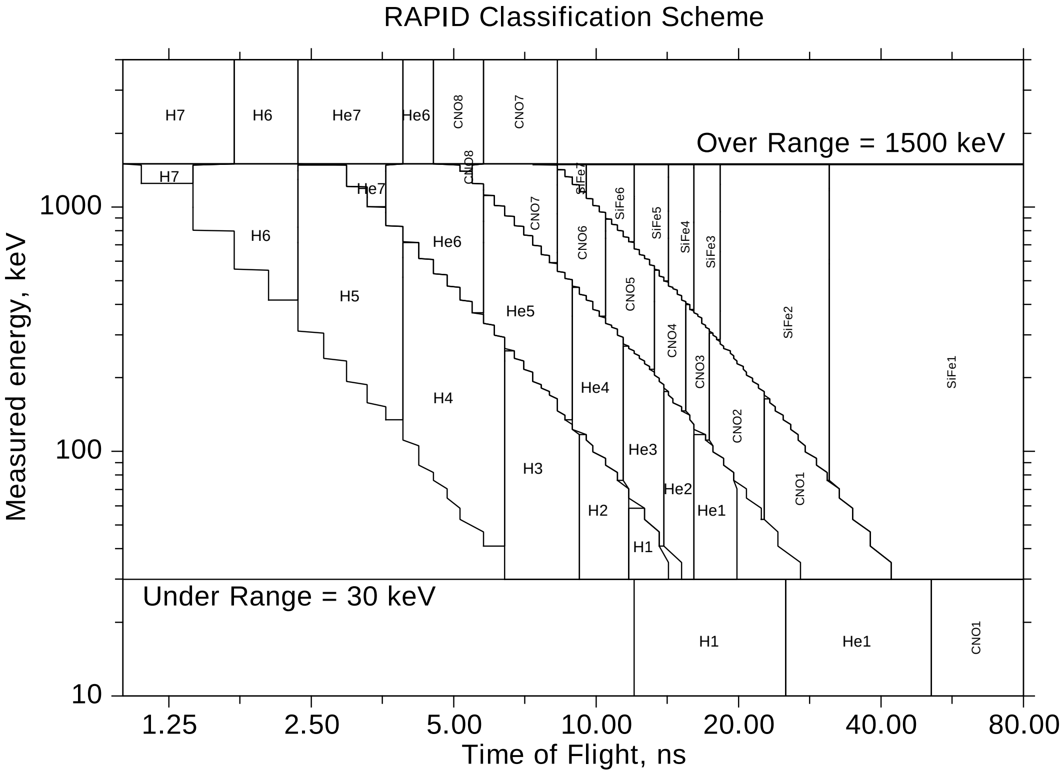

Figure 4: The division of the IIMS $E - T$ space into various bins for species and energy.

The following data sets are populated with IIMS data, as described in the Data Analysis Reference Document, DARD [Ref. 8]:

HSPCT hydrogen spectrum: contains the sum of the counts in the 8 H bins over one spin, independent of direction.

ISPCT ion spectrum: contains the sum of the counts in the 8 He and 8 CNO bins, accumulated over 4 spins, independent of direction.

I3DD 3D ion distribution, sum of counts in the 8 H, He, CNO bins sorted by the 12 directions and 16 spin sectors; accumulated over 8 spins (S/C 1, 3, 4) or 1 spin (S/C 2) and read out over 8 spins (BM) or 32 spins (NM).

MTRX ion matrix, sum of counts in the mass-E/A matrix (32×64), accumulated over 64 spins and read out over 64 (BM) or 256 (NM) spins.

DE direct events, for each spin, up to to 20 (NM) or 106 (BM) events are given with their energy (0–255), TOF (0–255), direction (0–15), sector (0-15). Since the number of events per spin is limited, a prioritization scheme is employed to ensure that the rarer heavier masses are output over the abundant protons.

IPAD ion pitch angle distribution, counts in 3 directions per sector for 2 H energy ranges (combinations of the 8 H bins); the 3 directions are variable, depending on the current direction of the magnetic field as measured on board. See section 3.3.4. (Not available after the reprogramming for L3DD in May 2004.)

3.3.2 IES Onboard Data Processing

The IES micro-strip detectors deliver signals to the DPU that are proportional to the charge accumulated on them during a set *integration time*. This charge is proportional to the energy deposited by absorbed electrons, plus a constant charge due to a background current. If no electrons arrive during the integration time, the signal represents this *pedestal* charge; if a single electron is absorbed, the signal is enhanced by an amount proportional to the electron's energy.

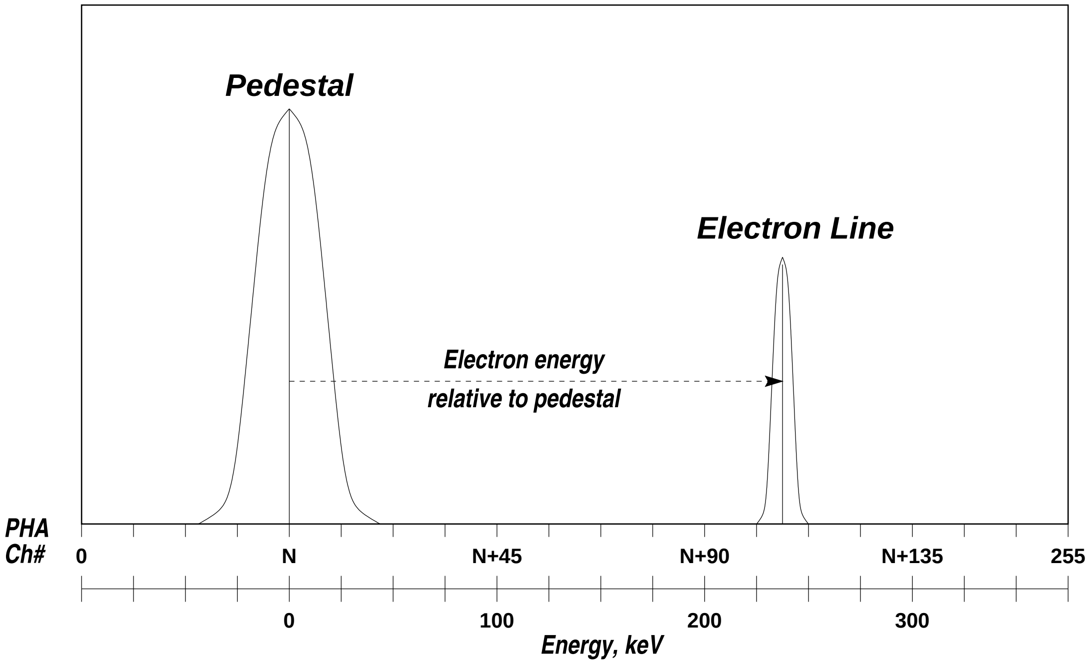

Figure 5: The IES pulse-height analysis. The analog signal, reflecting the electron's energy on top of a background pedestal, is digitalized from 0 to 255, and then sorted into broad energy bins that must be set relative to the pedestal.

The analog signal is initially sorted into 256 bins, at ~2.2 keV per bin. The total energy of all electrons detected during one integration period is registered as a single count in one of these bins; after the integration interval, that count is read out and the energy accumulation reset. The integration time must be selected to avoid multiple incidences in single strips. Possible values are 2, 5, 15, and 50 μs. IES normally operates in *autoswitching* mode, meaning the integration time automatically follows the observed count rates.

The bin corresponding to zero energy is different for each strip and also depends on the integration time. Here electronic noise accumulates, the so-called *pedestal*. Its position determines the energy offset and its width the first useful lower energy threshold.

Broad energy bins (8 in NM, 12 in BM) are defined in terms of the 256 fine bins, relative to the known pedestal position, as shown in Figure 5. (Since the pedestal can wander slowly with time, or can vary even with count rate, it is necessary to monitor it and occasionally redefine the broad bins.) The broad energy bins are specified by *Look-Up Tables* (LUT), one for each detector strip and integration time. Whenever the integration time is switched, a new set of LUTs must be loaded.

Full energy resolution of 256 bins is available only in *histogram* mode, a test mode for monitoring the pedestals.

The following IES products are in the EDB, according to the DARD [Ref. 8]:

E3DD_BM the burst mode electron 3D distribution, sums of electrons sorted into 96 directions (combination of polar direction and sectors), and 12 energy channels, for each spin. Four of the energy channels monitor the pedestal, leaving 8 for the actual electrons.

The 96 directions consist of 8 doubled sectors for polar directions 0–2 and 6–8, and the regular 16 for the central directions 3–5. In the data products delivered by science software on the ground, these are unpacked into the original 9×16 array with half the counts in the doubled sectors going into each of the halves. Thus the user will always be working with a square matrix of directions and not with the complicated original one.

E3DD_NM the nominal mode electron distribution, sums of electrons sorted into 9 directions and 8 energy channels, summed over all sectors for one spin. Two of the energy channels monitor the pedestal; of the remaining 6, the last 2 cover the same range as the last 4 in BM.

EPAD electron pitch angle distribution, equivalent to the IPAD for IIMS. Unlike IPAD, EPAD exists only in NM, since the E3DD_BM enough information to reproduce EPAD. (Not available after the reprogramming for L3DD in May 2004.)

MDATA, MSIGNS additional data that depends on the on-board magnetic field measurement, indicating via tables which of the 3 directions go into the IPAD and EPAD sets.

L3DD or *E3DD Lite*, available in NM as of May 2004 after a reprogramming of the DPU. This consists of two of the E3DD_BM energy channels with the full set of 96 directions. These overwrite the EPAD and IPAD data blocks, which each happens to be 96 words long.

HIST or histogram mode data; this is a test mode that is commanded about once month. A fixed integration time is selected, histogram mode activated, the counts in all 256 channels are read out for all 9 detector strips, uncompressed, and then regular operation is resumed.

3.3.3 Compression of Counts

All the summed counts mentioned above are accumulated in 24-bit counters, but are written to the output EDB as a single byte each. A 24-to-8 bit compression algorithm is used to accomplish this. Numbers up to 32 are encoded without loss, but higher numbers retain only the 5 most significant bits with a mantissa and exponent system. Thus the delivered data have a accuracy of no more than 3%. (Since counts are subject to Poisson statistics with a standard deviation equal to their square root, the compression error is usually smaller than the intrinsic statistical noise.)

Ground-based science software must decode the compressed bytes to the original full count. This is done by assigning it a value that is the middle of the range of numbers producing that byte value. For example, counts between 1280 and 1343 all are compressed to 74 (hex), so 74 is decoded to the central value of 1311.5.

3.3.4 Onboard Pitch Angle Computation

The RAPID spectrometer is connected to the magnetic field instrument FGM via an inter-experiment link (IEL). FGM sends 64 uncorrected magnetic field vectors per spacecraft spin. With this information, RAPID calculates the perpendicular to the magnetic field within the current sector, which is then used to select 3 of the 9 IES or 12 IIMS directions for the EPAD and IPAD distributions. These 3 directions are to be:

1. that closest to 90° to the magnetic field;
2. that perpendicular to the first direction;
3. another direction, close to the spin axis.

The MDATA product contains a number 0–15 for each sector, representing the perpendicular to the magnetic field vector being from 0–180° from the spin axis. A look-up table is used to translate this number into the set of directions for EPAD and IPAD.

The MSIGNS product is single bit per sector indicating the sign of the magnetic field in that sector plane.

The interpretation of these data and their application to EPAD and IPAD is complicated and prone to error; thus the archived products will contain data sets that are so organized that the user need not be concerned about these details.

3.4 Ground Data Processing

3.4.1 Level 1: The Raw Data Set

The RAPID data ground processing begins by merging the raw data from the CD-ROMs (level 0) to *Merged Science Files* (MSF, or level 1). Each such file contains the RAPID raw data for one spacecraft for a single day, regardless of how many CDs originally contributed to it. Records of instrument housekeeping data, spacecraft housekeeping data, and instrument science data (nominal or burst mode, whichever is current) are interspersed on a common time basis. Whereas as the instrument data records are identical to those on the CD-ROMs, the spacecraft housekeeping records are limited to the sun reference pulse data plus a temperature byte.

3.4.2 Level 2: Science Data Processing

A particle instrument like RAPID delivers only a set of counts accumulated over a known time period. Thus, after having processed the raw data set to the so-called MSF, the data have to be calibrated before providing them to the CAA. The standard RAPID software (`MSF2SCI`) produces counts-per-sec or fluxes from the MSF data and calibration files. These are written to files in an ASCII format specific to RAPID (called SCI files), for further processing, plotting, analysis. For CAA, there will be a conversion program to put them into CEF (Cluster Exchange Format) which allows subsequent conversion to CDF with existing software.

Calibration is performed with adequate files per spacecraft and particle type (electron/ions) for 8 in all. Each one contains all the temporal changes to the various parameters. In addition to the raw data processing, caveat and instrument mode files will be provided. Knowledge of the instrument mode is required to understand the products. Caveats give information about instrument behaviour, explanations for problems, warnings when the data are unreliable, and why.

Calibration and Auxiliary Files

To get some impression of the way how calibration files are working one has to be familiar with a couple of definitions described in the following. A more detailed description of RAPID calibration files can be found in the PI SW document [Ref. 9].

Calibration set: is a set of parameters needed for calculating flux from counts, valid for one spacecraft and for a given period of time.

Calibration file: is the file that the processing software reads, containing a collection of calibration sets.

The software reads this file until it finds the set that is valid for the time being processed, noting the end time as well. When the current process time exceeds this end time, the calibration file is read once more, to find the next valid set. Thus the current calibration set can change at any time, not just at day boundaries.

Caveat file: contains lines of text (with date indicators) that are written into the SCI files for the appropriate days; they provide explanations and warnings about any problems with the processing. The CAA caveat files are generated from such SCI files.

Parameter file: sets values for various parameters used during processing, including the names and locations of the calibration and caveat files and various flags to control the processing software. There is one parameter file containing the values of all spacecraft. The name of this file is stored in the environment `PDB_PARAMETER`.

This file contains date stamps to allow values to change with time. It is input until a date in found exceeding the processing date, so all the parameter values at that point become the current ones used.

Since this file is read only once per processing day, values can only be changed at a day boundary.

This complicated arrangement has the advantage that per spacecraft and IIMS/IES, there is only one calibration file containing all the time-dependent changes in any of the parameters. This avoids having several files valid for only certain times. The RAPID calibration files as a whole are valid for all times, although the sets they contain may have limited validity.

Of course, if it should be decided to revise the parameters for all times, as opposed to adding a time-dependent change, then new files are issued containing totally new sets. An example of this is the replacement of the calibration *sets* (in new files) prepared for the commissioning phase with those based on the evaluation of real data. An example of a time-dependent change is when the IES pedestal were altered on-board, following commissioning evaluation. In this case, new files were issued containing both the old and new sets, valid for different times.

For Cluster/RAPID science data users another important fact will be of interest. To understand the relationship between count rates and fluxes a few notes have to be taken on factors and calculation procedures, being involved in the data processing chain performed by the RAPID software.

Geometry Factor

Consider a particle of energy E and incoming direction Ω, striking the detector surface at some point S. The probability that it successfully navigates through the entrance aperture and collimators to reach the detector at that point is $\mathrm{Pr}(E, \Omega, S)$, which is either 1 or 0. The integral of this probability over the field-of-view $\Delta\Omega$ and detector surface ΔS is the *geometry factor* (GF):

$$G(E) = \int_{\Delta\Omega} d\Omega \int_{\Delta S} dS \ \mathrm{Pr}(E, \Omega, S) \tag{1}$$

The geometry factor $G(E)$ has units of $\mathrm{cm}^2 \cdot \mathrm{sr}$; it essentially describes how much of the detector surface can be 'seen' externally, summed over all input directions.

In the case of RAPID, the particle paths do not contain electric and magnetic fields, hence the GF is independent of energy and species.[1] Calculations for one SCENIC sensor yield

$$G = 8.85 \times 10^{-3} \ \mathrm{cm}^2 \cdot \mathrm{sr} \tag{2}$$

or 2.21×10^{-3} $\mathrm{cm}^2 \cdot \mathrm{sr}$ for one polar segment of $15°$.

The rate of particles of energy E striking the detector surface can now be written as

$$\begin{aligned} \mathcal{R}(E) &= \int_{\Delta\Omega} d\Omega \int_{\Delta S} dS \ j(E, \Omega, S) \cdot \mathrm{Pr}(E, \Omega, S) \\ &= G(E) \cdot \bar{\jmath}(E) \end{aligned} \tag{3}$$

where

$$\bar{\jmath}(E) = \frac{1}{G(E)} \int_{\Delta\Omega} d\Omega \int_{\Delta S} dS \ j(E, \Omega, S) \cdot \mathrm{Pr}(E, \Omega, S) \tag{4}$$

Note that $\bar{\jmath}$ is the average of j over the field-of-view and detector area, weighted by the geometry factor.

Detector Efficiency

The probability that a particle is detected and measured once it strikes the detecting surface is described by the *detector efficiency* $\epsilon(E)$, which is a function of particle energy and species, but not of direction and position on the surface.

The efficiency has been measured by ion beam experiments on the channel plate detectors, and can be fitted to an exponential:

$$\begin{aligned} \epsilon &\approx a \exp(bE) + c \quad \text{for } E < E_{\max} \\ &\approx \epsilon_{\max} \qquad\qquad\quad\;\; E > E_{\max} \end{aligned} \tag{5}$$

The coefficients a, b, c, as well as $E_{\max}$ and $\epsilon_{\max}$ depend on particle type. The maximum $\epsilon_{\max} \sim 0.1$–0.2.

[1] This statement does not apply when the deflection voltage is on to sweep ions out of the detection region.

Conversion Factor

We now derive the *conversion factor* (CF) between particle flux and measured count rates.

The number of counts recorded per unit time is the integral over the selected energy range of the rate $\mathcal{R}$ (equation 3) that particles strike the detector times the probability ϵ that they are measured:

$$\int_{\Delta\Omega} d\Omega \int_{\Delta S} dS \ \Pr(E,\Omega,S)\,\epsilon(E)\cdot j(E,\Omega,S) = \int_{E_1}^{E_2} dE\ G(E)\,\epsilon(E)\cdot \bar{\jmath}(E) \tag{6}$$

We now want to find an approximation for the particle flux knowing the count rate $\mathcal{N}$. The problem is to invert equation (6). In fact, what we really obtain is only the *integral flux* J:

$$J(E_1,E_2) = \int_{E_1}^{E_2} dE\ \bar{\jmath}(E) \tag{7}$$

Let us define the *weighted mean conversion factor* for this energy range as

$$\overline{CF} = \frac{\int dE\ w(E)\,G(E)\,\epsilon(E)}{\int dE\ w(E)} \tag{8}$$

$$\approx \frac{1}{\Delta E}\int_{E_1}^{E_2} dE\ G(E)\,\epsilon(E) \tag{9}$$

If the weighting function $w(E)$ were to be proportional to $\bar{\jmath}(E)$, then (8) yields

$$\overline{CF}\int_{E_1}^{E_2} dE\ \bar{\jmath}(E) = \int_{E_1}^{E_2} dE\ \bar{\jmath}(E)\cdot G(E)\,\epsilon(E)$$

$$\overline{CF}\ J(E_1,E_2) = \mathcal{N}(E_1,E_2) \tag{10}$$

or

$$J(E_1,E_2) = \mathcal{N}(E_1,E_2)/\overline{CF}(E_1,E_2) \tag{11}$$

energy channel and the count rate in that channel.

From equation (8) we see that the conversion factor at a given energy is $G(E)\,\epsilon(E)$ and that $\overline{CF}$ is the mean of this factor over the energy channel. Since $G(E)\,\epsilon(E)$ varies only slightly with energy (except at low energies), the mean value should not differ too much from any value within the range.

Ideally the weighting function $w(E)$ in equation (8) should be of the same shape as $\bar{\jmath}(E)$; in reality we take it to be constant. This assumption is legitimate to the extent that $G(E)\,\epsilon(E)$ is only weakly dependent on energy.

The averaged CF *does not depend directly on the ΔE of the energy channel*. One often quotes a *differential conversion factor*, in units of $\mathrm{cm}^2\cdot\mathrm{sr}\cdot\mathrm{keV}$ which is really $\overline{CF}\times\Delta E$. In this paper, we deal entirely with the 'integral' CF.

Differential Flux

One really would like to have an estimate for the differential flux $\bar{\jmath}$. This is usually achieved with

$$\bar{\jmath} = J(E_1,E_2)/\Delta E \tag{12}$$

but this produces only the average differential flux within the energy channel, and it is not at all clear to which energy it should be assigned. A better method is to try to fit the observed counts, or integral fluxes, to a spectrum model.

Incidently, by taking $w(E)$ in equation (8) as constant, the flux in equation (12) is really an average of the differential flux $\bar{\jmath}(E)$ over the energy channel, weighted by the conversion factor $G(E)\,\epsilon(E)$.

Combining Conversion Factors

From the basic CFs, it will be necessary to produce derived ones. Two cases arise.

Effective Energy Channels: The data for the anisotropy calculation are sorted on board into two effective energy channels: low (channels 1–4) and high (5–8). The effective conversion factors for these pseudo channels is simply found by generalizing equation (8). For example, for an effective channel that consists of the sum of the counts in channels 1 and 2:

$$\begin{aligned} \overline{CF}_{\text{eff}} &= \frac{1}{E_3 - E_1} \int_{E_1}^{E_3} dE\, G(E)\, \epsilon(E) \\ &= \frac{(E_2 - E_1)\,\overline{CF}_1 + (E_3 - E_2)\,\overline{CF}_2}{(E_3 - E_2) + (E_2 - E_1)} \end{aligned} \tag{13}$$

which means that the effective CF is the average of the individual ones, weighted by the energy widths.

Summed Directions: The omnidirectional data are the sums of counts in all the various directions, but still for a single energy channel. In this case, the effective CF is the *sum*, not the average, of all the individual ones.

The sum should go over all the polar directions, producing the effective CF for a detector that looks from 0–180° to the spin axis, but for one sector. Rather than summing this over all sectors (which are in fact identical) it is sufficient to consider the accumulation time for the omnidirectional counts to be that of a full spin.

A further complication arises in that the omnidirectional ion counts in `HSPCT` and `ISPCT` are not exactly the same as the sum of the appropriate parts of `I3DD` (counts sorted into both polar directions and sectors) since the latter is also influenced by the efficiency of the directional determination. The given geometry factors apply to `I3DD` so that any derived factors for `HSPCT` and `ISPCT` must take this possible difference into account.

Calculation of Omnidirectional Flux

For each of the three ion species, we will be given the omnidirectional counts for 8 energy channels. For each energy channel, and species, we will have the effective omnidirectional CF, $\Sigma\overline{CF}$ (Section 3.4.2).

We also have a background count rate for each energy channel and direction. The background rates must also be summed over all polar segments to produce the rate in the pseudo omnidirectional detector, ΣBG.

The omnidirectional flux in channel n is thus:

$$\boxed{J_n = \frac{C_n/T - \Sigma BG}{\Sigma\overline{CF}}} \tag{14}$$

where C_n is the number of counts in channel n accumulated over time T (one spin for protons, 4 spins for the others); C_n/T corresponds to $\mathcal{N}$ of equations (6) and (11).

Note: it was originally thought that the background would be isotropic penetrating particles or electronic noise. It now turns out that for the ions, there is solar contamination, predominantly in the sun sector. It is also a different rate in serial and parallel mode, since in serial only one third of the sector is "active", and this third misses the sun. In the latest version of the calibration data, background rates are given for all sectors and polar directions, for serial and parallel mode, but only for the first energy channel. No background has been observed in higher channels.

3.5 Instrument Data Products

3.5.1 EDB Formats

The Experimental Data Block contains the so-called compressed science data produced by the DPU. One EDB is generated per spin (∼4 s). The data structure varies with the telemetry mode. The RAPID supports three different telemetry formats:

NM: Nominal modes (NM[1-3]) and burst mode 2 (BM2), with the same allocated bitrate of 1024.8 bits/second. This mode is active most of the operation time of the instrument. The DPU formats EDBs of 512 Bytes per spin; spin period: $4\,\mathrm{s} \pm 10\%$.

BM1: Burst mode 1 (BM1), with an allocated bitrate of 4620.92 bits/second. In this mode EDBs have a size of 2304 bytes, which allow a greater resolution in time of measurement data.

BM3: Burst mode 3 (BM3), has a bitrate of 1925.38 bits/second. This mode is intended to read out scratch memories of the instrument. It takes about 4 3/4 minutes to dump that memory content through telemetry. For RAPID BM3 simply forms a data gap during this time.

As can be seen from the above, the principle difference between NM EDBs and BM EDBs is the higher sampling rate in the BM mode except for the electron data EPAD and E3DD. The former is omitted from the BM EDB because the pitch-angle distribution can be computed on the ground from the E3DD distribution which covers the sphere with high angular resolution. The E3DD data in NM mode are integrated over a spin whereas these data are subdivided in 16 azimuthal sectors in BM mode.

The following description of the EDB contents shall give a short impression of science data provided for ground processing.

3.5.2 IIMS Science Data

HSPCT: Counts of protons (hydrogen ions) accumulated over one spin in all directions, in 8 different energy ranges; this input consists of 8 bytes.

ISPCT: Counts of He and CNO ions accumulated over 4 spins in all directions, in 8 different energy ranges; this input consists of 8 bytes for each mass selection for a total of 16 bytes.

I3DD: Counts of H, He, and CNO sorted by energy and direction.

IPAD: Proton pitch angle distribution: for each sector, the counts are accumulated in three different polar segments, in two different energy ranges (1–4 and 5–8); a total of 96 bytes.

SGL-Data: The DPU samples the 45 accumulators in COUNTER ARRAY with specified frequencies and forms single parameter rates called SGL Data.

DE-Data: A fraction of unprocessed (E, T, D) events is selected to bypass the classification for transmission to the ground (so-called direct events DE). The selection of DE events is based on a four-step priority P which is assigned to the bin number B (this assignment can be changed by telecommand; default is P = const for all B of a given particle species). Priority P = 3 refers to high priority particles. With this definition priorities are assigned as follows:

Priority P	0	1	2	3
Species	e,p	He	CNO	Si-group

MTRX: A-E/A matrix consisting of 32 mass classes (A) over 64 energy/mass classes (EA) summing up to 2048 individual counters.

3.5.3 IES Science Data

E3DD: Electron counts sorted by energy and direction.

L3DD: Electron counts sorted by energy and direction.

EPAD: Electron pitch angle distribution: analogous to IPAD, 96 bytes; only in normal mode; in burst mode, must be simulated from the E3DD data.

	Bytes per record		Bytes per Spin		Accumulation period per counts [spins]		Transfer time [spins]	
	NM	BM1	NM	BM1	NM	BM1	NM	BM1
DE 3×20(NM) ions								
3×106(BM) ions	60	318	60	318	1	1	1	1
SGL0 2 counters	4	–	1	–	4	–	4	–
SGL1 3 counters	3	5	1	80	4	1/16	4	1
SGL2 18 counters	18	18	3	9	4	2	8	2
SGL3 22 counters	22	22	1	3	4	2	32	8
HSPCT	8	8	8	8	1	1	1	1
ISPCT	16	16	4	4	4	4	4	4
IPAD	96	96	96	96	1/16	1/16	1	1
I3DD	288	288	144	576	8/16	8/16	32	8
MTRX	2048	2048	8	32	64	64	256	64
EPAD	96	–	96	–	1/16	–	1	–
E3DD	72	1152	72	1152	1	1/16	1	1
(*L3DD*)*	(*192*)	–	(*192*)	–	(*1/16*)	–	(*1*)	–
m	8	8	8	8	1/16	1/16	1	1
m-signs	2	2	2	2	1/16	1/16	1	1
Sync marker	3	9	3	9	–	–	1	1
Subcommutation INDEX	1	1	1	1	–	–	1	1
Content descriptors	2	2	2	2	–	–	1	1
E/T–CAL	2	2	2	2	–	–	1	1
spare	–	2	–	2	–	–	1	1
			Σ 512	Σ 2304				

Table 2: The EDB for Nominal Mode and Burst Mode 1.
*In April–May 2004, a new patch has been uploaded to RAPID that replaces the data in the IPAD and EPAD in nominal mode with data from 2 channels of burst mode E3DD. This pseudo data product (or class) is called L3DD (for E3DD-Lite).

3.5.4 Two types of science data for IIMS and IES

Detector index m: defines for each sector the direction perpendicular to the magnetic field vector (m = 0–15).

B vector polarity m-signs: indicates the polarity of the **B** field in each sector.

Table 2 shows the distribution of the Science Data in an EDB for the nominal (NM1 to NM3) and burst mode (BM1 and BM2) telemetry.

3.6 Processed Science Products

The RAPID software produces the following products from the compressed data in the EDB. These level 2 products are the inputs to the RAPID data sets to be provided to CAA science users as counts/s and as flux, produced using the best calibration data known at the time of archiving.

- **HSPCT** omnidirectional protons in 8 energy channels, 1 per spin
- **ISPCT** omnidirectional He and CNO in 8 energy channels, 1 per 4 spins
- **I3DD** 12×16 directions for 3 ion species, 8 energies,
  NM: 8 spins out of 32 (SC 1,3,4) – 1 spin out of 32 (SC 2)
  BM: 8 spins out of 8 (SC 1,3,4) – 1 spin out of 8 (SC 2)
- **IFLOW** Two 12×16 arrays listing GSE polar and azimuth angles of the I3DD flow direction
- **IPITCH** Two 12×16 arrays listing the ion pitch angle and magnetic azimuth angle relative to the Sun, from the on–board magnetic data.
- **E3DD** BM: 9×16 directions for 8 electron energies, 1 per spin
  NM: 9 directions for 8 electron energies, 1 per spin
- **EFLOW** Two 9×16 arrays listing GSE elevation and azimuth angles of the E3DD flow direction

EPITCH Two 9×16 arrays listing the electron pitch angle and magnetic azimuth angle relative to the Sun, from the on–board magnetic data.

L3DD (since June 2004) L3DD records (one per spin) are very much like those for E3DD in BM: for each energy, there are fluxes in 9×16 directions, but for 2 instead of 8 energies (channels 1 and 3 from E3DD).

ESPCT Generated product from E3DD: electrons in 8 energy channels, omnidirectional. 1 per spin

PED electron "pedestal" counts below zero energy, for diagnostic purpose
NM: 2 energies × 9 polar directions
BM: 4 energies × 9 × 16 directions

EPAD Electrons in 2 (wide) energy bins, 3 polar directions, 16 sectors. The 3 directions are determined by the onboard magnetic field measurements, and are intended to be perpendicular to B in that sector, 90° to first direction, and another direction. Just which of the 9 available directions these are is determined by the on-board magnetic field data. This product exists only in NM; in BM, it is emulated from E3DD data. 1 set per spin.

EPADEX Expanded EPAD, to simplify interpretation for the user, the values are placed into their locations within the 9×16 direction array, with all other values set to the pad value (no data)

IPAD Similar to EPAD but for protons. The 3 directions are selected from 12 available according to on-board magnetic data. Available both in BM and NM. 1 set per spin.

IPADEX Expanded IPAD, the output is sorted into the 12×16 ion direction array with all other values set to the pad value (no data).

DE Direct events, 20 (NM) or 106 (BM) per spin. Each event consists of 4 numbers, for energy (0–255), time-of-flight (0–255), sector (0–15), ion polar direction. A priority system is used to ensure that higher mass ions are included over protons. Use of this data product requires considerable understanding of the instrument.

MDATA Result of the the on-board magnetometer measurements. For each sector, a number 0–15 indicating the perpendicular to the magnetic field in that sector, and a second number (0–1) to indicate the direction of the field in that sector. It is used mainly with EPAD and IPAD, to construct EPADEX and IPADEX. 32 words per spin.

HK Housekeeping parameters, 137 words per spin. Needs documentation to interpret.

HIST Special mode for electrons, with 256 energy bins. Only used occasionally (once a month) to analysis electron sensor performance.

SGL "Singles" counters, allowing analysis of time-of-flight performance; require understanding of the instrument. Diagnostic, but should be archived.

In addition to the counts/s and flux, variances derived from compression losses and Poisson statistics are available.

4 Production Provision—General Conventions

4.1 Formats

4.1.1 Data Products

The final data format produced by the RAPID CAA software will be the Cluster Exchange Format version 2 [Ref. 10].

The level 2 data used as input for the CEF generation is stored in so-called SCI files, an ASCII format specific for the RAPID software.

The name of the SCI file contains the spacecraft number, date, data class, and has the extension `.SCI`. By default the files contain differential fluxes, whereas the given suffix `_I`, `_R`, `_K`, specifies an optional output as integrated flux, count rates, or raw counts, respectively.

Each science file starts with a header, whereas each header line is indicated by starting with an `!`. The header gives information about the data content and characteristics (data class, date, time range, spacecraft), its production history (software name and version, data source file and version, operating system) and the name of the used calibration files for IES and IIMS. After the line

```
!  **** End of Header *****
```

the actual data start, whereas these include science data as well as additional information about housekeeping, caveats, orbit, and energy thresholds. A more detailed description of the SCI files is given in the Software Access Document [Ref. 11].

4.1.2 Graphical Products

In addition to the RAPID data products summary plots in png and pdf format will be delivered for CAA. The purpose of these graphical products is to provide the CAA user with a quicklook onto the RAPID science data and instrument performances. The graphics contain 4 panels showing 6 hour time series of energy spectra of electron, hydrogen, helium, and CNO, and 3 panels displaying the status and settings of the IES and IIMS instrument. The spectra are presented as differential fluxes or count rates, respectively with a time resolution of 1 min.

4.2 Standards

Time is represented as a text string in the strict ISO format adopted by CSDS. This is of the form:

yyyy-*mm*-*dd*T*hh*:*mm*:*ss*.*sss*Z

e.g., 1996-01-30T13:30:00.000Z for January 30 1996 at 1.30 pm. The time stamp refers to the middle of the accumulation time interval.

The 3D particle distributions (like E3DD and I3DD) are provided in a RAPID-based coordinate system with the polar direction relative to the spacecraft spin axis and the azimuth relative to the start of the RAPID spin sector 0.

Additional data sets will be available to translate each of the RAPID polar/azimuth bins into the particle flow direction in true GSE, also allowing for the slight offset of the spin axis from the GSE southern pole. These numbers will change only very slowly over the course of a day, hence they will be provided only once an hour, or whenever a large change occurs, such as when the RAPID sun sector is reset.

Note: strictly speaking, it is sufficient to provide only a 3×3 rotation matrix to effect the above conversions. However, to avoid any ambiguities that could arise from such an application (of which there are many) it was decided to provide the user with the much large set of finished results.

Differential flux will be given in $1/(\mathrm{cm}^2\,\mathrm{s\,sr\,keV})$ with a conversion factor of 6.242×10^{19} to get units in the SI system ($1/(\mathrm{m}^2\,\mathrm{s\,sr\,J})$. If there is no differential flux given, data will be presented in counts/s.

4.3 Production Procedures – The RAPID CAA Software

For the CAA the RAPID Team generates MSF files and delivers the according software to produce SCI files and the final CEF files. Additionally, so-called RAPID production support files, which include calibration (.CAL), caveat (.DAT), CEF template (.TPL), and pdb-parameter files (.DAT) have to be delivered for the SCI file processing (see section 4.3.3). These files contain information about the calibration, caveats, and templates, which define the structure and content of the CEF file for a given data product. Thus, the CAA team requires to run partly the RAPID software including the main production routines and its used subroutines and libraries, all packed in one zip file for Win32 users and three zip files for Unix and Linux users.

4.3.1 Installation

Installation of the software under Unix, Linux and Win32 is described in the Data and Software Access Document [Ref. 11].

4.3.2 Running the software

The final development of the RAPID data products for the CAA is the result of several steps performed by the MPS/RAPID software, which will partly also be available for the CAA Team. Core programs of this procedure are the so–called `gcdc_pmgr`, and `sci_trans` Fortran77 and Fortran90 routines, respectively.

However, for the special purposes of CAA exist aliases, which invoke only part of the programs. Thus the routine `msf2sci` together with the SCI file production support file (see below) converts the level 1 MSF files to the level 2 SCI files. The final CAA data products are generated with the call of `sci2caa`, which itself invokes the `sci_trans` program together with `sci2caa.cfg`. This configuration file defines the various outputs, the form of the output file name, the requirements on the SCI file input, and list of template files that go into each output.

4.3.3 RAPID production support files

The RAPID production support files include those files, which are necessarily used for the correct calibration of data streams and which provide important information about caveats and CEF- templates, i.e., parameter files, caveat files, calibration files, and CEF template files. These files can be found in the subdirectory `system`.

Parameter file In the first instance the parameter file is named pdb_parameter.dat that is read by the RAPID software to set various parameters for the processing. Among these are the names of the calibration files themselves. The names of the caveat files are also included in the parameter file. The parameter file can also contain time stamps of the form `yyyymmdd`, indicating that all the parameters that follow are effective as of that date. Thus certain parameters can be made time dependent in this way. It should also be mentioned that the parameter file has an expiry date to assure that the newest calibration files are used.

Caveat file The caveat files pointed to by the parameter file contain texts that are written to the SCI files. They indicate background problems to explain why the processed data may be missing. Some caveats are generated automatically during processing, whereas those in the caveat files are always inserted, provided the date is correct. For CAA caveats are extracted from the SCI files to generate separate caveat CEF files.

Calibration file The RAPID calibration files contain necessary information for the conversion of raw data to physical parameters, e.g. geometry factors of the instruments, high voltage settings, accumulation times for count rates and other timing relevant data, etc. Calibration files are time dependent and thus need a regular update. For more information about calibration files, their update and creation see the PI SW document [Ref. 9].

CEF template file CEF template files (.TPL) are generic CEF files, containing the complete text, with logical variables in place of the parts that are to be replaced when the true CEF file is created. These are dates, names, spacecraft number, and of course, the actual data. An overall configuration file `SCI2CAA.cfg` specifies how the various output CEF files are to be generated: which SCI files and options are needed, the name of the resulting CEF file, which templates are to be used to form it.

The CEF header text common to all RAPID products is in a single template file, while the product-specific text is to be found in separate templates. It is the configuration file that knits these all together.

4.4 Quality Control Procedures

Data quality: Quality flags in the final CEF files depend on the set of calibration files used. These range from 0 for “Not applicable” to 4 for “Excellent data which has received special treatment”.

Validation control: After the installation of the CAA/RAPID software, the RAPID team will perform quality checks of final products, to verify the full and correct functionality of the software. After installation of software and template updates sample CEF files will be submitted to allow comparison for CAA. During regular processing spot checks will be carried out by the MPS Team on the CAA produced CEF files.

4.5 Delivery Procedures

The CAA shall get access to the Cluster/RAPID software via the web and the MSF raw data via ftp connection to the following servers, whereby the username and password are the same for both connections.

Software address:	`www.mps.mpg.de/dokumente/projekte/cluster/software/`
Data address:	`sun1.mpae.gwdg.de`
Data location:	`/proj/cluster/rapid/dist/`
Alternative:	`/temp/home/rapid/dist`
User:	cluster
Password:	*distributed privately*

The data location contains the zipped MSF files, one zip file per day.

The Software Access Document [Ref. 11] provides more detail.

4.5.1 Delivery Timetable

		Delivery dates for the data products of years 2001-2002		
Product	Product Level	02-06/2001	07-12/2001	2002
MSF-Files	1	1-May-2005	1-Oct-2005	2-Jan-2006
CAA data products	2	1-May-2005	1-Oct-2005	2-Jan-2006
Extended products	2	1-Sep-2006	1-Sep-2006	1-Sep-2006
Diagnostic products	2	1-Sep-2006	1-Sep-2006	1-Sep-2006
Caveat Files	2	1-Sep-2006	1-Sep-2006	1-Sep-2006
Summary Plots	-	1-May-2005	2-Jan-2006	2-Jan-2006
		Delivery dates for the data products of years 2003-2005		
Product	Product Level	2003	2004	2005
MSF-Files	1	1-Jun-2006	1-Sep-2006	1-Jan-2007
CAA data products	2	1-Jun-2006	1-Sep-2006	1-Jan-2007
Extended products	2	1-Sep-2006	1-Sep-2006	1-Jan-2007
Diagnostic products	2	1-Sep-2006	1-Sep-2006	1-Jan-2007
Caveat Files	2	1-Sep-2006	1-Sep-2006	1-Jan-2007
Summary Plots	-	1-Jun-2006	1-Sep-2006	1-Jan-2007
		Delivery dates for the data products of years 2006-2007/1		
Product	Product Level	2006/1	2006/2	2007/1
MSF-Files	1	1-Jun-2007	1-Jan-2008	1-Jun-2008
CAA data products	2	1-Jun-2007	1-Jan-2008	1-Jun-2008
Extended products	2	1-Jun-2007	1-Jan-2008	1-Jun-2008
Diagnostic products	2	1-Jun-2007	1-Jan-2008	1-Jun-2008
Caveat Files	2	1-Jun-2007	1-Jan-2008	1-Jun-2008
Summary Plots	-	1-Jun-2007	1-Jan-2008	1-Jun-2008
		Delivery dates for the data products of years 2007/2-2008		
Product	Product Level	2007/2	2008/1	2008/2
MSF-Files	1	1-Jan-2009	1-Jun-2009	1-Jan-2010
CAA data products	2	1-Jan-2009	1-Jun-2009	1-Jan-2010
Extended products	2	1-Jan-2009	1-Jun-2009	1-Jan-2010
Diagnostic products	2	1-Jan-2009	1-Jun-2009	1-Jan-2010
Caveat Files	2	1-Jan-2009	1-Jun-2009	1-Jan-2010
Summary Plots	-	1-Jan-2009	1-Jun-2009	1-Jan-2010
Plotting Software	-	1-Sep-2006		
Final RAPID data products from 2001-2009 shall be online till the end of 2010.				

Table 3: Delivery Schedule of the CAA Data Products of RAPID

5 Production Provision—Specific Descriptions

5.1 Data Products

In the following, the section heading is the name of the RAPID product as it is usually referred to internally. Each of these products is provided in a separate CEF file. The variable names given within each description are those seen externally, i.e., by the CAA users.

The complete external variable name will bear the additional suffix

__C*n*_CP_RAP_*prod*

where *n* is the spacecraft number 1–4 and *prod* is an identifying product code.

Variables common to all files (without the additional suffix):

`Time_tags` the time stamp of the middle of the accumulation interval

`Time_half_interval` half the width of the accumulation interval, in seconds

`Quality` a data quality indicator, defined by CAA, for the data set. For RAPID, this is determined by the particular set of calibration files being used.

Recall that *differential flux* (page 11) is the particle flux per unit energy, in units of $cm^{-2}\ s^{-1}\ sr^{-1}\ keV^{-1}$. Omnidirectional differential flux is integrated over all directions, and has units of $cm^{-2}\ s^{-1}\ keV^{-1}$.

Count rates are the number of particles per second measured within the given energy range and direction, without allowance for any bin sizes. The count rates include an *effective accumulation time* which is the conversion factor between the measured counts and the count rates. This differs from the measurement *time interval* since it also contains possible duty cycle effects.

5.1.1 HSPCT

Omnidirectional proton differential fluxes in 8 energy channels and their standard deviations.

File name: C*n*_CP_RAP_HSPCT__*yyyymmdd*_V*xx*.cef

Variables:

`Proton_Dif_flux` [8] differential particle flux for protons in 8 energy channels

`Proton_Dif_flux_SD` [8] standard deviations of the above

Comment: Measurments in energy channel 8 are set to fill values because the instrument registrates particles beyond its realistic sensitivty.

5.1.2 HSPCT_R

Omnidirectional proton count rates in 8 energy channels, their standard deviations, and accumulation time.

File name: C*n*_CP_RAP_HSPCT_R__*yyyymmdd*_V*xx*.cef

Variables:

`Proton_Rate` [8] count rates for protons in 8 energy channels

`Proton_Rate_SD` [8] standard deviations of the above

`Proton_Rate_Acc_time` effective accumulation time in seconds

Comment: Measurments in energy channel 8 are set to fill values because the instrument registrates particles beyond its realistic sensitivty.

5.1.3 ISPCT_He

Omnidirectional helium differential fluxes in 8 energy channels and their standard deviations.

File name: `Cn_CP_RAP_ISPCT_He__yyyymmdd_Vxx.cef`

Variables:

`Helium_Dif_flux` [8] differential particle flux for helium in 8 energy channels

`Helium_Dif_flux_SD` [8] standard deviations of the above

Comment: Measurments in energy channel 1 are set to fill values because this channel is contaminated by hydrogen particles and measurements in channel 8 are set to fill values because the instrument registrates particles beyond its realistic sensitivty.

5.1.4 ISPCT_He_R

Omnidirectional helium count rates in 8 energy channels, their standard deviations, and accumulation time.

File name: `Cn_CP_RAP_ISPCT_He_R__yyyymmdd_Vxx.cef`

Variables:

`Helium_Rate` [8] count rates for helium in 8 energy channels

`Helium_Rate_SD` [8] standard deviations of the above

`Helium_Rate_Acc_time` effective accumulation time in seconds

Comment: Measurments in energy channel 1 are set to fill values because this channel is contaminated by hydrogen particles and measurements in channel 8 are set to fill values because the instrument registrates particles beyond its realistic sensitivty.

5.1.5 ISPCT_CNO

Omnidirectional CNO differential fluxes in 8 energy channels and their standard deviations.

File name: `Cn_CP_RAP_ISPCT_CNO__yyyymmdd_Vxx.cef`

Variables:

`CNO_Dif_flux` [8] differential particle flux for CNO in 8 energy channels

`CNO_Dif_flux_SD` [8] standard deviations of the above

5.1.6 ISPCT_CNO_R

Omnidirectional CNO count rates in 8 energy channels, their standard deviations, and accumulation time.

File name: `Cn_CP_RAP_ISPCT_CNO_R__yyyymmdd_Vxx.cef`

Variables:

`CNO_Rate` [8] count rates for CNO in 8 energy channels

`CNO_Rate_SD` [8] standard deviations of the above

`CNO_Rate_Acc_time` effective accumulation time in seconds

5.1.7 I3DD_H

Differential fluxes for protons in 8 energy channels, 16 azimuthal sectors and 12 polar directions, and their standard deviations. The directions are defined in a RAPID-referenced spacecraft system, which are converted to GSE with the `IFLOW` variables described later.

File name: `C`*n*`_CP_RAP_I3DD_H__`*yyyymmdd*`_V`*xx*`.cef`

Variables:

`Proton_Dif_flux_3D` [8,16,12] differential particle flux for protons in 8 energy channels, 16 azimuthal sectors and 12 polar directions

`Proton_Dif_flux_3D_SD` [8,16,12] standard deviations of the above

Comment: Measurments in energy channel 8 are set to fill values because the instrument registrates particles beyond its realistic sensitivty.

5.1.8 I3DD_H_R

Count rates for protons in 8 energy channels, 16 azimuthal sectors and 12 polar directions, their standard deviations, and accumulation time. The directions are defined in a RAPID-referenced spacecraft system, which are converted to GSE with the `IFLOW` variables described later.

File name: `C`*n*`_CP_RAP_I3DD_H_R__`*yyyymmdd*`_V`*xx*`.cef`

Variables:

`Proton_Rate_3D` [8,16,12] count rates for protons in 8 energy channels, 16 azimuthal sectors and 12 polar directions

`Proton_Rate_3D_SD` [8,16,12] standard deviations of the above

`Proton_Rate_3D_Acc_time` effective accumulation time in seconds

Comment: Measurments in energy channel 8 are set to fill values because the instrument registrates particles beyond its realistic sensitivty.

5.1.9 I3DD_He

Differential fluxes for helium in 8 energy channels, 16 azimuthal sectors and 12 polar directions, and their standard deviations. The directions are defined in a RAPID-referenced spacecraft system, which are converted to GSE with the `IFLOW` variables described later.

File name: `C`*n*`_CP_RAP_I3DD_He__`*yyyymmdd*`_V`*xx*`.cef`

Variables:

`Helium_Dif_flux_3D` [8,16,12] differential particle flux for helium in 8 energy channels, 16 azimuthal sectors and 12 polar directions

`Helium_Dif_flux_3D_SD` [8,16,12] standard deviations of the above

Comment: Measurments in energy channel 1 are set to fill values because this channel is contaminated by hydrogen particles and measurements in channel 8 are set to fill values because the instrument registrates particles beyond its realistic sensitivty.

5.1.10 I3DD_He_R

Count rates for helium in 8 energy channels, 16 azimuthal sectors and 12 polar directions, their standard deviations, and accumulation time. The directions are defined in a RAPID-referenced spacecraft system, which are converted to GSE with the `IFLOW` variables described later.

File name: `Cn_CP_RAP_I3DD_He_R__yyyymmdd_Vxx.cef`

Variables:

`Helium_Rate_3D` [8,16,12] count rates for helium in 8 energy channels, 16 azimuthal sectors and 12 polar directions

`Helium_Rate_3D_SD` [8,16,12] standard deviations of the above

`Helium_Rate_3D_Acc_time` effective accumulation time in seconds

Comment: Measurments in energy channel 1 are set to fill values because this channel is contaminated by hydrogen particles and measurements in channel 8 are set to fill values because the instrument registrates particles beyond its realistic sensitivty.

5.1.11 I3DD_CNO

Differential fluxes for CNO in 8 energy channels, 16 azimuthal sectors and 12 polar directions, and their standard deviations. The directions are defined in a RAPID-referenced spacecraft system, which are converted to GSE with the `IFLOW` variables described later.

File name: `Cn_CP_RAP_I3DD_CNO__yyyymmdd_Vxx.cef`

Variables:

`CNO_Dif_flux_3D` [8,16,12] differential particle flux for CNO in 8 energy channels, 16 azimuthal sectors and 12 polar directions

`CNO_Dif_flux_3D_SD` [8,16,12] standard deviations of the above

5.1.12 I3DD_CNO_R

Count rates for CNO in 8 energy channels, 16 azimuthal sectors and 12 polar directions, their standard deviations, and accumulation time. The directions are defined in a RAPID-referenced spacecraft system, which are converted to GSE with the `IFLOW` variables described later.

File name: `Cn_CP_RAP_I3DD_CNO_R__yyyymmdd_Vxx.cef`

Variables:

`CNO_Rate_3D` [8,16,12] count rates for CNO in 8 energy channels, 16 azimuthal sectors and 12 polar directions

`CNO_Rate_3D_SD` [8,16,12] standard deviations of the above

`CNO_Rate_3D_Acc_time` effective accumulation time in seconds

5.1.13 IFLOW

Conversion of the `I3DD` flow directions in 16 azimuthal sectors $\times$ 12 polar directions from spacecraft frame to GSE. These values are normally given only once an hour or whenever the spacecraft attitude changes "suddenly".

File name: `Cn_CP_RAP_IFLOW__yyyymmdd_Vxx.cef`

Variables:

`Ion_GSE_Pol` [16,12] GSE polar (0–180°) angle for the flow direction of the corresponding `I3DD` direction/sector

`Ion_GSE_Az` [16,12] GSE azimuth (0–360°) angle for the flow direction of the corresponding `I3DD` direction/sector

This set does not contain the variable `Time_half_interval`.

5.1.14 IPITCH

Ion pitch angle and magnetic azimuth angle relativ to the Sun for 16 azimuthal sectors × 12 polar directions. These angles are calculated using the on-board magnetic data.

File name: `C`*n*`_CP_RAP_IPITCH__`*yyyymmdd*`_V`*xx*`.cef`

Variables:

`Ion_Pitch` [16,12] Ion pitch angle for 16 azimuthal sectors and 12 polar directions

`Ion_MagAz` [16,12] Magnetic azimuth angle for 16 azimuthal sectors and 12 polar directions

5.1.15 ESPCT

Omnidirectional electron differential fluxes in 8 energy channels and their standard deviations.

File name: `C`*n*`_CP_RAP_ESPCT__`*yyyymmdd*`_V`*xx*`.cef`

Variables:

`Electron_Dif_flux` [8] differential particle flux for electrons in 8 energy channels

`Electron_Dif_flux_SD` [8] standard deviations of the above

Comment: Measurments in energy channels 7 and 8 are set to fill values because in normal mode just 6 energy channels are active and thus these settings are also applied to burst mode data.

5.1.16 ESPCT_R

Omnidirectional electron count rates in 8 energy channels, their standard deviations, and accumulation time.

File name: `C`*n*`_CP_RAP_ESPCT_R__`*yyyymmdd*`_V`*xx*`.cef`

Variables:

`Electron_Rate` [8] count rates for electrons in 8 energy channels

`Electron_Rate_SD` [8] standard deviations of the above

`Electron_Rate_Acc_time` effective accumulation time in seconds

Comment: Measurments in energy channels 7 and 8 are set to fill values because in normal mode just 6 energy channels are active and thus these settings are also applied to burst mode data.

5.1.17 E2DD

Differential fluxes for electrons in 8 energy channels, and 9 polar directions (summed over all sectors), and their standard deviations.

This product exists only in nominal mode. It is the nominal mode variant of E3DD.

File name: `C`*n*`_CP_RAP_E2DD__`*yyyymmdd*`_V`*xx*`.cef`

Variables:

`Electron_Dif_flux_2D` [8,9] differential particle flux for electrons in 8 energy channels, 9 polar directions, summed over 16 sectors.

`Electron_Dif_flux_2D_SD` [8,9] standard deviations of the above

5.1.18 E2DD_R

Count rates for electrons in 8 energy channels, and 9 polar directions (summed over all sectors), their standard deviations, and accumulation time.

This product exists only in nominal mode. It is the nominal mode variant of E3DD.

File name: `Cn_CP_RAP_E2DD_R__yyyymmdd_Vxx.cef`

Variables:

`Electron_Rate_2D` [8,9] count rates for electrons in 8 energy channels, 9 polar directions, summed over 16 sectors.

`Electron_Rate_2D_SD` [8,9] standard deviations of the above

`Electron_Rate_2D_Acc_time` effective accumulation time in seconds

5.1.19 E3DD

Differential fluxes for electrons in 8 energy channels, 16 azimuthal sectors and 9 polar directions, and their standard deviations. The directions are defined in a RAPID-referenced spacecraft system, which are converted to GSE with the `EFLOW` variables described later.

This product exists only in burst mode (or in the special NM3 mode on SC2).

File name: `Cn_CP_RAP_E3DD__yyyymmdd_Vxx.cef`

Variables:

`Electron_Dif_flux_3D` [8,16,9] differential particle flux for electrons in 8 energy channels, 16 azimuthal sectors and 9 polar directions

`Electron_Dif_flux_3D_SD` [8,16,9] standard deviations of the above

5.1.20 E3DD_R

Count rates for electrons in 8 energy channels, 16 azimuthal sectors and 9 polar directions, their standard deviations, and accumulation time. The directions are defined in a RAPID-referenced spacecraft system, which are converted to GSE with the `EFLOW` variables described later.

This product exists only in burst mode (or in the special NM3 mode on SC2).

File name: `Cn_CP_RAP_E3DD_R__yyyymmdd_Vxx.cef`

Variables:

`Electron_Rate_3D` [8,16,9] count rates for electrons in 8 energy channels, 16 azimuthal sectors and 9 polar directions

`Electron_Rate_3D_SD` [8,16,9] standard deviations of the above

`Electron_Rate_3D_Acc_time` effective accumulation time in seconds

5.1.21 L3DD

Differential fluxes for electrons in 2 (non-contiguous) energy channels, 16 azimuthal sectors and 9 polar directions, and their standard deviations. The directions are defined in a RAPID-referenced spacecraft system, which are converted to GSE with the `EFLOW` variables described later.

This product exists in both burst and nominal modes, but only after May 2004. It is a "light" version of the burst mode `E3DD`.

File name: `Cn_CP_RAP_L3DD__yyyymmdd_Vxx.cef`

Variables:

`Electron_L_Dif_flux_3D` [2,16,9] differential particle flux for electrons in 2 energy channels, 16 sectors, 9 polar directions

`Electron_L_Dif_flux_3D_SD` [2,16,9] standard deviations of the above

5.1.22 L3DD_R

Count rates for electrons in 2 (non-contiguous) energy channels, 16 azimuthal sectors and 9 polar directions, their standard deviations, and accumulation time. The directions are defined in a RAPID-referenced spacecraft system, which are converted to GSE with the `EFLOW` variables described later.

This product exists in both burst and nominal modes, but only after May 2004. It is a "light" version of the burst mode `E3DD`.

File name: `Cn_CP_RAP_L3DD_R__yyyymmdd_Vxx.cef`

Variables:

`Electron_L_Rate_3D` [2,16,9] count rates for electrons in 2 energy channels, 16 sectors, 9 polar directions

`Electron_L_Rate_3D_SD` [2,16,9] standard deviations of the above

`Electron_L_Rate_3D_Acc_time` effective accumulation time in seconds

5.1.23 EFLOW

Conversion of the `E3DD` flow directions in 16 azimuthal sectors × 9 polar directions from spacecraft frame to GSE. These values are normally given only once an hour or whenever the spacecraft attitude changes "suddenly".

File name: `Cn_CP_RAP_Electron_GSE__yyyymmdd_Vxx.cef`

Variables:

`Electron_GSE_Pol` [16,9] GSE polar (0–180°) angle for the flow direction of the corresponding `E3DD` direction/sector

`Electron_GSE_Az` [16,9] GSE azimuth (0–360°) angle for the flow direction of the corresponding `E3DD` direction/sector

This set does not contain the variable `Time_half_interval`.

5.1.24 EPITCH

Ion pitch angle and magnetic azimuth angle relativ to the Sun for 16 azimuthal sectors × 9 polar directions. These angles are calculated using the on-board magnetic data.

File name: `Cn_CP_RAP_EPITCH__yyyymmdd_Vxx.cef`

Variables:

`Electron_Pitch` [16,9] Electron pitch angle for 16 azimuthal sectors and 9 polar directions

`Electron_MagAz` [16,9] Magnetic azimuth angle for 16 azimuthal sectors and 9 polar directions

5.1.25 IPADEX

Expanded pitch angle distribution for protons as differential fluxes in 2 energy channels, 16 azimuthal sectors and 12 polar directions, and their standard deviations. Particles are registrated just in 3 of the 12 sensors. The 3 directions are determined by the onboard magnetic field measurements, and are intended to be perpendicular to the magnetic field in that sector, 90° to first direction, and another direction. Just which of the 12 available directions these are is determined by the on-board magnetic field data.

File name: `C`*n*`_CP_RAP_IPADEX__`*yyyymmdd*`_V`*xx*`.cef`

Variables:

`Proton_Dif_flux_Pad` [2,16,12] differential particle flux for protons in 2 energy channels, 16 azimuthal sectors and 12 polar directions

`Proton_Dif_flux_Pad_SD` [2,16,12] standard deviations of the above

5.1.26 IPADEX_R

Expanded pitch angle distribution for protons as rates in 2 energy channels, 16 azimuthal sectors and 12 polar directions, and their standard deviations. Particles are registrated just in 3 of the 12 sensors. The 3 directions are determined by the onboard magnetic field measurements, and are intended to be perpendicular to the magnetic field in that sector, 90° to first direction, and another direction. Just which of the 12 available directions these are is determined by the on-board magnetic field data.

File name: `C`*n*`_CP_RAP_IPADEX_R__`*yyyymmdd*`_V`*xx*`.cef`

Variables:

`Proton_Rate_Pad` [2,16,12] differential particle flux for protons in 2 energy channels, 16 azimuthal sectors and 12 polar directions

`Proton_Rate_Pad_SD` [2,16,12] standard deviations of the above

`Proton_Rate_Pad_Acc_time` effective accumulation time in seconds

5.1.27 EPADEX

Expanded pitch angle distribution for electrons as differential fluxes in 2 energy channels, 16 azimuthal sectors and 9 polar directions, and their standard deviations. Particles are registrated just in 3 of the 9 sensors. In NM the 3 directions are determined by the onboard magnetic field measurements, and are intended to be perpendicular to the magnetic field in that sector, 90° to first direction, and another direction. Just which of the 9 available directions these are is determined by the on-board magnetic field data. In BM enough information is available to determine the product from E3DD measurements. Since May 2004 this product is replaced by L3DD.

File name: `C`*n*`_CP_RAP_EPADEX__`*yyyymmdd*`_V`*xx*`.cef`

Variables:

`Electron_Dif_flux_Pad` [2,16,9] differential particle flux for electrons in 2 energy channels, 16 azimuthal sectors and 9 polar directions

`Electron_Dif_flux_Pad_SD` [2,16,9] standard deviations of the above

5.1.28 EPADEX_R

Expanded pitch angle distribution for electrons as rates in 2 energy channels, 16 azimuthal sectors and 9 polar directions, and their standard deviations. Particles are registrated just in 3 of the 9 sensors. In NM the 3 directions are determined by the onboard magnetic field measurements, and are intended to be perpendicular to the magnetic field in that sector, 90° to first direction, and another direction. Just which of the 9 available directions these are is determined by the on-board magnetic field data. In BM enough information is available to determine the product from E3DD measurements. Since May 2004 this product is replaced by L3DD.

File name: `Cn_CP_RAP_EPADEX_R__yyyymmdd_Vxx.cef`

Variables:

`Electron_Rate_Pad` [2,16,9] differential particle flux for electrons in 2 energy channels, 16 azimuthal sectors and 12 polar directions

`Electron_Rate_Pad_SD` [2,16,9] standard deviations of the above

`Electron_Rate_Pad_Acc_time` effective accumulation time in seconds

5.2 Diagnostic Products

5.2.1 DE

Up to 22 unprocessed events allowing exact identification of particles within an energy and time-of-flight range of 256 bins, 16 azimuthal sectors and 16 polar directions. The 256 bins cover an energy range from 0 to 1500 eV and a TOF range from 0 to 80ns. For the classification scheme see also Figure 4. NM(20 events/record) and BM(106 events/record) data from level 2 `.sci` data are reordered into a standard format of 22 events per record.

File name: `Cn_CP_RAP_DE__yyyymmdd_Vxx.cef`

Variables:

`Direct_events` [4,22] Direct events in 256 energy and time-of-flight bins, 16 azimuthal sectors and 16 polar directions.

5.2.2 PED_NM

IES pedestal counts in 2 energy channels and 9 polar directions, nominal mode only.

File name: `Cn_CP_RAP_PED_NM__yyyymmdd_Vxx.cef`

Variables:

`Pedestal_counts_NM` [2,9] IES pedestal counts in 2 energy channels and 9 polar directions

5.2.3 PED_BM

IES pedestal counts in 2 energy channels, 16 azimuthal sectors and 9 polar directions, burst mode only.

File name: `Cn_CP_RAP_PED_BM__yyyymmdd_Vxx.cef`

Variables:

`Pedestal_counts_BM` [2,16,9] IES pedestal counts in 2 energy channels, 16 azimuthal sectors and 9 polar directions.

5.2.4 PEDPOS_NM

Calculated position of the IES pedestal relative to its standard location, in keV, one value for 9 polar directions, once per spin, nominal mode only.

The pedestal is the true energy origin for all energy channels; if it is shifted, usually to lower, negative values, then all energy channels are effectively at higher values and must be corrected (see Figure 5).

File name: `Cn_CP_RAP_PEDPOS_NM__yyyymmdd_Vxx.cef`

Variables:

`Pedestal_pos_NM` [9] IES pedestal position in keV 9 polar directions

5.2.5 PEDPOS_BM

Calculated position of the IES pedestal relative to its standard location, in keV, for 9 polar directions, spin averaged and for 16 sectors per spin, burst mode only.

File name: `Cn_CP_RAP_PEDPOS_BM__yyyymmdd_Vxx.cef`

Variables:

`Pedestal_pos_BM` [9,17] IES pedestal position in keV 9 polar directions, once spin averaged and then for 16 sectors

5.2.6 HK

Housekeeping parameters as 137 unsigned bytes. For more information see `.cef` header meta data information on housekeeping parameters or Table 4.2 of Instrument Users Guide [Ref. 12].

File name: `Cn_CP_RAP_HK__yyyymmdd_Vxx.cef`

Variables:

`HK_para` [137] 137 housekeeping parameters.

5.2.7 CAVEATS

File name: `Cn_CQ_RAP__yyyymmdd_Vxx.cef`

Variables:

`Caveat_Range` Validity of a specified caveat as time range (start date-and-time plus stop date-and-time).

`Caveat_text` A string containing caveat information.

This set does not contain the variables `Time_tags` or `Time_half_interval`.

5.2.8 Instrument settings

Instrument settings consist of 10 integer values providing information on instrument modes and other flags that help to understand the state of the data. These are also contained in the housekeeping data, but are provided here separately in a more user-friendly manner.

File name: `Cn_CP_RAP_Inst_Set__yyyymmdd_Vxx.cef`

Variables (see also Table 4 for information on possible values):

`Telemetry` An integer value giving the telemetry mode.

`IIMS_Mode_A` The *A* flag in the current configuration mode of the IIMS instrument, indicating serial or parallel mode.

`IIMS_Mode_B` The *B* flag in the current configuration mode of the IIMS instrument, giving the status of the time-of-flight voltages.

`Start_Volt` An integer between 128-255 representing the current level of the start voltage.

`Stop_Volt` An integer between 128-255 representing the current level of the stop voltage.

`Def_Volt` An integer between 128-255 representing the current level of the ion deflection voltage.

Variable	Description	Values	Meaning	Notes
Telemetry	Telemetry	0	Nominal mode	Low bitrate, small data block
		1	Burst mode 1	High bitrate, large data block
		2	Burst mode 2	Never used
		3	Nominal mode 3	Only on SC2, same as BM1
Notes: Telemetry mode must be known because many products are differently formatted or only exist in one telemetry. There is a BM3 but RAPID never takes any data in it, hence the value 3 is used to indicate the NM3 on SC2.				
IIMS_Mode_A	Data Status	0	Off	
		1	Serial mode	The 3 IIMS heads are cyclic within each sector
		2	Parallel mode	The 3 heads are all active simultaneously
		4	In-flight test	Calibration test performed when turned on, no data
		5	DPU dump	Download of DPU contents, no data
IIMS_Mode_B	HV Status	0	Cold Standby	The high voltage relay is turned off
		1	Hot Standby	The relay is on, but voltages down
		2	HV on	Voltages are non-zero, but not at operating levels
		3	Defl HV on	Deflection voltage non-zero, but not at operating level
		4	HV ok	Voltages at operating levels
		5	ENA	Neutral mode, deflection voltage at operating level
Notes: The high voltages are those on the start and stop MCPs, needed for the time-of-flight processing; the deflection voltage sweeps ions away, so only neutrals enter the device (only used rarely at the start of mission). Fluxes are only calculated when the voltages are at the operating levels, i.e., for values 4 or 5.				
Start_Volt	Start HV	128–255	HV on start MCP	digitized voltage, from 0 to 6.7 kV, on the MCP giving the start signal
Stop_Volt	Stop HV	128–255	HV on stop MCP	digitized voltage, from 0 to 6.7 kV, on the MCP giving the stop signal
Def_Volt	Def HV	128–255	HV on defl. plate	digitized voltage, from 0 to 11.9 kV, on ion deflection plates
IES_Mode_L	IES Test	0	Normal	Regular measurements
		1	In-flight test	Calibration test, no data
IES_Mode_M	IES Hist	1	Normal	Regular measurements
		3	Histograms	Dumping HIST data, no regular data
IES_Mode_N	IES Int. Time	1–4	Integration time	Values 2, 5, 15, 50 μs
Autosw	IES Autoswitch	0	Off	The integration time is fixed
		1	On	Integration time switches automatically as needed

Table 4: The instrument mode settings and their meanings.

`IES_Mode_L` The *L* flag in the current configuration mode of the IES instrument, indicating normal or test data.

`IES_Mode_M` An integer value standing for the *M* flag in the current configuration mode of the IES instrument, indicating normal or histogram data.

`IES_Mode_N` An integer value standing for the *N* flag in the current configuration mode of the IES instrument, indicating the current integration time.

`Autosw` An integer value of 0 or 1 telling if the IES autoswitching is turned off or on

This set does not contain the variable `Time_half_interval`. The records are not uniformly spaced in time, but are issued whenever at least one of the flags changes value.

5.3 Graphical Products

In this subsection we give a short description of the layout of RAPID summary plots available for differential fluxes and count rates. In Figure 6 we present an example plot of Cluster 1. From top to the bottom omnidirectional differential energy flux spectra of electrons, hydrogen, helium, and CNO with 1 min time resolution for January 25, 2005 within a 6 hour period from 12:00 to 18:00 UT are shown. At the right hand side of each plot panel a colorbar defines the color code of the spectra. This range is autoscaled, which has to be considered when comparing several plots.

The second part of the plot (panels 5-7) reflects the IES and IIMS instrument settings. For more information about instrument settings and their meaning see also the instrument description at the beginning of this document.

At the top of panel 5 the status of the IES autoswitching is drawn, i.e., green line – Autoswitching on; red line – Autoswitching off. In autoswitching mode, the integration time t in the detector read-out system is not fixed but changes automatically with count rate. The second line in panel 5 displays the current IES integration time (Y-Axis) and the IES operation mode (color coded with green – normal science operations; red – IES off; blue – Histogram mode)

Panel 6 provides some general information about the IIMS status and operation settings.

color code	top line IIMS status	center line high voltages (HV)	bottom line telemetry
red	IIMS off	standby	BM1
green	IIMS in serial mode	HV operational	NM
yellow	IIMS in parallel mode	HV on but not operational	
blue	Inflight functional test	ENA	BM3

Finally, the last panel shows to which level the high voltages, Start HV (green), Stop HV (blue), and Deflector HV (red) are set.

At the bottom of the summary plots orbit information in GSE coordinates is given.

File names:

C*n*_CG_RAP_SUMPLOT_D__*yyyymmdd*_*hhmm*_*hhmm*_V*xx*.png

C*n*_CG_RAP_SUMPLOT_R__*yyyymmdd*_*hhmm*_*hhmm*_V*xx*.png

C*n*_CG_RAP_SUMPLOT_D__*yyyymmdd*_*hhmm*_*hhmm*_V*xx*.pdf

C*n*_CG_RAP_SUMPLOT_R__*yyyymmdd*_*hhmm*_*hhmm*_V*xx*.pdf

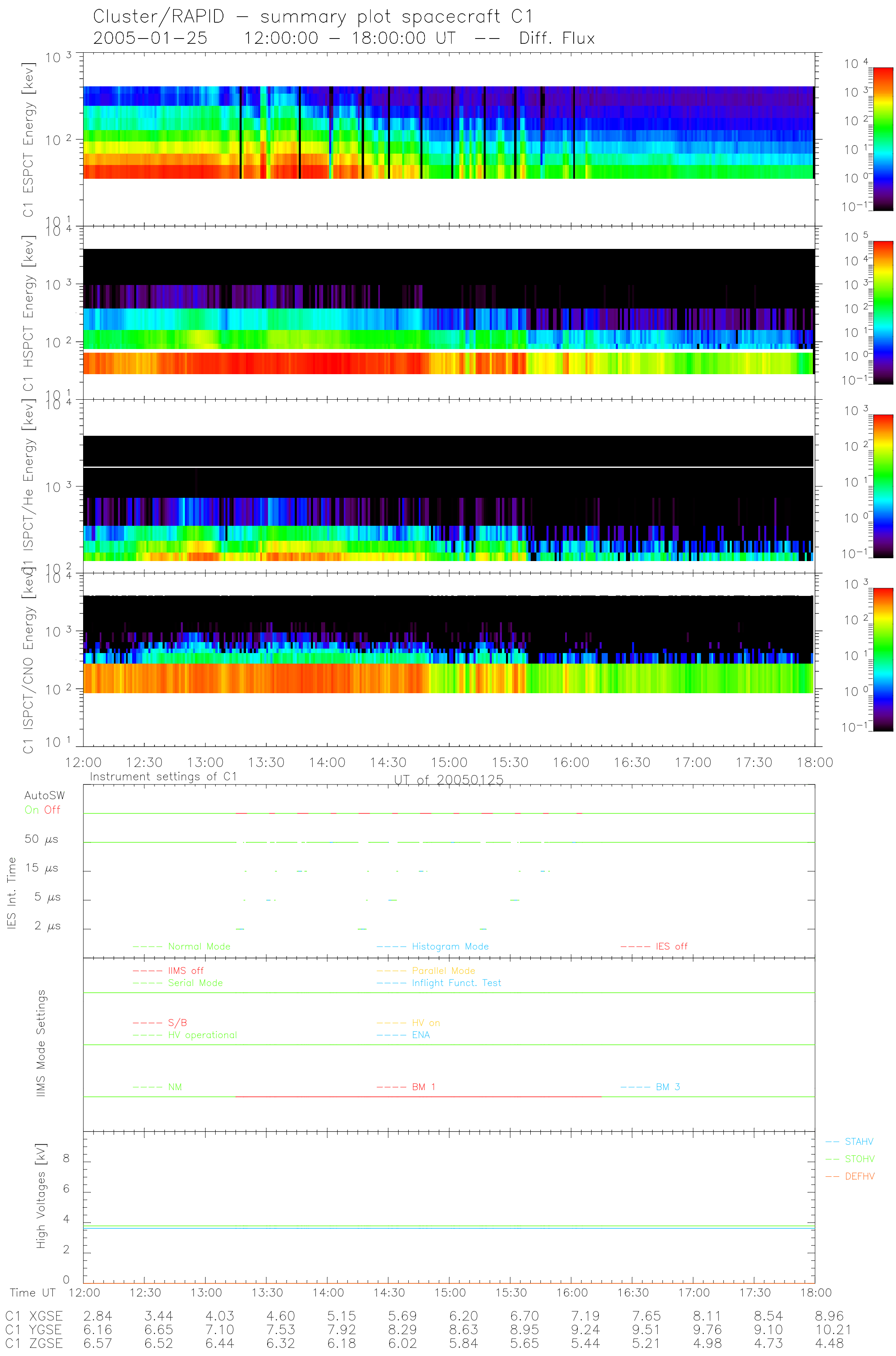

Figure 6: Example of a CAA RAPID summary plot. Panels 1-4 show from top to bottom differential fluxes of ESPCT, HSPCT, ISPCT_He, and ISPCT_CNO. Panels 5-7 display several instrument settings.

5.4 Software Products

5.4.1 Introduction and system requirements

For RAPID CAA, a software is developed, which helps the CAA user to get a quick look into the RAPID data products without the need of programming his own plotting software. The software is developed in IDL6.0 in a WIN32 environment but is also running in a UNIX environment and with older IDL versions down to 5.4. Each plotting widget offers the possibility to save plots either as `*.jpg`, `*.eps`, or `*.pdf`. For the latter a version of Adobe pdf writer or similar has to be installed on the users machine. Default input data are the CAA `*.cef` or `*.cdf` data files.

5.4.2 Short description

The RAPID data visualization software offers five different options of graphical display of RAPID data. Four of have a predefined plotting layout.

Quicklook Plots have the same appearance as the preproduced graphical products described in the section above. They consist of four panels, which display omnidirectional fluxes or count rates depending on the users selection as energyspectra versus time. The bottom panels show the spacecraft and instrument settings. The user has to specify date, time range, time resolution, the omnidirectional data product of a single spacecraft per panel and the data type.

Channel Plots are energy versus time line plots for selected energy channels of a specific omnidirectional data product. Having given the date and time range, the user can decide how many spacecraft and how many channels he wants to have shown at which time resolution.

3D Angle-Angle Plots display count rates or fluxes in a 3D resolution for a selected species, energy channel and spacecraft, optional in GSE or SC coordinates and as rectangular or bispherical plots. Another possible setting defines how many 3D chronological data records the user wants to display per page. In addition the 90° to the magnetic field and the magnetic field vector calculated from a CAA FGM data set can also be shown. To allow an appropriate display the zrange can either be autoscaled or defined.

Pitch Angle Distribution Plots show the pitch angle distribution in a selected time range and of one selected species, spacecraft, energy channels and data type. The angular resolution can also be defined as well as the zrange. As a source for pitch angle data the user can select either the RAPID `EPITCH` or `IPITCH` data sets, which are calculated using the onboard magnetic field, or choose the RAPID `EFLOW` or `IFLOW` data and calculate the pitch angles with CAA FGM spin resolution data.

Finally, the fifth visualization tool offers the possibility to compose up to 8 different panels as the user wants to. Each panel can either show an omnidirectional spectra of electrons, hydrogen, helium or CNO, a line plot of energy versus time for several energy channels or a pitch angle distribution. Selected panel settings can be saved or saved settings can be imported, respectively.

For a full description of the installation and running of the software we refer to the RAPID data visualization software document [Ref. 13].