# JOINT EUROPEAN X-RAY MONITOR

# JEM - X

X-RAY MONITOR FOR THE INTEGRAL MISSION

**Experiment Interface Document Part B**

**Issue 5   Revision 1**

**December 1999**

| **Approval** | ______________________ | DSRI |
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# List of acronyms

| | |
|---|---|
| ADC | Analog to Digital Converter |
| AOCS | Attitude Orbit Control System |
| Co-I | Co-Investigator |
| CPU | Central Processing Unit |
| DAE | Detector Analog Electronics |
| DCRS | Data Change Record Sheet |
| DFEE | Digital Front End Electronics |
| DM | Development Model |
| DPE | Data Processing Electronics |
| DPE | Data Processing Electronics |
| DRD | Document Requirement Description |
| DSRI | Danish Space Research Institute |
| EGSE | Electrical Ground Support Equipment |
| EICD | Electrical Interface Control Document |
| EID | Experiment Interface Document |
| EM | Engineering Model |
| EMC | Electro Magnetic Compatibility |
| ESA | European Space Agency |
| FCFOV | Fully Coded Field Of View |
| FIFO | First In First Out |
| FIFOV | Fully Illuminated Field Of View |
| FM | Flight Model |
| FOV | Field of View |
| FPGA | Field Programmable Gate Array |
| FS | Flight Spare |
| FWHM | Full Width Half Maximum |
| GND | Ground |
| GSE | Ground Support Equipment |
| HEPC | High Energy Proportional Counter (on-board SRG) |
| HK | House Keeping |
| HS | High Speed |
| HURA | Hexagonal Uniformly Redundant Array |
| HV | High Voltage |
| I/F | Interface |
| IBIS | Imager on Board Integral Satellite |
| ICD | Interface Control Document |
| ILS | Instrument Line-of-Sight |
| ISVR | Instrument Science Verification Review |
| JEM-X | Joint European X-Ray Monitor |
| LEPC | Low Energy Proportional Counter (on-board SRG) |
| LS | Low Speed |
| LV | Low Voltage |
| MGSE | Mechanical Ground Support Equipment |
| MS | Micro Strip |
| MSGC | Micro Strip Gas Chamber |
| MSPC | Micro Strip Proportional Counter |
| OBDH | On-Board Data Handling |
| OCC | Operations Control Center |

| | |
|---|---|
| PA | Product Assurance |
| PCB | Printed Circuit Board |
| PCFOV | Partially Coded Field Of View |
| PDU | Power distribution Unit |
| PI | Principal Investigator |
| PLM | Payload Model |
| QM | Qualification Model |
| RDF | Rationalized Data Format |
| ROM | Read Only Memory |
| RTU | Remote Terminal Unit |
| S/C | Spacecraft |
| SMM | Structural Mathematical Model |
| SPI | Spectrometer |
| SRG | Spectrum Roentgen Gamma |
| STM | Structural Thermal Model |
| STR-LOS | Star Tracker Line Of Sight |
| TBC | To be confirmed |
| TBD | To be defined |
| TBV | To be verified |
| TBW | To be written |
| TC | Tele Commands |
| TM | Telemetry |
| TMM | Thermal Mathematical Model |
| ZRFOV | Zero Response Field Of View |

# DOCUMENTATION CHANGE RECORD

EID-B issue 4.0 to 5.1
**Document generally updated. Change Record reflects only major changes**.

| Page | Chapter | tbl/fig | ECR | Description of Change |
|---|---|---|---|---|
| **Mechanical** | | | | |
| 17 | 1.2 | Table 1 | | Updated according to detector redesign (see MICD) |
| 21-22 | 1.3.2 | Figure 3 | | Updated according to detector redesign (see MICD) |
| 33 | 2.1.1 | | x | Field-of-wiev definition updated |
| 35 | 2.1.3 | | x | *(") stated as goal only |
| 35 | 2.1.3 | | x | *(T) stated as goal only |
| 36 | | | x | Mounting handles deleted (previous section 2.1.5.2) |
| 42 | 2.5.1 | Table 2 | x | Mass Budget updated |
| 46 | 3.2.3 | Figure 14 | | Unit Support Brackets now integrated with DFEE box |
| 48 | 3.2.7 | Table 5 | | MICD Drawing Change Record re-initialized |
| 135 | Appendix A | 130010B | x | Updated MICD |
| **Electrical** | | | | |
| 55 | 3.4.1 | Figure 16 | x | Power interface drawing updated |
| 57 | 3.4.7 | Table 11 | x | Power budget updated |
| 59 | | Figure 17 | x | Grounding scheme updated. Ground bus bar removed. |
| 60 | 3.6.2 | | x | Internal timing concept updated |
| 63 | 3.6.4 | | x | New thermistor lines added, discrete command added |
| 150 | Appendix B | Pin alloc. | x | All heater wiring deleted |
| 147 | Appendix B | J06 | x | Pin functions for 1Hz and 8 Hz BCP interchanged |
| 145 | Appendix B | J04 | x | Pins 36, 37, 38, 39 used for temp. sensors |
| 150 | Appendix B | J03 | x | Connector renamed to “Test” |
| 153 | Appendix B | | x | Interface circuit 5 redesigned |
| 153 | Appendix B | | x | Interface circuit 6 added (HV off from RTU) |
| 154 | Appendix B | | x | Interface circuit 7 added (FIFO flag) |

| Page | Chapter | Table Figure | new ECR | Description of Change |
|---|---|---|---|---|
| **Thermal** | | | | |
| 49-54 | 3.3 | | x | Thermal interface chapter rewritten |
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| 17 | 1 | Table 1 | x | Timing accuracy updated |
| 43 | 2.5.3 | Table 3 | | Telemetry packet rate updated |
| 99 | 3.7.7.2 | | x | Time format in packet header |
| 65-121 | 3.7 | | | Software and Interface chapter updated |
| 115-117 | 3.7.7.14 | | | On Event Telemetry updated |
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| **Telecommand** | | | | |
| 80-95 | 3.7.5 | | | Detailed descriptions of TC-packet formats added |
| 93-95 | 3.7.5.3 | | x | JEM-X state description updated |
| 96-97 | 3.7.6 | | | TC parameter description updated |
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| 120 | 3.7.9 | | | CPU memory budget added |
| 120 | 3.7.10 | | | Autonomous Functions defined |
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# 1 INSTRUMENT DEFINITION

## 1.1 Scientific Objectives

The purpose of the INTEGRAL mission is to study celestial objects in great detail in the gamma-ray region of the electromagnetic spectrum. INTEGRAL comprises two main instruments, the SPECTROMETER (SPI) covering the energy range 20 keV - 8 MeV and the IMAGER (IBIS) covering 15 keV - 10 MeV that will provide unique opportunities to detect and identify celestial gamma-ray sources and to resolve spectral features.

In order to fully exploit the information about the physical conditions in the sources provided by the two main instruments, it is essential to have simultaneous observations both in the X-ray region and in the optical region. Therefore the INTEGRAL payload includes both an X-ray monitor and an optical monitor. The X-ray monitor JEM-X will play a very significant role in the detection and identification of the gamma ray sources and in the analysis and scientific interpretation of the gamma ray data.

JEM-X will make observations simultaneously with the main gamma ray instruments and provide images with arcminute angular resolution in the 3 - 35 keV band. The instrument consists of two identical high pressure imaging Micro strip Gas Chambers that view the sky through coded masks located about 3.4 m above the detectors.

### 1.1.1 Active Galactic Nuclei

1.1.1.1 Introduction

Active Galactic Nuclei (AGN) are among the most luminous objects in the Universe. Most AGN emit approximately equal luminosity per decade of frequency from the IR to hard X-rays. Since the X-ray band covers three (0.1-100 keV) out of those ten decades of frequency, AGN emit up to 30 % of their bolometric luminosity as X-rays. Observations in the X-ray band exhibit the most rapid time variations, an indication that their origin lies at the most central part of the AGN. The determination of the nature of the processes that drive the energy emission from the core of an AGN requires, therefore, spectroscopic and time variability studies in both X-rays and soft gamma-rays.

The only viable and sufficiently efficient mechanism to explain the enormous power output from an AGN is the release of gravitational power as matter falls into the deep potential well of a central massive black hole. The actual geometry and physical state of the accreting gas flow is uncertain, but it may be that most of the gas accretion takes place in a relatively cold ($10^5$ K) accretion disc. Most of the accreting power is released just outside the black hole and here (possibly in a disk corona) part of the accreting matter is heated to high temperatures ($10^9$ K), i.e., hot enough to allow for the efficient emission of X-rays.

The existence of different classes of AGN now seem to be largely due to different viewing directions of the observer. According to the Unified Model for AGN (e.g. Antonucci, 1993) the central black hole, the accretion disk as well as broad line emitting gas are surrounded by a molecular and dusty torus that obscures the view for some observers. Among the radio-quiet AGN, Seyfert 2s are simply Seyfert 1s viewed through the torus. Radio-quiet QSOs would be the more distant or luminous counterparts. Among the radio-loud AGNs, blazars, radio-loud quasars and broad line radio galaxies, and narrow line radio galaxies also form a sequence of different viewing directions and obscuration. High resolution spectroscopic and variability studies in the X-rays and gamma-rays will be very important in determining the physical properties and geometry of the torus, the accreting gas close to the black hole, as well as other diffuse gas components.

The X-ray spectra for different classes of AGN seem to be different (e.g., see the review by Mushotzky, Done, and Pounds 1993). Most spectra are known only over a limited energy range and that precludes a detailed physical interpretation. The most well studied class, the typical Seyfert 1, has power law spectra with photon index -1.7 in the 2-20 keV range. Twelve co-added Ginga-spectra of Seyfert 1s showed that the X-ray spectrum is not a simple power law but consists of an intrinsic power law component of index -1.9 and a component peaking at 20-30 keV that is due to reflection (or reprocessing) of the intrinsic power law by cold opaque matter (Pounds *et al.* 1990). Later analysis of 60 spectra from 27 Seyferts (Nandra and Pounds 1994) confirms these conclusions. The reflecting matter must intercept about half of the intrinsic X-rays, but otherwise its location and spatial distribution are not yet known.

The reflection component shows strong spectral features such as an Fe K-shell absorption edge in the 7.1-9.3 keV range and an associated Fe K" fluorescence line in the 6.4-6.9 keV range (e.g. George and Fabian 1991). The higher the ionization state of Fe, the higher is the energy of the edge and the line. The actual shape of the reflected spectrum and the equivalent widths of the lines from an X-ray ionised accretion disk depend strongly on the classical ionization parameter of the gas being exposed to the primary intrinsic X-ray spectrum (Ross and Fabian 1993, Matt, Fabian, and Ross 1993b). The varying ionization parameter across such a disk gives rise to complex line shapes containing important diagnostic information about the geometry (Matt, Fabian, and Ross 1993a). Detailed theoretical studies have been made of the contribution to the X-ray spectrum from both transmission through and reflection from the obscuring torus (Ghisellini, Haardt, and Matt 1994). They show that the variability pattern as function of wave-length is an important diagnostic for the column depth of the torus. Fe lines may finally be produced in any warm or cold dense material partially covering the X-ray source (such as e.g, the broad line region, Yaqoob *et al.* 1993). Finally, sufficiently hot material of sufficient column depth may scatter and broaden the line.

Ginga observations (Nandra and Pounds 1994) show that Seyfert 1s have, in general, a Fe K" line at 6.4 keV with an EW consistent with reflection. In about 40 % of the sources, there are indications of a warm absorber of $N_H$ . $10^{23}$ $cm^{-2}$ that causes an absorption edge at 8 - 9 keV and complex soft X-ray absorption. In Seyfert 2s, on the other hand, the Fe line has very large EW. The few moderate resolution BBXRT spectra show narrow (< 300 eV FWHM or, equivalently, 7500 km/s in NGC 4151; Weaver *et al.* 1992), sometimes complex lines (NGC 1068, Marshall *et al*. 1992) that exclude an origin in a relativistic accretion disk and indicate the presence of both fluorescence and recombination photons. In the unified model, the large EW is explained by torus obscuration of the X-ray continuum, while the Fe line originates in any reflecting gas.

A major result from GRO OSSE and BATSE is that the soft gamma-ray spectra of Seyferts have, on average, a photon index of -2.2. The spectra must, therefore, show a break from the X-ray index of -1.7 to -2.2 at about 50 keV. The detailed shape of this important break is not known for any source. Theoretical studies of the generation of X-ray spectra in AGNs over the last decade has resulted in two types of models, thermal and nonthermal, depending on whether the dissipated power is channeled to most of the electrons or just a few of them. Both models make detailed predictions regarding spectral shape and other spectral features, e.g the nonthermal pair cascade models predict an annihilation line having a few per cent of the X-ray luminosity. JEM-X together with IMAGER and SPECTROMETER will for the first time provide the detailed spectral shapes needed for a useful theoretical interpretation.

#### 1.1.1.2 Role of JEM-X

GINGA showed that the apparent X-ray power law spectra of Seyfert 1 galaxies, one of the most well studied class of AGNs, consist of two spectral components, one intrinsic power law of photon index -1.9 and one component, supposedly peaking at 30-40 keV arising from reflection (or reprocessing) of the intrinsic power law by cold opaque matter. The reflected component falls off both towards lower energies (due to photoelectric absorption) and towards higher energies (due to Compton downscattering). Knowing the equivalent width (EW) of the fluorescent Fe-line at 6.4 keV in the reflected spectrum is of primary importance when making the two-component fit. Detailed X-ray to gamma-ray spectra, 2-500 keV (with large spectral gaps) have been obtained for only two Seyfert galaxies, IC 4329A (Madejski *et al.* 1995, see Figure 1) and NGC 4151 (Zdziarski *et al.* 1993, Maisack *et al.* 1993). They show different cutoff behavior for each source in the hard X-rays and gamma rays. For IC 4329A, simultaneous ROSAT and GRO OSSE data have been supplemented with archival GINGA data. For NGC 4151 non-simultaneous GINGA and GRO OSSE data are used. It is clear from Figure 1 that using only the GRO OSSE data covering the range 60-500 keV does not allow the separation of the intrinsic component from the reflected one. Knowledge of the spectrum below about 10 keV, where the reflected component only makes a small contribution is required. Similarly, for NGC4151 the GRO OSSE data does not allow meaningful modelling using any physical process since the low energy power law below the break at 70 keV is not known. For INTEGRAL, the 20 keV-10 MeV spectra from IMAGER must be supplemented with X-ray spectra down to and including the Fe line at 6.4 keV before any meaningful analysis of the Seyfert spectra is possible.

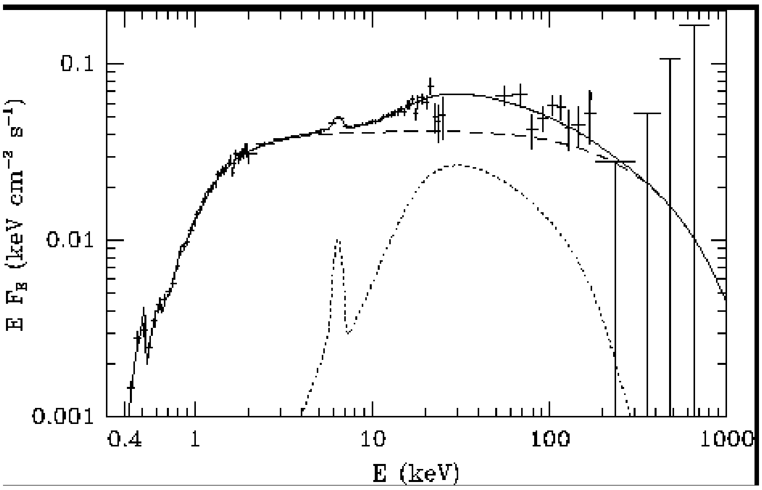


**Figure 1**. Model fits (curves) of the broad-band spectrum (crosses) of IC 4329A. The data are from a simultaneous ROSAT/OSSE observation (M95) and a Ginga observation. The upper limits here are 2F. The dashed curve represents the best-fit absorbed power law (" = 0.99) with an exponential cutoff ($E_c$ = 480 keV). Absorption is due to both an ionized medium with $n_H = 3.4 \times 10^{21}$ $cm^{-2}$ and . = 1.7 and a neutral medium with $n_H = 2.3 \times 10^{21}$. The dotted curve represents the absorbed reflected component (R = 1.28; the reflected spectrum includes a fluorescent Fe K" line). The solid curve is the sum.

1.1.1.3 PI Team Science with JEM-X

The PI team intends to study, in great detail, a set of AGNs containing both Seyfert 1s and Seyfert 2s. Spectral monitoring from 3 keV-35 keV and for stronger sources up to 60 keV with JEM-X together with simultaneous data from the IMAGER and SPECTROMETER will allow the various continuum components to be separated. Of particular importance is the determination of the spectral shape of the intrinsic continuum and its time-dependent behaviour in different classes of objects.

Detailed spectral modelling of the intrinsic continuum will be performed by the PI-team using state of the art thermal and non-thermal models that allow for the determination of model parameters and their time evolution. In the same process, the time dependent behaviour of the reflected component and the Fe line will be obtained. Correlation studies between the various components including the intrinsic one will set constraints on the geometry of the matter responsible for each component.

Data of less quality from a larger sample of AGNs will be used to make statistical analysis, to compare the properties of different classes of AGN, and to test the predictions of the unified model. Knowing the spectral shape from 3 - 120 keV for a larger sample of Seyferts will allow the PI team to address the question of the origin of the Cosmic X-ray background and whether or not it is mainly due to Seyfert 2s, a recently fashionable suggestion.

### 1.1.2 Accreting X-Ray Pulsars

1.1.2.1 Introduction

X-ray pulsars are binary systems where a magnetized neutron star having magnetic fields of order $10^{12}$ gauss accretes matter from a companion star (for a brief review, see Parmar 1994). The dipole field of the neutron star disrupts the accretion disk flow and channels the matter onto the magnetic poles where a luminosity of up to $10^{38}$ ergs $s^{-1}$ is released. The heated matter radiates in a beamed pattern probably along the field lines in low luminosity sources (where the accretion column has a pill-box shape) and perpendicular to the field lines in high luminosity sources (where the accretion column is narrow). The neutron star rotation together with this beaming and further effects are thought to be responsible for the various X-ray pulse profiles.

To date, more than 30 X-pulsars are known (see review by Parmar 1994). Their X-ray continuum spectra are fitted with power laws having an (exponential) high energy cutoff at about 15 keV. The most well studied object is Her X-1 (discovered in 1972) from which additional spectral features are detected. Pre-eclipse dips are also observed and are thought to be caused by X-ray absorption in clouds near the point where the gas stream from the companion impacts on the disk. Detailed analysis of GINGA data (Choi *et al.* 1994) shows that during the absorption dips another (unpulsed) spectral component becomes dominant caused, most likely, by the primary unobscured spectrum scattering in an optically thin corona. A fluorescent Fe line at 6.4 keV also shows the same pre-eclipse absorption as the pulsed X-ray beam.

Early balloon experiments by Trümper *et al.* in 1977 (see Voges *et al.* 1982 for final analysis) showed the existence of a shoulder in the spectral tail above the spectral cutoff in Her X-1. It was interpreted as a cyclotron feature either in emission at 52 keV or in absorption at 38 keV with the line centroid varying sinusoidally during the pulsar period. This discovery confirmed the existence of $10^{12}$ gauss magnetic fields in pulsars. The detailed analysis and spectral fitting by Soong *et al.* (1990) of the phase resolved spectroscopy in the 12-180 keV range, seen by HEAO 1 in 1978, favours the absorption interpretation, as does most theoretical modelling. LAC on GINGA could be used up to 60 keV in a low gain mode allowing the highest energy resolution studies (8% at 35 keV) of the cyclotron feature in Her X-1 to date (Mihara *et al.* 1990). Resolving the cyclotron (resonance scattering) feature allowed Mihara *et al.* to favour the absorption line interpretation with greater certainty. GINGA increased the number of X-ray pulsars with known cyclotron features from 2 to 9 (e.g review by Parmar 1994). The cutoff energies are typically around 15 keV with the cyclotron line energy between 20 and 40 keV.

CGRO BATSE with its continous monitoring was able to obtain the light curve of Her X-1 for the full 35 day precession cycle in hard X-rays (15-70 keV), pulse profiles up to 200 KeV, and a phase averaged spectrum from 15 to 200 keV (Wilson *et al.* 1993). The quality of the spectral data were such that a power law of index -4.5 was an adequate fit with no need for any cyclotron feature. Her X-1 was also observed at three different times by CGRO OSSE (e.g. Kurfess *et al.* 1993). Although the OSSE threshold at 40-50 keV does not allow the cyclotron line, to be observed, the OSSE data will be analysed for the existence of higher cyclotron harmonic features.

<u>1.1.2.2 Role of JEM-X</u>

The hard X-ray emission from accreting X-ray pulsars will be observed by INTEGRAL's main instruments. For the presently known sample of sources, the SPECTROMETER will be able to obtain phase resolved spectroscopy down to energies covering the cyclotron line energies (20-35 keV) as well as to search for higher cyclotron harmonics. JEM-X will be a crucial supplement for the extension of the spectra to lower energies. It is of strong importance to have a full knowledge of the behavior of different spectral components when analysing the phase dependent behavior of the cyclotron line features and of any hard X-ray and soft gamma-ray emission.

<u>1.1.2.3 PI Team Science with JEM-X</u>

The PI team intends to make phase resolved spectroscopy of most of the 9 X-ray pulsars known to have cyclotron lines in order to better determine the spectral shapes as function of phase and to search for higher harmonic features and their phase dependent characteristics. Searches for cyclotron features in additional X-ray pulsars will be also made. The lack of detection by Ginga may simply be due to the limited energy range of LAC (even in the low gain mode).

Detailed theoretical interpretations will be made using both the phase dependent spectral shapes and the pulse profiles in various energy ranges. The cyclotron features will be fitted with the standard analytical shapes that have been sufficient thus far (or with improvements if necessary). The fits will be interpreted in terms of recent radiative transfer models in highly magnetized media.

### 1.1.3 X-Ray Transients and Galactic Black Hole Candidates

<u>1.1.3.1 Introduction</u>

Several binary X-ray sources in our Galaxy (and nearby galaxies) show strong evidence that the X-ray emitting component is matter accreting into a black hole. Studies of these objects are very important for establishing the existence of black holes of stellar mass and for probing the near environment of a black hole where gravity is in the strong field limit. The clearest evidence that black holes are involved is obtained first from X-ray observations of an unusual X-ray source and second from optical measurements that the companion star is orbiting a mass larger than 3 $M_{à}$, this being the maximum accepted mass for a neutron star. The nature of the X-ray source is unusual in the sense that there are no pulses attributable to the spin of a rigid body (such as a neutron star) - the X-ray light curve is often chaotic in form - and the spectrum is particularly hard, better fitting the expectation of accretion onto a body with no hard surface. Indeed, most of the objects detected by the instrument HEAO-1 A4 at energies between 50 - 100 keV are considered to be Black Hole Candidates (BHC), the most famous of which is Cygnus X-1. The hard tail to the spectrum is remarkably similar in shape to that observed from AGN.

Another notable feature of many BHC is that they show a number of separate intensity states; many of them are transient, being undetectable in between outbursts that may last a few months and recur every few decades.

To date almost a dozen good BHC have been identified. Some of those orbit massive stars and are persistent in the sense that they can always be detected in X-rays e.g. Cyg X-1, LMC X-1 and LMC X-3. Some are X-ray transient BHC which orbit low mass stars e.g. A0620-00, GS2023+338 (V404 Cyg) and GRS1124-68 (Nova Muscae). These last 2 are perhaps the best candidates of all since their mass functions are 6.1 and 3.1 $M_{à}$ respectively. There are also many other possible BHC (objects which have similar X-ray properties to the established candidates) which are difficult or currently impossible to study optically because of obscuration due to their location in the Galactic Plane or near the Galactic Centre where they are highly obscured.
Hard X-ray data from HEAO-1, Ginga, SIGMA and OSSE show that BHC have particularly hard spectra, or at least hard tails. In some cases, spectral features are seen which have been attributed to electron-positron annihilation in the accreting material (Sunyaev *et al.*, 1992; Goldwurm *et al.*, 1992). Rapid variability, showing time lags between different spectral bands, is common. Broad iron line and/or edge features are also common (Tanaka, 1992). Studies of these bright objects and comparison with AGN (which are much fainter and have much longer time scales) should reveal the emission processes and behaviour of matter accreting into a black hole, and hopefully the nature of the hole itself. The transient BHC also show a much larger range of intensity in a single object compared with AGN, so providing an extra dimension for study.

<u>1.1.3.2 Role of JEM-X</u>

The hard spectrum of BHC will make them important targets for INTEGRAL. Possible annihilation features and the spectral break seen around 100 keV or so, which is important for understanding the emission mechanisms, will make spectra of these objects a high priority. The whole X-ray/soft gamma-ray spectrum is essential here and it is vital that JEM-X provides coverage down to 3 keV.

<u>1.1.3.3 PI Team Science with JEM-X</u>

The PI team intends to make detailed spectral and variability studies of the persistent BHC; Cygnus X-1, LMC X-1 and LMC X-3, as well as some candidate BHC such as GX339-4. The transient sources are more difficult to schedule since they do not yet recur in a predictable manner. Neverthe-less we intend to study any that occur in the first years of operation of INTEGRAL.

The INTEGRAL core program including repeated surveys of the galactic plane and the central radian favours this type of source monitoring and spectral analysis.

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## 1.2 Scientific Performance Summary

The key properties for the scientific capabilities are: Field of view, source detection sensitivity, angular resolution, point source location accuracy, and spectral resolution as listed in **Table 1**.

The Field of View has been dimensioned to allow the 2E dithering steps required by the gamma-ray instruments. A source, offset 2E with respect to the instrument axis, will still be inside the fully illuminated[1] field of view .

**Table 1**: JEM-X Specifications

| | |
|---|---|
| Active mask diameter | 535 mm |
| Active detector diameter | 250 mm |
| Distance from mask to detector entrance window | 3398 mm |
| Energy range | 3 - 35 keV Primary range<br>35-60 keV First extension[1]<br>60 - 100 keV Second extension[2] |
| Energy resolution | ) E/E = 0.47 (E/1 keV)$^{-½}$ |
| Angular resolution | 3 arcmin |
| Field of view (diameter) | Fully illuminated 4.8E<br>Partially illuminated[3] 7.5E<br>Zero response 13.2E |
| Relative point source location error | < 30 arcsec (10F source) |
| Narrow line sensitivity (isolated source) | 2.5 $10^{-4}$ photons $cm^{-2}$ $s^{-1}$ @ 6 keV<br>2.5 $10^{-4}$ photons $cm^{-2}$ $s^{-1}$ @ 30 keV<br>for a 5F line detection in a $10^{5}$ s observation |
| Continuum sensitivity (isolated source) | 7 $10^{-6}$ photons $cm^{-2}$ $s^{-1}$ $keV^{-1}$ @ 6 keV<br>for a 3F cont. detection in a $10^{6}$ s observation |
| Timing accuracy | 122 µs (1/8192 s) |

*1) JEM-X will operate in this range but the quantum efficiency is reduced.*
*2) Photons can still be registered in this range but the imaging capabilities are reduced since the mask is not completely opaque at these energies.*
*3) At this angle the sensitivity is reduced by a factor 2 relative to the on-axis sensitivity.*

[1] We use the term "fully illuminated field" here rather than the more conventional "fully coded field" because the JEM-X detector does not cover, even for an on-axis source, the complete code pattern of the mask.

# 1.3 Instrument description

## 1.3.1 Measurement principle

The JEM-X instrument is based on the same measurement principle as the two gamma-ray instruments on INTEGRAL: sky imaging using a Coded Aperture Mask. An imaging X-ray detector observes the sky through a perforated mask, the hole pattern on the mask is designed to assure that each source within the Field-of-View can be recognized through its shadowgram. The dimensions of the holes in the mask and the separation between the mask and the detector determines the angular resolution of the instrument, in the case of JEM-X the angular resolution is 3 arcminutes, which is the best of the three high-energy instruments on INTEGRAL.

### 1.3.1.1 Functional description

The description below follows the diagram in Fig. 2 from top to bottom. The cosmic X-ray photons enters the JEM-X instrument through the holes in the coded mask situated 3.4 m above the detector entrance window. Inside the detector the photons are absorbed in the xenon gas, and resulting ionization cloud is amplified and detected on the Micro strip plate. The energy of the incoming photon and its position can be determined from the electrical signals induced on the micro strips.

Thanks to the hole pattern in the mask the photons originating from a particular point source on the sky will produce a unique pattern of illuminated spots on the detector. Sources in different positions on the sky will produce different spot patterns on the detector. These patterns can later be disentangled and the source positions and strengths can be determined from the complex image.

The Field of View of JEM-X is defined by a collimator placed on top of the detector entrance window. The collimator has an acceptance angle of 6.6E at zero response. This angle matches the angle defined by the mask-detector combination. The collimator is important for reducing the count rate caused by the cosmic diffuse X-ray background. However, the presence of the collimator unavoidably also mean that sources near the edge of the Field-of-View will be attenuated with respect to on-axis sources.

The photon absorption process is mostly dominated by the photo-electric absorption of the photon in the xenon gas in the detector. This process causes an electron to be emitted from the struck Xe-atom. The emitted electron will ionize other atoms along its track and thus create a cloud of electrons. An electric field between the entrance window and the Micro strip sensor plate, will cause the electron cloud to drift towards the Micro strip plate. When it is sufficiently close to one of the individual anode strips the electric field becomes so strong that an avalanche of ionizations is created and a significant electric charge is picked up on the strip as an electric impulse.

A capacitive read-out system is used on the Micro strip plate for determination of the avalanche position. The signals from the read-out chains delivered to the Digital Front End Electronics (DFEE) for calculation of the position of the interaction and for rejection of unwanted events. The majority of the background events will be due to cosmic ray or Solar energetic particles, but some of the high energy photons are absorbed through a two stage process, which leaves two spatially separated charge clouds in the gas. The position of the first interaction for these events is ambiguous and they will be rejected by the electronics.

The event data is finally passed to the Digital Processing Electronics (DPE) which formats the data for the telemetry. The full set of parameters for an event consists of arrival time, position in the detector (x and y), and pulse-height (proportional to energy). When observing source fields with integrated source fluxes exceeding about 750 mCrab (about 100 counts per s) the telemetry allocation will be fully used, and some data must be rejected.

The Mask is based on a Hexagonal Uniformly Redundant Array (HURA) as described by Finger and Prince (1985), however for JEM-X a pattern with only 25% open area have been chosen, based on a so-called "Bi-quadratic Difference Residue Set" corresponding to the prime number 22501 (see in't Zand et al, 1994). In order to obtain an angular resolution of 3 arcminutes the dimension of the hexagonal cells have been chosen as 3.3 mm. measured across the hexagon faces. The total number of elements in the mask will be about 23300, so a slight repetition of the pattern will be needed at the edge of the mask.

The 25% transparent mask surprisingly achieves better sensitivity than a 50% mask, particularly in complex fields with many sources, or in fields where weak sources should be studied in the presence of a strong source. Very importantly in the case of JEM-X, the mask with lower transparency reduces the number of events to be transmitted (while at the same time increasing the information content of the remaining events!). Considering the limited telemetry allocation to JEM-X, this will mean a improved overall performance for the instrument, particularly for observations in the plane of the Galaxy.

The pointing stability if INTEGRAL is sufficiently good that the image data can be integrated directly without continuous position corrections. A new source can be located to a precision of about 1.0 arcminute including the pointing accuracy of INTEGRAL. If other, known, sources are detected in the same field, the position determination may be better, dependent on the counting statistics.

*References:* *in't Zand, J.J.M, Heise, J. and Jager, R., 1994, A&A, 288, 665*
*Finger, M.H. & Prince, T.A., 1985, 19. Cosmic Ray Conf., (La Jolla), OG 9-2, 295*

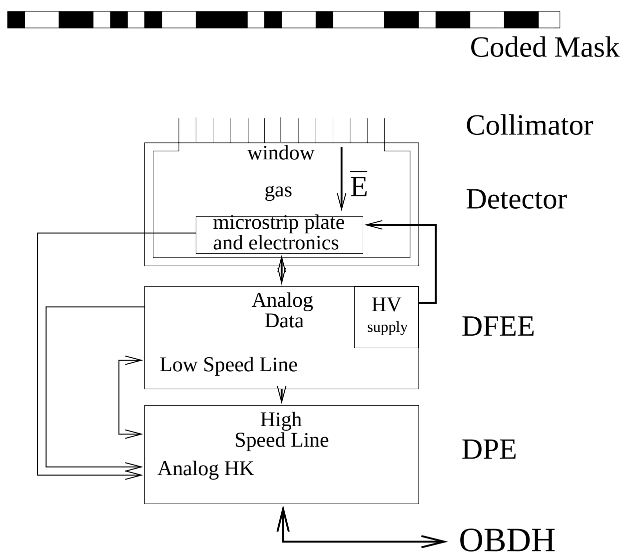



**Figure 2 Functional diagram**

1.3.1.2 Observation strategy

When observing a source field INTEGRAL will normally execute a sequence of sub-exposures with slight changes of the satellite pointing in between. This "dithering" improves the imaging for the gamma-ray instruments. The duration of the sub-exposures will be about 1000 seconds during the Galactic Plane Scans and about 1800 s during all other observations..

1.3.1.3 On board calibration

To calibrate the energy response of the JEM-X detectors a calibration system consisting of four radioactive sources is embedded in the detector collimators. These sources will permit to monitor the gas gain of the detector continously.

The detector position determination can be calibrated in-flight by observing a strong point-like source such as the Crab. The position determination precision in the detector is best at energies between 4 and 15 keV. The count rate of the Crab Nebula in this interval is about 150 cts $s^{-1}$. There are about 1300 open cells positions projected from the mask to the detector. In a 1000 s observation of the Crab we will therefore get about 120 source counts in each illuminated spot on the detector and we may compare with the mask pattern to verify the position resolution.

### 1.3.2 Hardware description

The JEM-X monitor consists of two coaligned, identical telescope units. A single JEM-X unit comprises 3 major subsystems: the detector, the associated electronics and the coded mask.

1.3.2.1 Detector

The JEM-X detector is shown Figure 3. It is a Micro strip Gas Chamber with a sensitive area of about 500 $cm^2$. The detector consists of the following modules: the detector vessel, the collimator, the X-ray window , the sensor package with the Detector Analog Electronics (DAE) and the calibration sources. The gas inside the detector is a mixture of xenon and methane at 5 bar pressure.

The diameter of the detector window is 250 mm, the height of the detector front window above the reference plane defined in the MICD is 127 mm.

1.3.2.1.1 Detector Vessel

The detector body is made of stainless steel and consists of two parts, the main-frame and the cover which are joined together by electron beam welding. There are no gaskets.

The cover is formed from 2 mm thick stainless steel plate. The shape of the cover is similar to that of the cap for a pressure vessel.

The main-frame is a cone shaped ring with a circular flange in the middle for mounting the collimator. The elctrical connectors, the high voltage feed throughs and the gas filling tube are welded to this main-frame. All internal structures also mounts to the main-frame. The internal structure consists of two sets of vertical studs and a spider structure. The field forming rings are fixed on one set of studs and the MS-sensor package and the spider structure is mounted on the other set of studs. The spider structure carries the Detector Analog Electronics (DAE).

1.3.2.1.2 Collimator

The collimator has a dual role, it acts as a support for the thin X-ray window against the internal pressure of the detector, and it limits the field of view (FOV). The full-width-at-half-maximum of the collimator FOV is tailored to have the same zero response as that of the detector-mask combination (6.6 deg). This is the best match to maximize the instrument signal-to-noise ratio. The collimator cell geometry is chosen to be square. This geometry is less expensive than a hexagonal one and it is fully compatible with the hexagonal cell geometry of the mask as verified by numerical simulations. The material chosen for the core of the collimator is molybdenum with a thickness of 180 micrometers. This allows to obtain a close to zero collimator response for incident angles greater than 6.6 deg. The K-fluorescence photons produced by the molybdenum could contribute to the detector background. To reduce this contribution the molybdenum will be covered by 35 micrometer copper from both sides of the cell walls. Finally a 100 micrometer aluminum layer will be added on top to absorb the 9 keV K-fluorescence photons of copper.

The manufacturing process of the collimator cells has been defined after a test campaign performed to verify the dynamical strength of the design. The cells will be made of crossed slats of Molybdenum covered on both sides with a bilayer of Copper and Aluminium. The Copper is fixed to the Molybdenum plates with a double side cladding process. The Aluminum layer is fixed on both sides by a diffusion bonding process. The single cells are stiffened with an eutectic Zn5Al brazing. The brazing process has been tested. The cell structure is contained in an external ring of Molybdenum which is brazed to the cell structure with the above eutectic. Collimator subscale elements have been assembled and the qualification tests to verify their strength and their life time are now in progress. The internal side of each cell is 6.6 mm and its height is 57.0 mm. The cell assembly is circular with a diameter of 250 mm corresponding to the beryllium window diameter. An external ring of 3 mm thick Molybdenum supports the collimator cell assembly and has the role to interface with the detector frame.

Figure 4 shows the angular response of the collimator at 60 keV

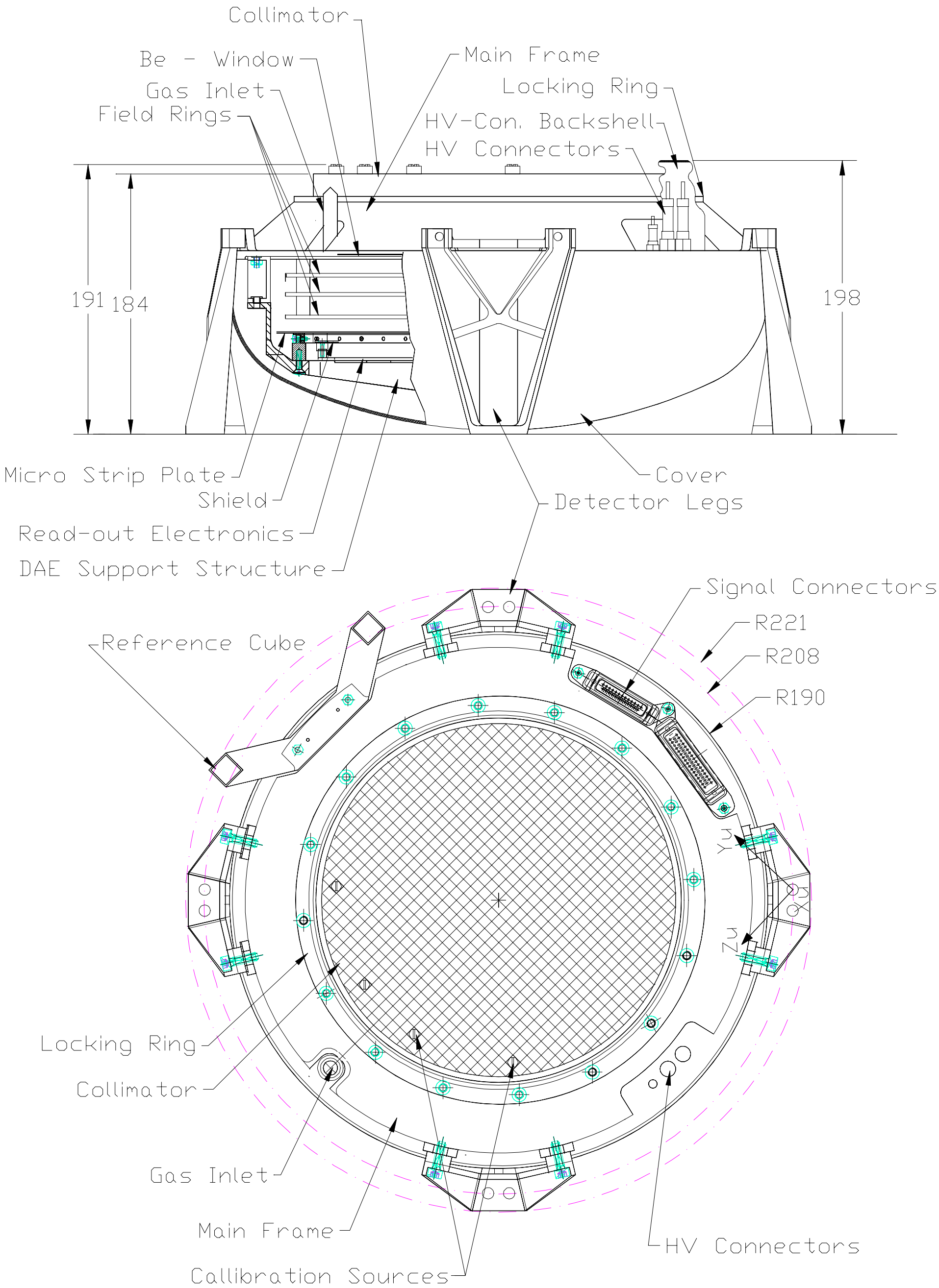



Figure 3 The JEM-X Detector box.

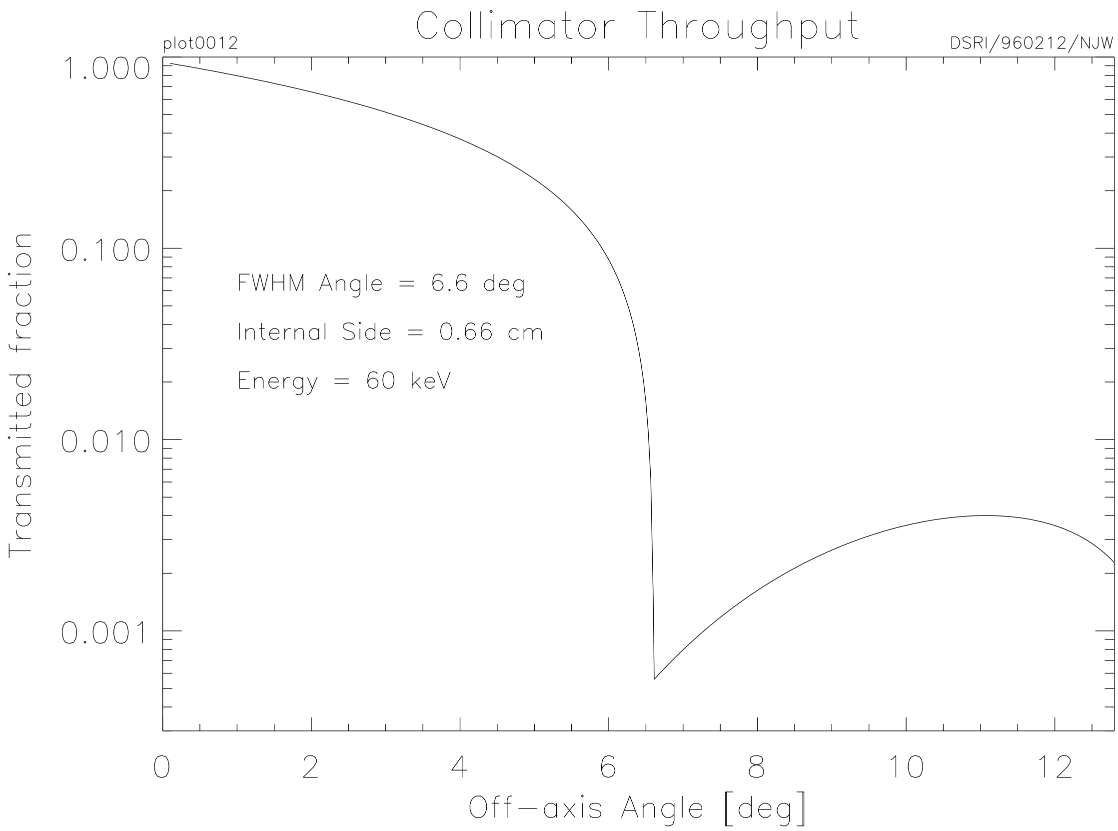



Figure 4 Angular response of the collimator

1.3.2.1.3 X-ray Window

The X-ray window of the detector must allow good transmission of low energy X-rays and be impermeable to the detector gas. The window is a 250 µm thick beryllium foil. The window is supported by the collimator structure against the internal pressure. The window is glued to a stainless steel mounting ring which is welded to the detector main-frame. The window is electrically conductive and at the same electrical potential as the detector body.

During transportation and storage the X-ray window and the collimator will be covered with a shield. This red tag item will be removed for tests and calibration and finally during the integration of the JEM-X units to the satellite.

1.3.2.1.4 Micro strip-sensor package

The Micro strip-sensor package consists of the following parts: The Micro strip plate, the support structure and the read-out electronics (DAE) mounted on ceramic plates around and underneath the Micro strip plate. The whole sensor package can be mounted and tested in the detector as a separate module. The read-out electronics (DAE) is described in 1.3.2.3.1 together with the DFEE electronics.

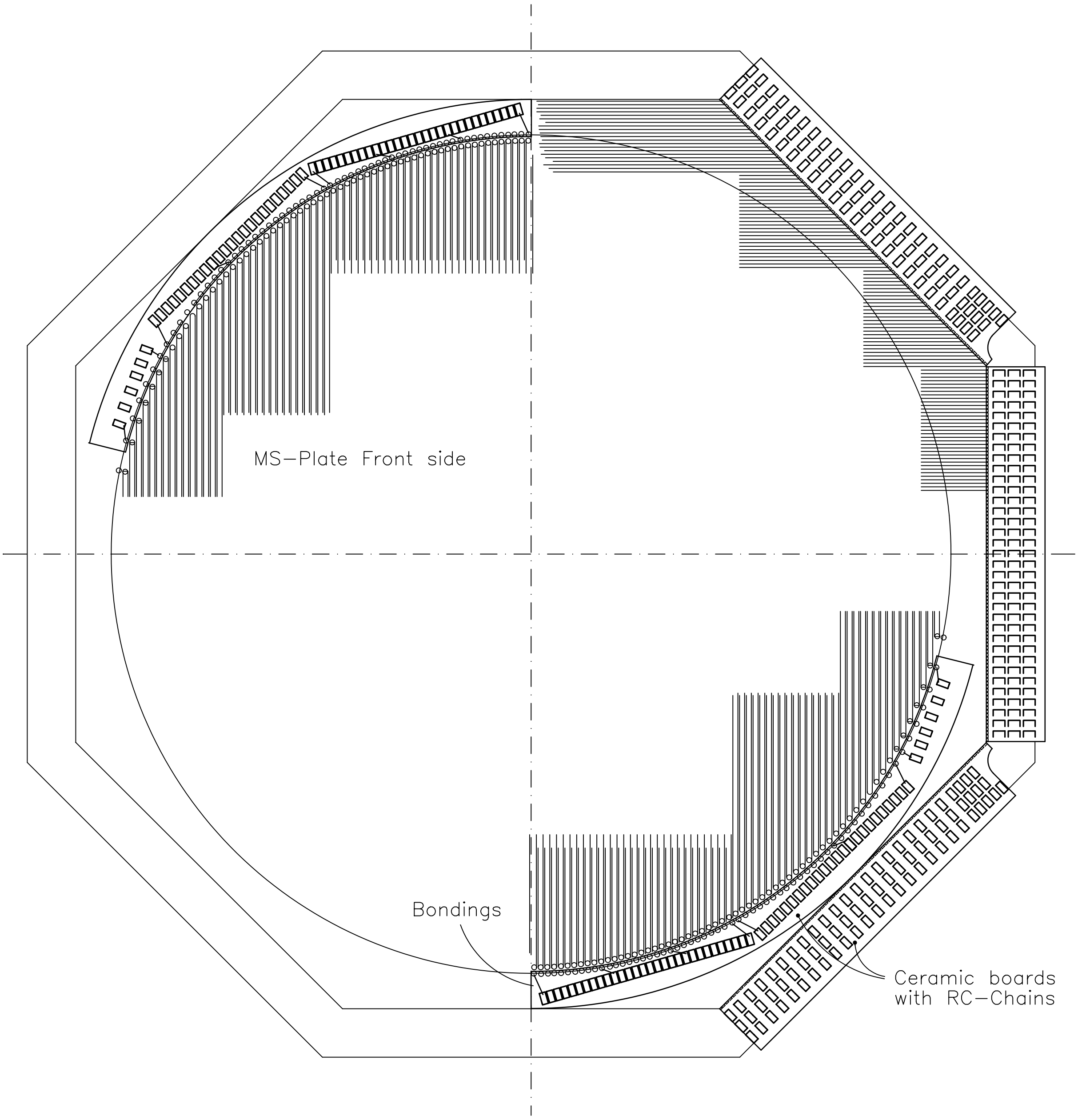



Figure 5 The electrical connections on the MS plate

The capacitive read-out chains are mounted on ceramic plates which are glued on the Micro strip plate edges. The Micro strip electrodes are bonded to these chains. Signals from the capacitive chains are led through high voltage blocking capacitors to the preamplifiers on the ceramic circuit boards underneath the Micro strip plate.

The layout of the capacitive charge division read-out chains on the plate is shown in Figure 5

The Micro strip pattern is shown schematically in Figure 6. The pattern is chosen to be shaped as a regular octagon with a diameter of 292 mm. The Micro strip pattern is similar to but larger than the one used for the Spectrum-RG project. The Micro strip pattern with alternating anode strips of 10 µm and cathode strips of 458 µm has a 1.062 mm pitch. This basic Micro strip pattern has previously been tested and qualified. The Micro strip will be formed in a 0.15 µm thick gold layer deposited on the substrate, D 263 glass. The Micro strip plate will be over coated with semiconducting S8900 glass . The micro strips will be connected to the printed circuit of the capacitive readout by wedge bonding.

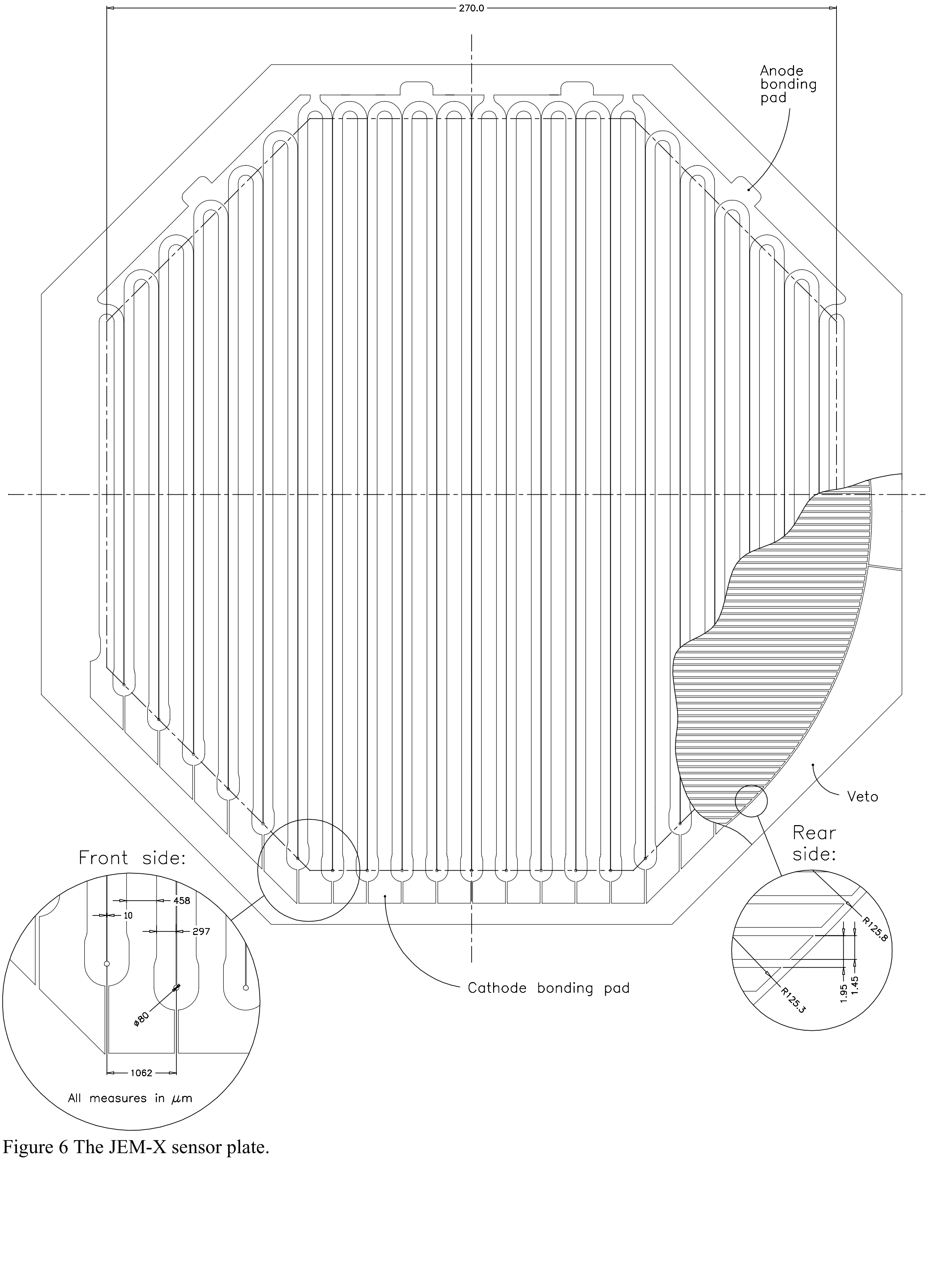



Figure 6 The JEM-X sensor plate.

The anode strips are connected into four groups, the signals from these are used for event triggering, energy determination and for pulse shape analysis. The cathode strips are read out using the capacitive charge division chains. The position of the avalanche in the direction perpendicular to the Micro strip pattern, the X-axis, are determined from the centroid of the avalanche charge.

The Y-coordinate for an event are obtained from an orthogonal set of pickup electrodes (also shown in Figure 6) deposited on the rear surface. These electrodes are arranged on a 2 mm pitch and are also read out by capacitive chains. For the 0.9 mm thick substrate, the pickup signal will be 18% of the avalanche charge. This is sufficient to achieve the required position resolution.

The rear strips are surrounded by a veto-electrode which is used to suppress events caused by charged particles entering through the sides of the detector.

1.3.2.1.5 Calibration Sources

Four calibration sources are integrated with the collimator.

The on board calibration system consists of the Fixed Radioactive Sources System.This system is composed of four 1.0 µCi, highly collimated radioactive $Cd^{109}$ sources.. The sources are located within four cells of the JEM-X collimator. The photons from the sources will produce spots of 4 $mm^2$ in each of the four anode groups on the microstrip plate. The $Cd^{109}$ sources will be collimated using Au and Mo absorbers and will be screwed into Al housings which will be glued in their respective collimator cells. Each $Cd^{109}$ source emits 22 and 88 keV photons and moreover they produce Ni fluorescence photons (7.5, 8.2 keV) from the source support Ni windows. The expected count rates are: 8 counts/s at 7.5 keV, 4 counts/s at 22 keV and 0.04 counts/s produced by the 88 keV photons. The latter events will only be suitable for long term checks of the detector calibration.

1.3.2.2 Coded Mask

The coded mask is a 0.5 mm thick tungsten plate. This thickness achieves the required opacities of 99.9% at 35 keV and 95% at 60 keV. The manufacturing technique chosen for the hole pattern is spark erosion using a wire electrode.
The height of the mask above the detector plane is about 3.4 m (see table 1). A peripheral titanium ring provides pretension and structural support to the coded mask . The ring also acts as the mechanical interface with the INTEGRAL Payload Module, by means of 12 equally spaced bolts. . The diameter of the mask coded area is 535mm. The mask elements will be hexagonal, and their size is 3.3 mm center-to-center.

The combination of the mask height and the mask element dimension means that the angular resolution of the instrument is 3.35 arcmin.

In order to withstand a 12 g axial and a 12 g lateral acceleration, and to have a fundamental resonant frequency above 60 Hz (axial) and 120 Hz (lateral), a reinforcement structure in titanium will support the mask. The reinforcement structure (exo-skeleton) has three internal rings connected by radial ribs. The loss of transparency due to the exo-skeleton is less than 2 % and the additional mass is about 1.7 kg.

Figure 7 is an illustration of the JEM-X coded mask pattern layout (mechanical interface not shown). The order of the basic pattern is 22501 (see section 1.3.1). The number of open cells in the mask is 5844.

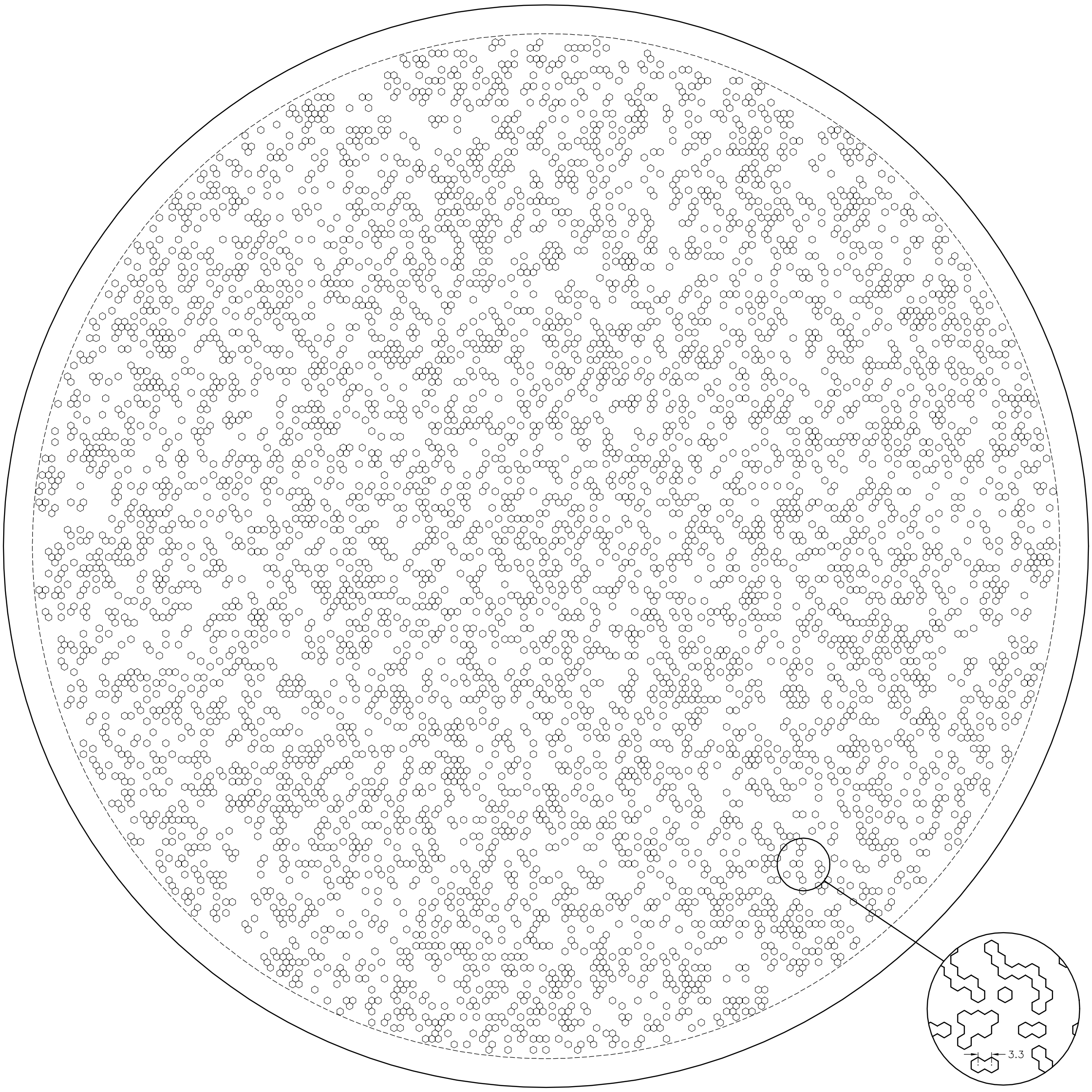



Figure 7 The JEM-X Coded Mask pattern layout

1.3.2.3 Electronics

The instrument contains the following two major electronic subsystems: Detector Analog Electronics (DAE), located in the detector box, and Digital Front End Electronics (DFEE), situated in the electronics box.

1.3.2.3.1 Detector Analog electronics (DAE)

See the block scheme in Figure 8.

The function of the DAE is to:

a) Distribute the high voltages to the Micro strip glass plate and field electrodes,
b) Monitor the temperature and the pressure of the detector.
c) To extract the detector signals for subsequent handling in DFEE,
d) Perform electronic calibration using a special in-build calibration pulse generator

The DAE can be divided into the following sub units:

1) High voltage boards for decoupling of the drift and gas gain voltages (Vc & DV),
2) Temperature and pressure sensors.
3) Preamplifiers for the anode and veto electrodes (4+1)
4) Preamplifiers for the cathode and backplane electrodes (11+20)
5) Electronic calibration circuit delivering signals to the inputs of all 36 preamplifiers

The preamplifiers are classical charge sensitive preamplifiers (Amptek). Prefiltering and buffering will assure reliable signal transfer to the DFEE.

1.3.2.3.2 Digital Front End Electronics (DFEE)

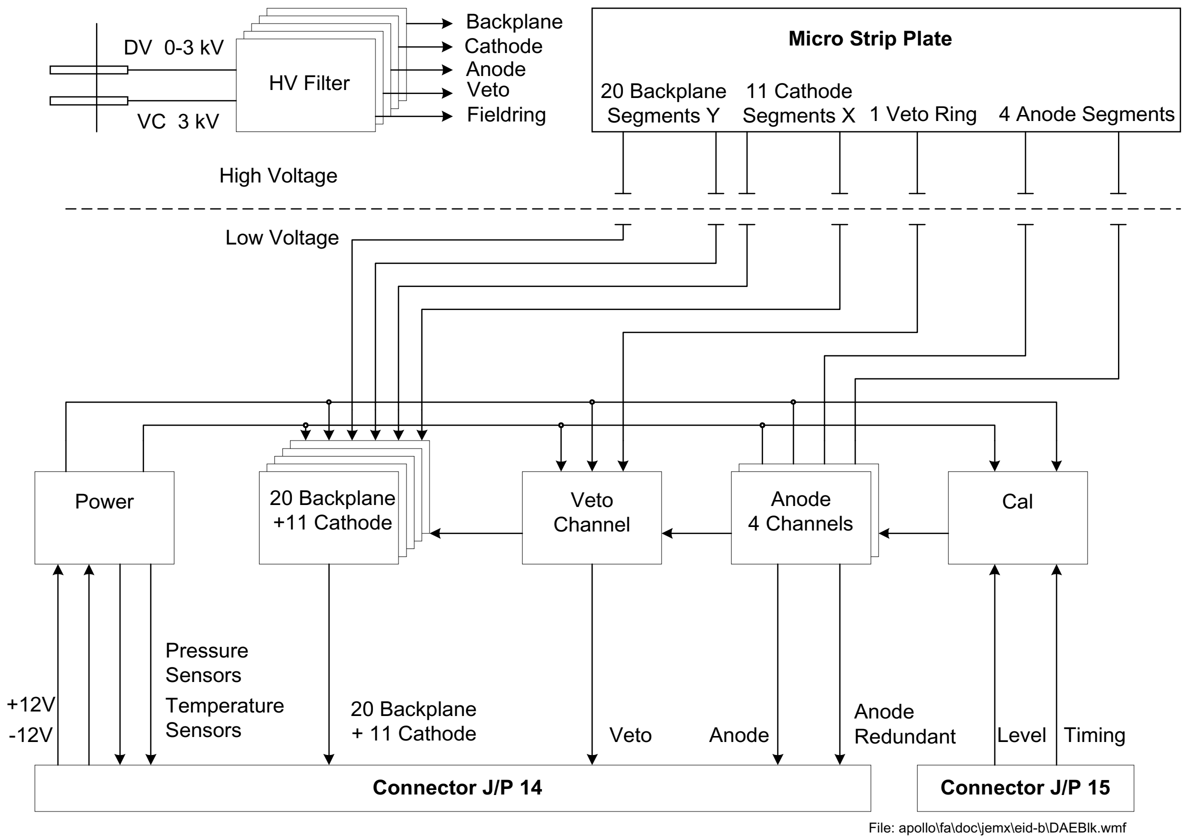



Figure 8 Detector Analog Electronics (DAE)

The block scheme is shown in Figure 9:

The function of the DFEE is to:

1) Generate main event trigger, based on the anode (Energy) signal,
2) Amplify, filter and peak detect the detector signals,
3) Digitize the signals
4) Validate the events (for background rejection),
5) Calculate position and energy of valid events,
6) Communicate with the DPE,
7) Generate and control the high voltages Vc & DV.
8) Adjust the discriminator level for the main event trigger,
9) Convert the primary 27V to the instrument voltages and distribute them,
10) Perform housekeeping monitoring of voltages, currents and temperature,

The DFEE can be divided into the following subunits:

1) Anode HF and LF filter amplifiers and peak detectors,
2) Anode discriminator,
3) Cathode and rear side filter amplifiers, peak detectors,
4) Fast 12 bit ADC reading all 34 peak detector channels,
5) 16 bit MA31750 processor controlling the high speed instrument bus,
6) Interrupt controller ,Watchdog, Memory (RAM and PROM),
7) Serial RS 422 interfaces to the DPE,
8) Housekeeping (Voltages,Temperatures,Pressures) and instrument control (high voltages settings, electronic calibration control, discriminator level),
9) Low Voltage converters,
10) High Voltage converter,

The MA31750 processor controls the reading of the analog bus and communicates with all functional units via the instrument bus. It performs all event validation (position footprint, centroid finding, anode, energy and signal risetime acceptance.

A hard-wired ratemeter circuit will monitor the pulse rate of the anode signals. The circuit will switch off the high voltages in case of very high rates. The high voltages can be switched on again by command from the ground. This ratemeter will operate independently of the processor, i.e. it will be functional even if the processor is stalled.

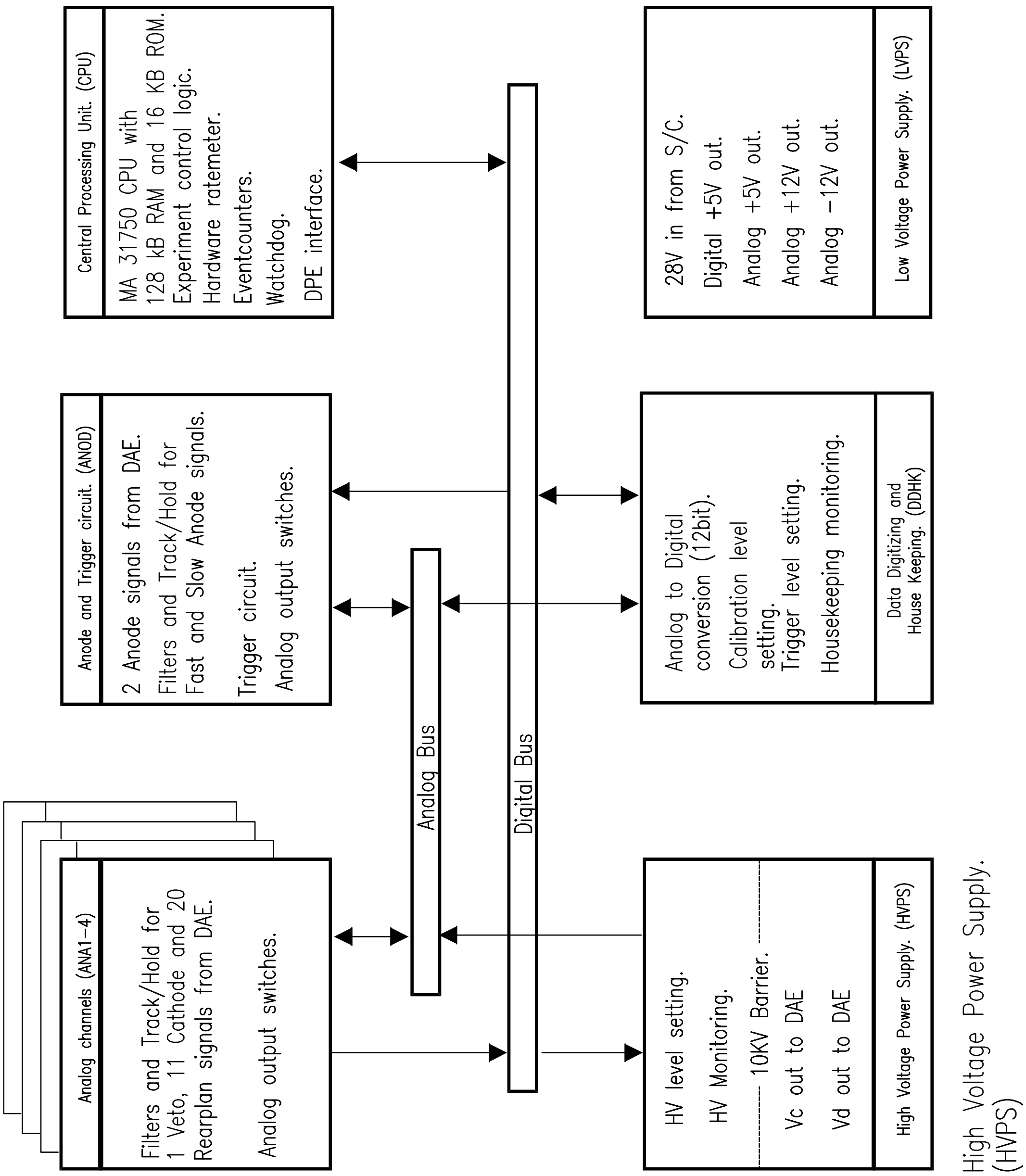



Figure 9 The Digital Front End Electronics (DFEE)

### 1.3.3 Software description

The JEM-X on-board software will be distributed between the DFEE processor and the DPE.

The DFEE processor will interface to the detector electronics on one side and via the fast serial line to the DPE on the other. The software in the DFEE processor will perform the following tasks:

- Detector read-out control
- Single event evaluation
- Background rejection
- Event buffering and transmission to DPE
- Hardware parameter control.

The DPE will interface to the DFEE processor on the one side and to the S/C OBDH on the other. The software supplied by the PI-team will perform the following tasks:

- Data reception from the front-end processor
- Data compression and TM-buffer build-up
- Housekeeping data acquisition
- Telemetry and Telecommand communication.

The on-board software will be developed according to ESA PSS-05-0. The DPE software will be written in ADA and the DFEE software will be written in assembler to achieve the required performance in terms of execution speed. As a consequence, the amount of software functionality implemented in the DFEE will be kept to a minimum.

## 1.4 Instrument operations

The two JEM-X instruments are operated independently. Housekeeping packets are generated in all states where the DPE is ON. Science data will only be generated when the DFEE is on, however, a large data buffer exists in the DPE and therefore Science-TM packets may be generated for some time after the DFEE is switched off. Special Science TM-formats are used in the CALIBRATION and DIAGNOSTIC states.

The following figure illustrates the DPE and DFEE operational states as well as the type of commands that may cause a change between states. The instrument operations are described in the User Manual.

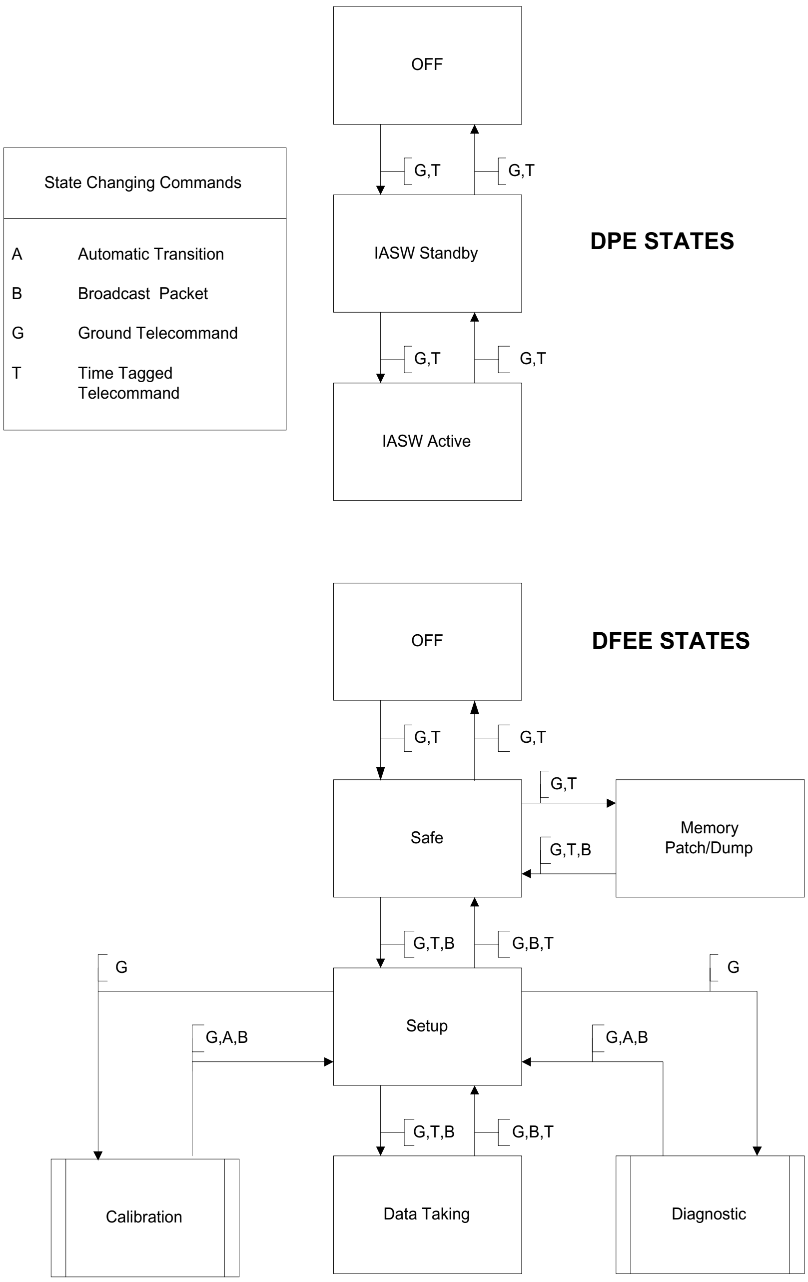



Figure 10: JEM-X State Diagram

# 2 COMPLIANCE OF INSTRUMENT DESIGN

## 2.1 Compliance with Spacecraft configuration

### 2.1.1 Accomodation constraint

In general the JEM-X accommodation constraints comply with the spacecraft baseline configuration, EID-A sec. 2.4.

The following points should be observed:

1. The field of view of each JEM-X unit must be free of obscuring objects. The field of view is a cone with a half opening angle of 6.6E. The apex of the cone is located on the instrument axis, 2257 mm below the mask mounting surface. (The opening of the cone is determined by the detector collimator, the diameter of the cone at the mask level is defined by the diameter of the coded mask).

2. The mounting of the JEM-X detectors must ensure that the operating in-orbit temperature stays within the limits given in section 3.3.1. Temperature change rates should not exceed 10EC per hour during operation.

3. The JEM-X detectors must be shielded against radiation from calibration sources located in other instruments.

### 2.1.2 FOV sensors/radiation

The zero response field of view of JEM-X is 13.2E (18.6E across the collimator diagonal).

The charged particle radiation, from the cosmic radiation and from the Sun, is the dominant source of background for JEM-X. About 1700 counts/s are expected from this source. The cosmic diffuse X-ray flux will add another 20 counts/s. To this must be added the flux from any X-ray source in the FOV.

### 2.1.3 Alignment requirements

Figure 11 shows the angles of importance in the alignment of JEM-X on INTEGRAL. The reference system $X_R Y_R Z_R$ is defined by the AOCS with the axis $X_R$ / STR-LOS of the startracker. The optical axis or Instrument Line-of-Sight (ILS) of JEM-X is defined as the axis through the centers of the mask and the detector. The detector is equipped with a collimator with a direction ($X_C$) where the throughput has a maximum. Ideally these three axes should coincide.

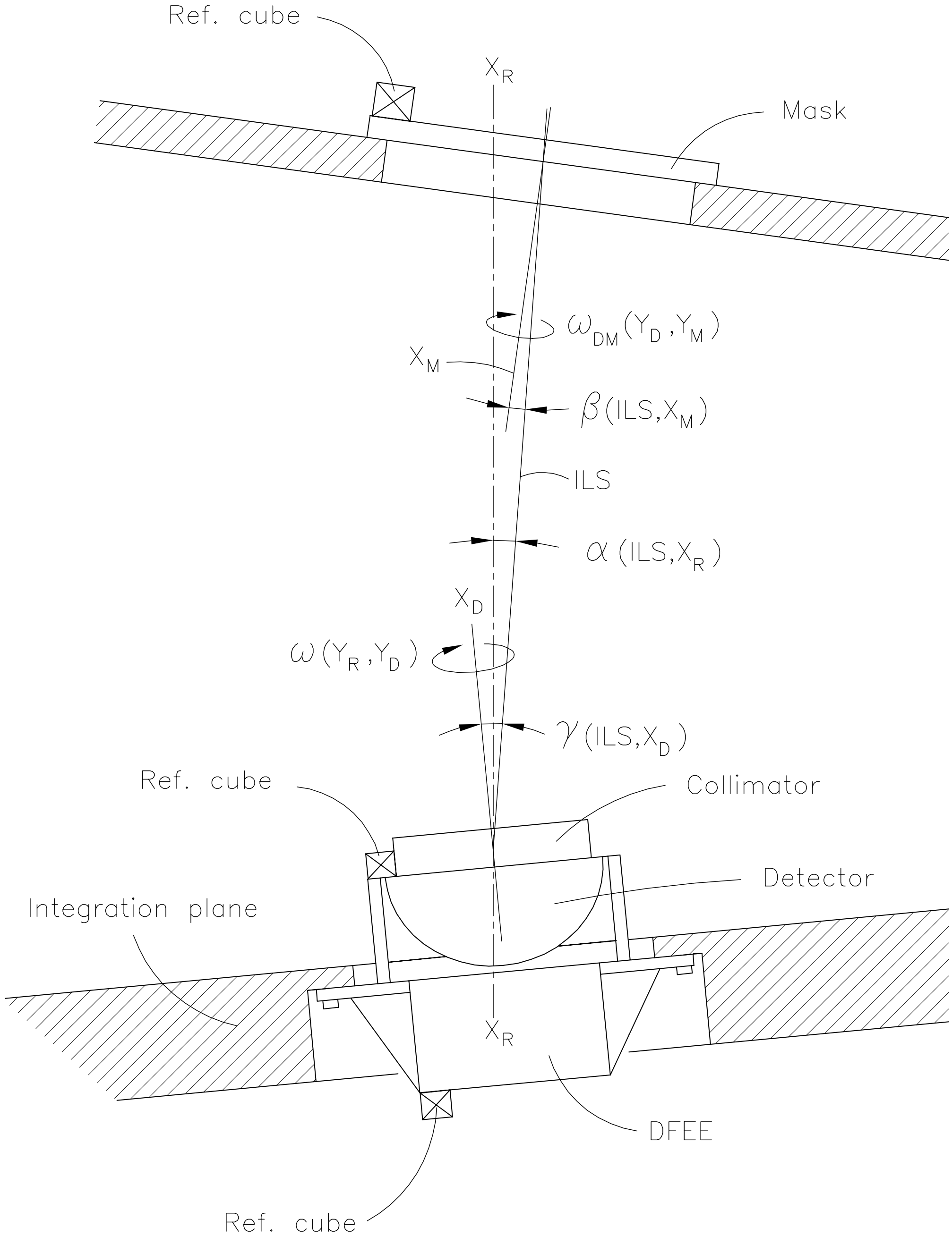



Figure 11 shows the angles where the requirements apply

The coordinate system attached to the detector is $X_D Y_D Z_D$ and to the mask is $X_M Y_M Z_M$.

The requirements that follow apply for each of the two JEM-X units.

Here and in the following parts the tolerance with respect to the nominal setting is given as the angle itself whereas the measurement accuracy is given with a ) in accordance with EID-A.

The alignment of the ILS and the $X_R$ must ensure that the primary target remains within the Fully Illuminated Field-of-view during the 7-point dither pattern foreseen for observation of bright point sources. This requires that

$$"(ILS, X_R) < 15 \text{ arcmin}$$

) "(ILS, $X_R$) < 1 arcmin (goal)

) " is directly related to the precision of the determination of a source position. In-flight calibration will give a better determination of ".

$X_D$, $X_M$, and ILS must be aligned to such a degree that the apparent shortening of pixels due to the projection effect is smaller than the error of the position determination in the detector. On the other hand the image reconstruction can take into account an apparent distortion of the mask hole shape.

The collimator transmission, T, as a function of the incoming direction with respect to the collimator axis, $X_C$, has a triangular shape. The JEM-X collimator system will be designed to have zero response at the same angle where the mask-detector combination have zero response. In order to make an X-ray flux determination to a precision of 1 %, the direction of the $X_C$ must be known to a precision of 5 arcmin relative to the source direction. The direction of the optical reference cube relative to the $X_C$ will be obtained from laboratory measurements.

There will be two optical reference cubes on the top of the detector and one on top of the mask as indicated on Figure 11 and on the ICD. The angle between $X_D$ and ILS is ((ILS,$X_D$), the angle between $X_M$ and ILS is $(ILS,$X_M$), and the condition mentioned above leads to

((ILS,$X_D$) < 40 arcmin

) ((ILS,$X_D$) < 5 arcmin

$(ILS,$X_M$) < 75 arcmin

) $(ILS,$X_M$) < 15 arcmin

This ensures that for deviations in opposite directions, the projected position errors on the detector will be no larger than 0.5 mm and will be known to 0.1 mm. A change in ((ILS,$X_D$) changes T, the collimator transmission coefficient, of a source at the nominal pointing direction. T should be known to a precision of 1% and, therefore, ) ((ILS,$X_D$) must be less than 5 arcmin. ((ILS,$X_D$) itself is limited to 40 arcmin to ensure that T is greater than 90% of its maximum for an on-axis source.

With regard to the rotational precision of the detector around the reference axis $X_R$ a similar condition should be met

T($Y_R$,$Y_D$) < 30 arcmin

) T($Y_R$,$Y_D$) < 5 arcmin

In addition, the rotation of the mask relative to the detector has influence not only on the source position determination but also on the source detection since an error in this angle will lead to erroneous assignment of photons to an allowed or forbidden region on the detector, when a particular point on the sky is analyzed.

Thus,

$T_{DM}$($Y_D$,$Y_M$) < 30 arcmin

) $T_{DM}$($Y_D$,$Y_M$) < 1 arcmin (goal)

### 2.1.4 Max distance between units

N/A

### 2.1.5 Red tag items

2.1.5.1 Detector windows

The detector windows are mechanically protected with covers at delivery. The covers are marked as red tag items and can be removed at the installation in the spacecraft according to the installation procedure.

2.1.5.2 Coded mask

The coded mask will be mechanically protected with covers on both sides at delivery. The covers are marked as red tag items and can be removed at the installation in the spacecraft according to the installation procedure. The covers will be made to withstand the environmental conditions for ground operations stated under section 3.1.1 in the EID-A

## 2.2 Compliance with System Requirements

### 2.2.1 Environment

2.2.1.1 Ground operations

With respect to the environmental conditions under section 3.1 in EID-A. All electronic circuits in the DFEE's will be made to meet the humidity conditions under 3.1.1.2.1 and 3.1.1.2.2 in EID-A, and no special action has to be taken.

No special mechanical environment precautions have to be taken for the detector units, since the environment stated under 3.1.1.1 in EID-A is less severe than the qualification ranges.

2.2.1.2 Launch Phase

The detector windows will be made to withstand the ascending static pressure during launch as stated under section 3.1.2.3 in EID-A.

The DFEE and the detector unit will be made to meet the frequency loads during launch.

The mask units will be made according to the stiffness and strength requirements shown in Table 4.2.2 and 4.2.3 in EID-A.

2.2.1.3 Orbit Phase

Both the DFEE and the interior electronic of the detectors will be made according to the recommendations with respect to radiation dose, proton flux and energetic particles under section 3.1.3.3 in EID-A.

The HV supplies must be allowed to outgas for at least 48 hours in space before they can be switched on.

### 2.2.2 Attitude control

The specification of the INTEGRAL Attitude Control system given in EID-A Section 3.2 fulfills the JEM-X requirements..

### 2.2.3 Flight operations

This chapter follows the outline in EID-A, section **3.5.5**. The instrument configurations, however, are discussed in section **1.4.**

JEM-X Instrument mode in the different mission phases. For a description of the individual modes, see below.

| **Mission Phase:** | **JEM-X Mode:** |
|---|---|
| Launch | OFF |
| Early orbit phase | OFF |
| Commissioning | Any mode |
| Eclipse | DFEE OFF |
| Radiation Belt | DFEE SAFE |
| Operations | Any mode |

**Contingency**

The basic contingency action will be to switch-off of the high voltage i.e. go to SAFE mode. A contingency can be initiated from the spacecraft or from the count rate monitor.

### 2.2.4 Fault tolerance

JEM-X consist of two independent, identical instruments. In each of these instruments possibilities for single point failure of the instrument function do exist.

All interfaces to the spacecraft will be designed such that failure cannot propagate to the spacecraft or to other instruments.

The dual instrument design concept ensures that 50% throughput is maintained even in case of catastrophic failure of one of the units. In terms of the scientific value of the data, we estimate that 75% of the results can be obtained using only one instrument.

## 2.3 Compliance with PA requirements

### 2.3.1 Materials and Processes

2.3.1.1 Selection and Evaluation of Materials and Mechanical Parts

Materials will be selected according to ESA requirements PSS-01-70, PSS-01-700, and PSS-01-701.

No materials or mechanical parts of JEM-X have been identified which do not comply with the INTEGRAL PA requirements.

2.3.1.2 Selection and Evaluation of Processes

No processes have been identified which do not comply with the INTEGRAL PA requirements.

### 2.3.2 EEE Parts

2.3.2.1 General

ESA PSS-01-60 will be used for the definition of components requirements for JEM-X EEE parts. It will be applicable for all EEE parts for the FM and FS and for all parts coming in direct contact with FM and FS units, such as test cables.

2.3.2.2 Procurement

The procurement activities will be an integral part of the design work and will be coordinated within the JEM-X PI and Co-I institutes by named persons. The coordination with ESA will be by the DSRI contact person.

### 2.3.3 Cleanliness

Cleanliness will be enforced according to ESA PSS-01-20 Issue 1.
The assembled JEM-X system will, at most, require cleanliness levels of clas 100000.

### 2.3.4 Reliability and Safety

Each JEM-X detector will have 4 radioactive calibration sources built into the collimator. The sources are shielded so they only irradiate the detector volume. There are therefore no particular safety precautions to be taken. The calibration system is described in section 1.3.1.2.

## 2.4. Compliance with Development and Verification Requirements

### 2.4.1 General

The Coded Mask model philosophy is defined in IN-JX-UV-PLN-0002. The main features are given below. The Detector/DFEE unit model philosophy is described below.

### 2.4.2 Math Model Definition

2.4.2.1 Structural Math Model

The design of the Detector unit and the Coded Mask has been followed by several multi nodal FEMs. For the Detector see document: JMX-TRA-QM01-SA-001 issue1/0 made by VTT (delivered as part of the JEM-X CDR package), Finland. For the Coded Mask see document: IN-JX-SR-NOT-002 made by SENER, Spain, included (on paper only) in the JEM-X CDR package.

Section 5.3.1.5 of the EID-A is not applicable, since there are no mechanisms in JEM-X.

2.4.2.2 Thermal Math Model

A simplified TMM for JEM-X QM/FM Detector/DFEE is given in section 3.3.5.

### 2.4.3 Instrument Model Definition

Development Models (DM) of the different subunits of JEM-X will be made to verify function, manufacturing processes and mechanical properties of these subunits. The DMs are not deliverable units.

The following deviations from the EID-A model requirements are identified:
- Only one JEM-X model will be provided to support the INTEGRAL EM programme.
  The detector EM will be used for this purpose.
  This model is equipped with a collimator dummy.
- There will be no Engineering Model of the Coded Mask.
- The Coded Mask STM1 is the refurbished QM.
- The Coded Mask STM2 is a dummy unit (Steel Plate).
- A Spare Model of the Coded Mask will be manufactured only if need be.
  It will be done with a short turn around time.
- Both Collimator STM2 and STM2 is mock-ups.

2.4.3.1 Structural Thermal Models (STM)

Both STM's are deliverable units.

2.4.3.1.1 Detector Units

Based on the results of the pressure test carried out on a development model detector vessel it was found necessary to redesign the mainframe of the detector and the detector support structure. This redesign took place after the STM test campaign was completed. The redesign have lead to an increase of the detector mass, but have not changed the power dissipation inside the detector vessel. As a result of the thermal tests at system level the thermal properties of the vessel have been modified to increase the emissivity of the mainframe towards the payload module.

Other remarks to the Detector Unit STMs:
-There are no mechanisms or pyrotechnical devices in JEM-X,
- Both Detector Unit STMs have been tested according to EID-C 1.3.4.3.

2.4.3.1.2 Coded Mask

One structural thermal / qualification model (STM/QM) has been manufactured and qualified in Spain before delivery to ESA as the first STM. It was built and tested according to EID-C 1.3.4.3 and will be mechanically and thermally fully representative of the flight design and was built using flight standard materials, parts and components.

The second structural thermal model (STM2) is a dummy unit representative in terms of mass and mechanical I/F. It will be a bolted steel plate. It has been tested according to EID-C 1.3.4.3

The deviation of STM2 from the EID-A requirements has been coordinated with ESA.

2.4.3.2 Engineering Model (EM)

The JEM-X EM will be used in the INTEGRAL EM program. One unit will be delivered.

2.4.3.2.1 Detector and Electronics unit (DAE/DFEE assembly)

This assembly will not be flight standard:

2.4.3.2.2 Coded Mask

There will be no engineering model of the coded mask. This deviation from the EID-A requirements is coordinated with ESA.

2.4.3.3 Qualification Model (QM)

The QM is not a deliverable unit. One complete model will be manufactured and tested according to EID-C 1.3.4.2. The build standard will be flight standard for the mechanical parts and a mixture of Hi-Rel and Commercial EEE components.

2.4.3.4 Flight Models (FM)

Both FM's are deliverable units.

2.4.3.4.1 Detector Units

Two complete flight models will be manufactured, tested and delivered. They will both be to full flight standard and will be tested according to EID-C 1.3.4.5.

2.4.3.4.2 Coded Mask

Two complete flight models will be manufactured, tested and delivered. They will both be to full flight standard and will be tested according to EID-C 1.3.4.5.

2.4.3.5 Spare Model (FS)

2.4.3.5.1 Detector Unit

The Detector will be manufactured and tested to FM levels. The DFEE electronics will be supported by spare electronics at board level and a refurbished box, including the legs interfacing to the detector and the PLM..

2.4.3.5.2 Coded Mask

No FS is foreseen. A replacement flight model will be delivered if necessary at short notice.

### 2.4.4 Model Summary

The JEM-X models are summarized in the following table:

| Coded Mask | DM | STM1 | STM2 | EM | QM | FM1 | FM2 | FS |
|---|---|---|---|---|---|---|---|---|
| Coded Mask<br>UV | Repre-<br>sentative<br>samples | QM<br>refurbis-<br>hed | Dummy<br>(Steel<br>plate) | N/A | Flight<br>represen-<br>tative | FM | FM | Not foreseen but will be made in time if necessary |

| Detector | DM | STM1 | STM2 | EM | QM | FM1 | FM2 | FS ***) |
|---|---|---|---|---|---|---|---|---|
| Collimator<br>UoF | Dummy | STM | STM | EM | QM | FM | FM | FM |
| Window<br>Metorex | DM | STM | STM | QM | QM | FM | FM | FM |
| Detector box<br>Metorex | DM | STM | STM | EM | QM | FM | FM | FM |
| Microstrip<br>Metorex | DM | Dummy | Dummy | QM | QM | FM | FM | FM |
| DAE<br>DSRI | DM | Dummy | Dummy | EM/QM | QM | FM | FM | FM |
| Detector Internal Structure<br>Metorex | DM | STM | STM | QM | QM | FM | FM | FM |
| Detector connectors<br>Metorex | DM | STM/<br>Dummy | STM/<br>Dummy | QM | QM | FM | FM | FM |
| DFEE Electronics<br>DSRI | DM | Dummy | Dummy | QM/Com | QM/Com | FM | FM | FM |
| DFEE HVPS<br>IAS | DM | Dummy | Dummy | QM | QM | FM | FM | FM |
| DFEE/Detector<br>Mech. Aassembly<br>DSRI/Metorex | DM | STM | STM | N/A | QM | FM | FM | FM/QM<br>refurb. |
| DFEE connectors<br>DSRI | DM | STM/<br>Dummy | STM/<br>Dummy | QM | QM | FM | FM | FM |
| DFEE SW<br>DSRI | DM | no | no | EM | QM | FM | FM | FM |
| DPE HW<br>ESA/DSRI/SRC | no | no | no | QM | QM | FM | no | no |
| DPE SW<br>ESA/DSRI/SRC | DM | no | no | EM | QM | FM | FM | FM |
| EGSE<br>SRC | no | no | no | QM | QM | QM | no | no |

**) If Collimator is late for EM1, then a dummy collimator will be used.
***) Detector FS fully verified & calibrated, DFEE spare boards + refurb.box.
DM: Development or Breadboard Model, also named Laboratory Model.
QM: Qualification Model, built standard: Flight
QM/Com: Qualification Model, built standard: Flight but using flight like parts to some extend
STM: Structural Thermal Model, built standard sufficient to support STM program
FM: Full Flight built standard

## 2.5 Compliance with resources

### 2.5.1 Mass Budget

This paragraph covers the details concerning the mass estimate for the sub-units. Additional radiation shielding may be required. All weights are in kg. The current 'Best Engineering Estimates', that are the basis for the estimates, can be found in the monthly progress reports for JEM-X.

| **Mass budget for one unit of JEM-X** | | | |
|---|---|---|---|
| Mass estimate, August 1999 | | | |
| H/W Item | Estimate [kg] | | |
| **1. DETECTOR** | 17.73 | | |
| 1.1 Main-frame-assembly | | 8.23 | |
| 1.1.1 Main-frame | | | 5.85 |
| 1.1.2 Window | | | 0.22 |
| 1.1.3 Internal structure | | | 0.21 |
| 1.1.4 Sensor package | | | 1.74 |
| 1.1.5 HV parts | | | 0.21 |
| 1.2 Cover | | 2.81 | |
| 1.3 External parts | | 1.94 | |
| 1.4 Collimator | | 4.40 | |
| 1.5 Gas | | 0.35 | |
| **2. DFEE BOX** | 8.60 | | |
| 2.1 Electronic boards | | 2.31 | |
| 2.2 HV-Supply | | 1.00 | |
| 2.3 Mother board | | 0.33 | |
| 2.4 Box structure | | 4.96 | |
| **3. CODED MASK** | 5.85 | | |
| 3.1 Coded plate | | 1.80 | |
| 3.2 Mounting ring | | 1.33 | |
| 3.3 Re-enforcing structure | | 1.37 | |
| 3.4 Pretension Plates | | 0.92 | |
| 3.5 Misc. | | 0.43 | |
| **4. HARNESS** | 1.10 | | |
| Total | 33.28 | | |
| Margin | 0.72 | | |
| **Total for one unit of JEM-X** | **34.0** | | |

**Table 2** Mass Budget for JEM-X, one unit

The instrument exceeds the weight allocation by 1.5 kg per JEM-X unit - 3 kg for both units. The table includes only the unit internal harness. It is assumed that the electrical interface between the JEM-X experiment and the satellite is located at the DFEE connectors.

### 2.5.2 Power Budget

See § 3.4.7 Power Budget.

### 2.5.3 Data rate TM, TC

JEM-X will use all allowed TM data rate. The maximum actual TC rate is 1 packet/sec.

| **JEM-X Experiment, both units** | | | |
|---|---|---|---|
| Modes: | Off | Standby | Operation |
| Nominal TM data rate | 0 | 0 | 2.25 packets/s |

**Table 3** The JEM-X TM rates

# 3 INTERFACE DEFINITION

This chapter relates to the Mechanical Interface Control Drawings (ICDs) for the separate units in the experiment. The name of the pdf-files of these drawings are:

**JEMX-MASK:** Mechanical ICD for the Coded Mask Interface. (PDF file: j-mask-i.pdf on DSRI jemx FTP)

**JEMX-DETECTOR:** Mechanical ICD for the Detector/DFEE assembly. (PDF file: j-det-b.pdf on DSRI jemx FTP)

(See 3.2.7 for Drawing Change Record Sheets).

The drawings can be found in A4 size in Appendix A.

For each of the major sub-units a specific unit number has been defined. The numbers are:

| **Unit numbers** | | |
|---|---|---|
| Number | Name | Number location |
| 130000 | JEM-X Experiment | N/A |
| 130100 | Detector/DFEE assembly | - on the DFEE connectors plate |
| 131000 | Detector unit | - on the main-frame |
| 131100 | Collimator unit | - on the edge of the wall on the support ring |
| 131200 | Detector legs | TBD |
| 131300 | Mirror cubes | - on mirror cube bracket |
| 132000 | DFEE unit | - on the DFEE connectors plate |
| 133000 | Coded mask unit | TBD |

The numbers are implemented as defined in the section 4.2.13 ‘Equipment identification’ in EID-A.

## 3.1 Definition of coordinate system for instrument.

The unit coordinate systems is defined on the ICDs.

## 3.2 Mechanical interfaces

### 3.2.1 Definition of structural dimensioning load cases

Structural dimensioning load cases have been defined for the Coded Mask and for the Detector interior/exterior according to the stiffness and strength requirements stated under section 4.2.2 and 4.2.3 in EID-A, and the structural test requirements in section 5.4.4. These load cases have been the design drivers for the current design.

### 3.2.2 Mechanical description of the instrument

Each JEM-X experiment consists of two units. The Detector/DFEE unit and the Coded Mask unit.

The Detector/DFEE unit defined as the assembly of the detector vessel with legs, the collimator, the DFEE box containing electronics and HV supplies and the unit interconnecting harness, and optical reference cubes.

The Coded Mask unit is defined as the tungsten plate containing the hexagonal mask coding, a surrounding titanium mounting ring with elastic pretension devices, and the optical reference cubes.

The section below is a mechanical description each part.

3.2.2.1 Detector

The detector, which is shown in Figure 3, consists of the following modules: detector vessel, collimator, X-ray window and MS-sensor package. The gas inside the detector is at 5 bar pressure.

3.2.2.1.1 Detector Vessel

The detector body is made of stainless steel and consists of two parts, the main-frame and the cover which are joint together by electron beam welding. There are no gaskets.

The main-frame has a conical shape with a circular flange in the middle for mounting the collimator. The gas filling tubes and vacuum tight signal connectors and high voltage feed-throughs are welded to this main-frame. The inside structure consists of two sets of vertical studs fastened to the main-frame. The field forming rings are mounted on one set of studs. The “spider”, a support structure for the detector electronics and the microstrip plate (see description in section 1.3.2.1.4) is mounted on another set of vertical studs.

The cover is formed from 2 mm thick stainless steel plate. The shape of the cover is similar to a pressure vessel cap form minimizing the weight and maximizing the strength. The detector cover is shown in Figure 12.

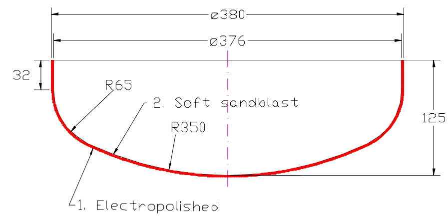



Figure 12 The Detector Cover

3.2.2.1.2 Detector window

The detector window is a 0.25 mm thick beryllium foil. The window is supported by the collimator structure against the internal operating pressure of 5 bar. The window is glued to a stainless steel mounting ring which is welded to the detector main-frame.

3.2.2.1.3 Collimator

The collimator consists of an array of brazed lamellae forming an array of square tubes of molybdenum with a wall thickness of 0.45 mm, a center-to-center spacing of 7.05 mm and a cell height of 57.0 mm. The lamellae are covered on both sides with layers of copper and aluminum. The collimator weight is about 4.4 kg including the outer support ring which is also made of molybdenum. The collimator is mounted from top and down into the detector main-frame. During transportation and storage the collimator will be covered with a protection cover.

The collimator is shown in Figure 13.

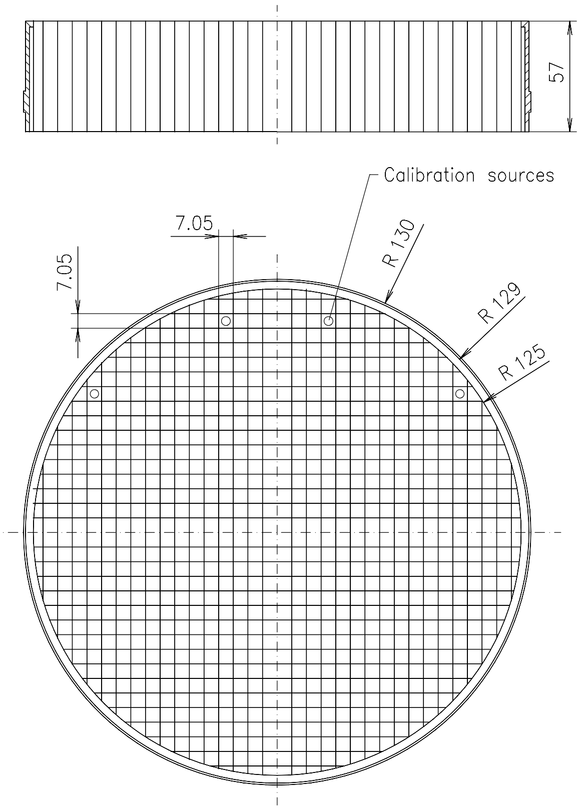



Figure 13 The Collimator layout

3.2.2.1.4 Calibration sources

There are four radioactive calibration sources in each JEM-X experiment. The sources ares mounted into four cells of the collimator and each illuminate a well defined spot on the microstrip plate. The sources are placed so that each illuminate one of the four anode sections in the detector. The sources are shielded so all radiation is kept within the detector volume. The source locations are indicated in figure 13.

3.2.2.2 DFEE box

The Detector Front End Electronics is located in a box just below the detector vessel. The box and its support brackets are machined from a single piece of aluminium. All electronics boards are mechanically clamped along three edges for optimizing the mechanical support and facilitating the heat conductance. The Detector Front End Electronics occupies eight circuit boards, a mother-board and a HV supply. Four brackets on the DFEE box form the interface between the Detector/DFEE assembly and the PLM. The brackets transfer the loads during launch and they also provide heat conductance to the PLM.

The box is shown on the MICD in Appendix A.

3.2.2.3 Coded Mask

The coded mask is realized as a pre-stressed membrane mounted in a peripheral ring and supported by an exo-skeleton in order to have the required strength and stiffness during launch. The supporting skeleton will be made of titanium. The active diameter of the coded mask is 535 mm and the ring around it is 15 mm wide and approximately 70 mm high. Excluding the alignment cubes the envelope for one mask is: Ø565 with a height of: 110 mm.

The code pattern is cut in a 0.5 mm thick tungsten plate. The hexagonal holes have a centre-to-centre separation of 3.3 mm. The interface drawing can be found in the MICD in Appendix A.

### 3.2.3 Mounting concept

JEM-X will arrive for integration as two identical sets each consisting of a Coded Mask unit and a Detector/DFEE unit.

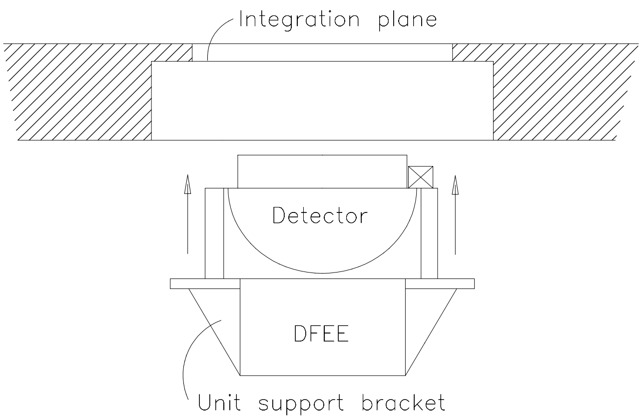



Figure 14 Mounting the JEM-X Detector/DFEE unit in the integration plane.

The Detector/DFEE unit will be mounted bottom up in its transportation box. When released from the box the unit can be lifted out, and mounted into the integration plane as shown in Figure 14. Checking, cleaning and handling procedure before mounting will be defined by DSRI and Metorex.

The position of the center of each detector is indicated by a white reference cross located on the central ribs on top of the collimator.

### 3.2.4 Mechanisms design

There are no mechanisms on JEM-X.

### 3.2.5 Alignment requirements/stability

See section 2.1.3 for alignment requirements.

### 3.2.6 Structural Math Model

A simplified SMM for the Detector/DFEE assembly can be found in document: 'Simplified SMM for the JEM-X-STM Detector/DFEE assembly' (IN-RP-JM-0001, v 1.0, 980609). This document describes a reduced nodal model in ANSYS of the STM Detector/DFEE assembly, and in greater therms it is valid for FM/QM also. The model can be converted and merged into the general S/C SMM.

For the Coded mask see documents from Univ. de Valencia: IN-JX-SR-RPT-002 (24/09/97) and IN-JX-SR-NOT-002 (02/06/97).

### 3.2.7 Mechanical ICD for the units.

The ICD for the JEM-X unit is shown in Appendix A. The Drawing Change Record Sheets for the drawings are given below.

| **DRAWING CHANGE RECORD SHEET** | | | |
|---|---|---|---|
| DRAWING NUMBER: JEMX-MASK-n, where n is Issue No. | | ORIGINATOR | |
| TITLE: Coded Mask Interface | | Uni. de Val./DSRI | |
| ISSUE | DESCRIPTION OF CHANGE | AUTH. | DATE |
| A | Banner added for the appendix version. | DSRI | 12.9.95 |
| D | Strong-back system added.<br>Envelope changed to Ø565, height: 110 mm, one unit.<br>Corresponding JEM-X EID-B drawing number added. | Uni. de Val<br>DSRI | 17.02.96<br>18.02.96 |
| E | No change | | |
| F | Single-sided strong-back changed to double-sided hexo-skeleton.<br>A second ring has been introduced in the reinforcement structure in order to be able to support the acoustic and the sine spectrum environment during launch.<br>Hexo-skeleton rotated approx. 4 deg. around X axis.<br>Coded Membrane Plate height changed from 58.0 to 60.0 mm | Uni. de Val. | 12.01.97 |
| G | Interface bolts changed to: M5.0, see location K11 - L11 on drawing | Uni. de Val | 14.04.97 |
| H | No change | Uni. de Val | 05.11.97 |
| I | In order to add more strength to the central area of the CM membrane the open area is reduced from 50% to 25% by closing some of the open pixels located in the central area and under the re-enforcement structure.<br>A third ring is introduced in the re-enforcement structure.<br>Optical cubes for alignment are added to the Masks.<br>RTV 566 silicone used for re-enforcement structure bonding to coded membrane. | Uni. de Val.<br>-<br>SENER | 08.06.98 |

**Table 4** DCRS for JEMX-MASK-n.

| **DRAWING CHANGE RECORD SHEET FOR JEM-X QM AND FM DETECTOR BLOCK** | | | |
|---|---|---|---|
| DRAWING NUMBER:130100-n, where n is Issue No. | | ORIGINATOR<br>DSRI | |
| ISSUE | DESCRIPTION OF CHANGE | AUTH. | DATE |
| A | New MICD corresponding to new detector and DFEE box design | DSRI | 24.09.99 |

**Table 5** DCRS for JEM-X ICD 130100-n.

## 3.3 Thermal interfaces

### 3.3.1 Definition of thermal requirements and design drivers

| Temperature Reference Point thermal requirements | | | | | |
|---|---|---|---|---|---|
| Unit | Ref. Point | Operational | | Non-operational | |
| Detector/DFEE | PLM Bench | -35EC | +35EC | -35EC | +45EC |
| Mask | Mounting Ring | -55EC | +30EC | N/A | N/A |

The JEM-X detector and the electronics will operate nominally in the full temperature range between !35EC and +35EC. The units will be qualified at the operational temperatures ±10EC.

The instrument temperatures will be monitored by 13 thermal sensors accessible through the RTU and the instrument housekeeping data.

### 3.3.2 Instrument thermal design description

Each JEM-X instrument is composed of three major subsystems: the coded mask, the detector and the electronics box. Electrical power is dissipated within the detector and the electronics box. The coded mask is a passive device in which no power is dissipated.

The temperature of the coded mask is controlled passively: a thermal protection foil prevents the top side of the mask from radiating directly into free space, the lower side of the mask exchanges heat radiatively with the payload module.

Inside the detector vessel power is dissipated in a set of 16 electronics boards mounted underneath the microstrip sensor plate. The heat produced will primarily be conducted away to the heavy top plate of the detector, the "mainframe", via the support structure on which the electronics and the microstrip plate is mounted. The conduction through the detector gas (5 bars of a Xenon/Methane mixture) will be negligible under zero gravity conditions.. From the detector mainframe the heat will be radiated from the surface area to the satellite sink or conducted to the payload module via the four detector legs. The detector legs do not interface to the payload module directly, but to the electronics box supports, in close proximity to the instrument mounting points on payload module detector bench.

The heat produced in the electronics box will be conducted from the circuit boards to the box mechanical structure. The electronics boards are thermally connected on three sides to the box structure. The box and its supports is machined from a single block of aluminium, thus good heat conduction to the supports is assured. The thermal-mathematical model discussed below indicates that most of the heat will be radiated from the surface of the box to the spacecraft module cavity and a smaller fraction will be conducted to the payload module.

With this design there is no need for substitution heaters on JEM-X.

### 3.3.3 Temperature and Energy Budgets

The operating temperatures boundaries for the JEM-X detector and electronics are !35EC to +35EC. For the coded mask the operating temperature environment as found from the thermal tests is !50EC to +10EC, this is acceptable.

The power budget for the detector and the electronics box can be found in table 10 of section 3.3.5.4.

### 3.3.4 Thermal hardware.

There will be 9 thermistors and four temperature sensors in each JEM-X unit. All thermistors are YSI 44908. All thermal sensors are type AD590. Drawings of the thermistor and thermal sensor locations are available in the mechanical ICD (Appendix A).

| Thermal sensors in JEM-X | | | | |
|---|---|---|---|---|
| Sensor Designation | Type | Location | Node | Comment |
| THA | YSI44908 | LVPS PCB | (EB) | RTU HK |
| THB | YSI44908 | Connector J06 | EB | RTU HK |
| THC | YSI44908 | Connector Board | EB | RTU HK |
| TH0 | YSI44908 | Connector J01 | EB | JEM-X HK |
| TH1 | YSI44908 | CPU Board | (EB) | JEM-X HK |
| TH2 | YSI44908 | LVPS Cooling Bridge | (EB) | JEM-X HK |
| TH3 | YSI44908 | DDHK Board | (EB) | JEM-X HK |
| TH4 | YSI44908 | Motherboard at ANOD | EB | JEM-X HK |
| TH5 | YSI44908 | Motherboard at ANA2 | EB | JEM-X HK |
| TH6 | AD590 | HVPS Board | (EB) | 10mV/EK, JEM-X HK |
| TH7 | AD590 | HVPS Board | (EB) | 10mV/EK, JEM-X HK |
| TH8 | AD590 | Detector PWR Board | DE | 10mV/EK, JEM-X HK |
| TH9 | AD590 | Detector PWR Board | DE | 10mV/EK, JEM-X HK |

Node names refer to the TMM described below. Names in parentheses are nodes inside the DFEE electronics box, close to power dissipating components.

The top surface of the detector Mainframe is covered by Sheldahl Thick Film Black adhesive tape for increasing the thermal emission.

The coded mask is covered on the outside by a thermal protection foil.

### 3.3.5 Thermal Mathematical Models

A TMM has been defined for the detector/electronics box assembly. The model is defined as a condensed nodal sub-level input for a general TMM at satellite level.

For the thermal analysis of the coded mask see Univ. de Valencia documents: IN-JX-INT-NOT-001 (10/02/97).

#### 3.3.5.1 Analysis requirements

The TMM for the Detector/DFEE can be input to the software ESARAD and ESATAN.

#### 3.3.5.2 Modelling description and main assumptions

A simplified TMM model of the JEM-X detector/DFEE electronics box assembly is shown in Fig 15. It contains ten nodes that links to each other either via a radiative area (shown with coil symbols) or a conductive area (shown with spring symbols). The list of links is shown in **Table 6**

| **Node Acronym** | **Description** | **Radiative coupling with nodes** | **Conductive coupling with nodes** |
|---|---|---|---|
| DE | Detector Electronics | | VS |
| VS | Detector Vessel | S1 | P1 to P4 |
| P1 | Support Structure 1 | | VS, EB, PM |
| P2 | Support Structure 2 | | VS, EB, PM |
| P3 | Support Structure 3 | | VS, EB, PM |
| P4 | Support Structure 4 | | VS, EB, PM |
| PM | PLM Detector Bench | | P1 to P4 |
| EB | DFEE Electronics Box | S2 | P1 to P4 |
| S1 | Payload Module Radiative Sink | VS | |
| S2 | Spacecraft Module Radiative Sink | EB | |

**Table 6** JEM-X detector/electronics box node definition summary

The model makes use of the symmetry of JEM-X, only one node is defined at each level, except for the four support structures, which are modelled separately to maintain compatibility with the earlier JEM-X thermal models.

A heat capacity is assigned to each JEM-X node according to the specific material and mass. The sub-division is described below.

**DE:** The **Detector Electronics** node includes both the detector internal electronics and support structures, the field forming rings, the microstrip plate and the gas. Power is dissipated by the electronics and conducted via the internal supports to the vessel, **VS**. Conduction through the gas is insignificant under zero gravity conditions. The effect of the radiative transfer from the electronics to the vessel is included in the heat conduction term, the value of this term is determined from a test with the vessel evacuated, i.e. the effect of convective heat transfer was eliminated.

**VS:** The **Detector Vessel** consists of a massive steel ring, the mainframe, on which the collimator, the bottom cover and the detector legs are mounted. The radiative area of the structure towards the Payload Module Radiative Sink (node **S1**) is taken to be the top surface of the mainframe plus the collimator. The detector legs do not have their own node, the heat capacity of the legs have been allocated partly (50%) to the detector vessel node, and partly to the support structure nodes, **P1** to **P4**.

**P1** to **P4:** The **Support Structures** are the four extensions of the electronics box which interfaces to the PLM detector bench and to the detector legs. The peripheral parts of the support structures connects to the satellite sink nodes, **PM**, and to the detector mainframe, **VS**, via the legs. The material is aluminium.

**EB:** The **DFEE Electronics Box** is an aluminium box housing the main electronics (the DFEE). Most of the electrical power is dissipated in this node. Heat is conducted to the support structure, **P1** to **P4**. The lower face and part of the sides of the electronics box radiates to the spacecraft module sink, **S2**. The side faces of the electronics box and the unit supports are machined from a single block of aluminium, thus the heat conductivity is optimized. The box is painted with Chemglaze Z306.

**PM**: The **PLM Detector Bench** is the conductive sink for JEM-X

**S1**: The **Payload Module Radiative Sink** is the sink for the topside of the detector vessel.

**S2**: The **Spacecraft Module Radiative Sink** is the sink for the lower face of the electronics box.

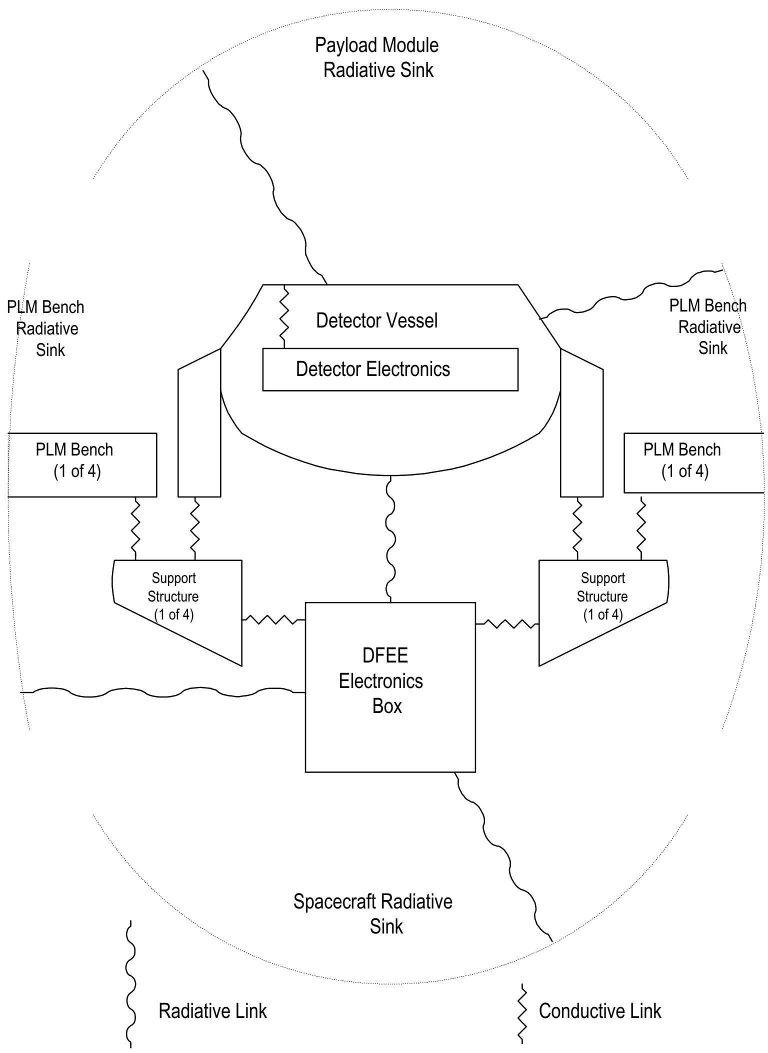
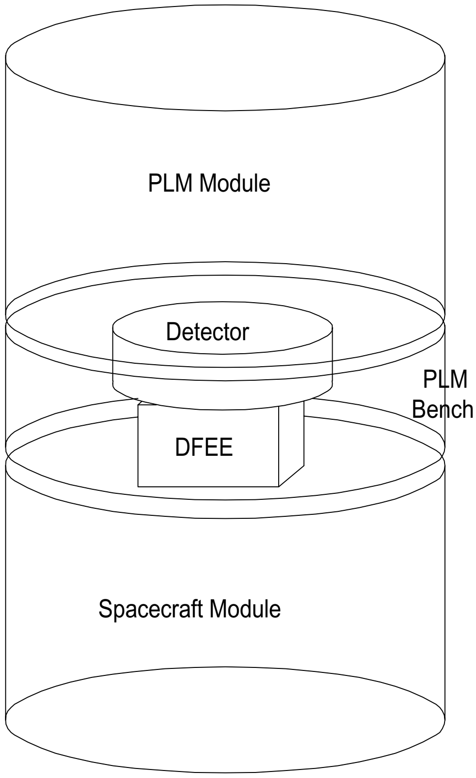



Figure 15 Simplified Thermal Model for JEM-X




The radiation environment of JEM-X is illustrated in the diagram shown here. The top surface of the detector facing the payload module has a high emissivity (g-0.85) whereas the sides and bottom facing the payload bench and the DFEE box is electropolished steel with (g-0.35). The DFEE box is painted with Chemglaze Z306 on all six faces.

3.3.5.3 Model file

The model is described in the tables below.

| From node | To node | K[W/EK] |
|---|---|---|
| DE | VS | 0.25 |
| VS | P1 to P4 | 0.16 (each of 4) |
| P1 to P4 | PM | 0.5 (each of 4)<br>(including contact resistance) |
| EB | P1 to P4 | 1.15 (each of 4) |

Table 7. Detector and DFEE conductive coupling data

| Node | Thermal capacity [J/EK] | Material |
|---|---|---|
| DE | 1450 | Xe-gas, Al51S, ceramics, glass electronics |
| VS | 7000 | AISI 316 |
| P1 to P4 | 460 (each of 4) | Al 51S |
| EB | 7300 | Al 51S, glass fibre |

Table 8. Detector/DFEE thermal capacities and materials

| Node | Area [$m^2$] | g | Surface treatment |
|---|---|---|---|
| VS top (R = 19 cm) | 0.11 | 0.8 | Black surface and collimator |
| VS side and bottom (R=19, H=12 cm) | 0.26 | 0.35 | Electropolished steel |
| EB (24×24×16 cm) | 0.27 | 0.85 | Chemglaze Z306 |
| PM | N/A | 0.8 | CFRP (Both the detector side and bottom and the DFEE siades are assumed to view the PLM bench node) |

Table 9. Detector/DFEE radiative coupling data

| Node (acronym) | Power [W] |
|---|---|
| Detector electronics (DE) | 5.6 |
| DFEE electronics (EB) | 22.7 |

Table 10. JEM-X power dissipation

# 3.4 Electrical power supply

## 3.4.1 Instrument power supply

The DC/DC power converter(s) will give galvanic insulation between primary power lines, secondary power lines and equipment structure (bonding stud) in accordance with EID-A 4.4.3.1 and 4.6.2.1.

Any voltage on the main bus power line in the full range 0 V to 30 V, including short circuit of the power line, is harmless to the instrument.

The interfaces will be designed such that no instrument failure can propagate into spacecraft subsystem. Protection against failures in the harness connection between the PDU and the JEM-X power input is ensured by the current limitation circuitry in the PDU.

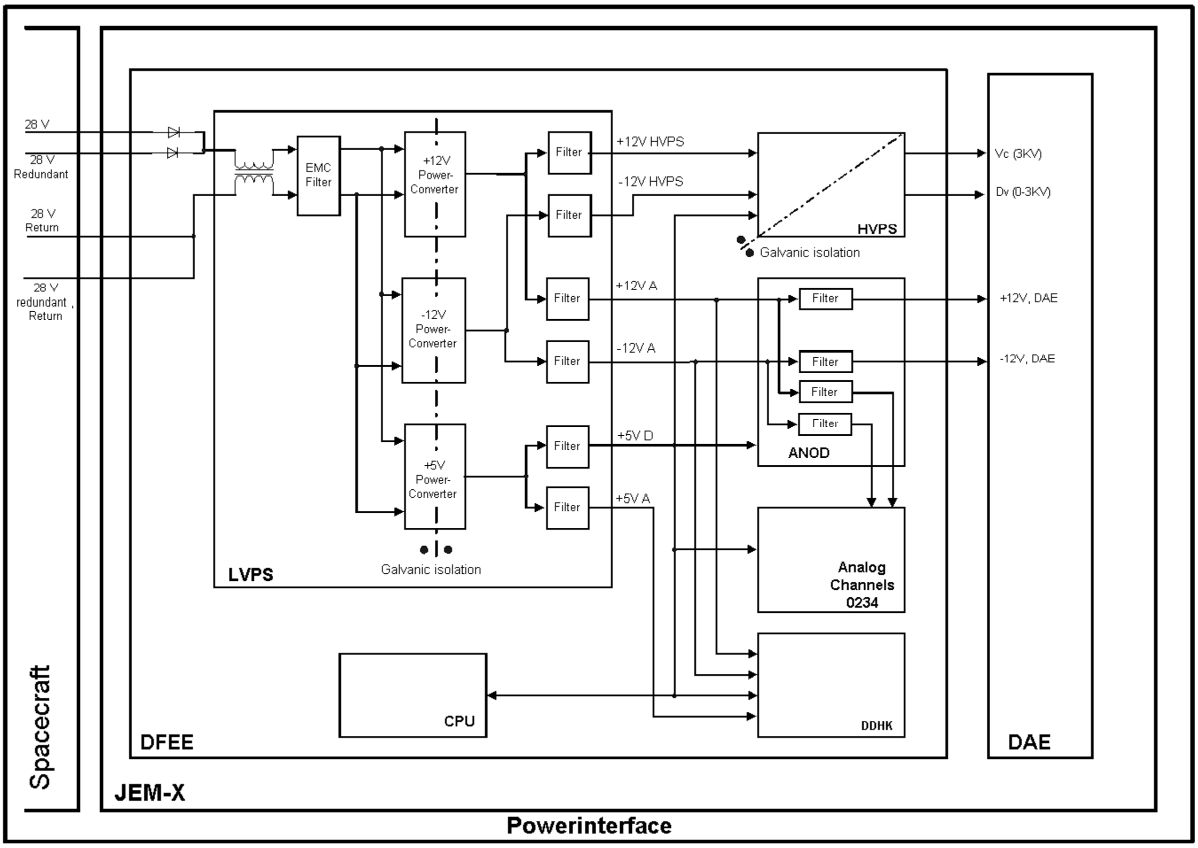



Figure 17 Power interface

## 3.4.2 Power supply block diagram

Figure 17 shows the power supply block diagram.

## 3.4.3 Required power lines

<u>3.4.3.1 Power bus lines for DFEE & DAE (PDU)</u>

+28 V. Redundant LCL connection.
GND. Redundant connection.

### 3.4.4 Pyrotechnic interfaces

There are no pyrotechnic devices in JEM-X.

### 3.4.5 Power profile

There are 3 power modes:

- Power Mode 1: DFEE OFF, HVC OFF
- Power Mode 2: DFEE ON, HVC OFF
- Power Mode 3: DFEE ON, HVC ON

Switching between Power Mode 1, Power Mode 2 and Power Mode 3 will give inrush current below the values given in EID-A, section 4.4.2.2.

After inrush, there will be only small fluctuations in power consumption in each of the functional, scientific modes.

3.4.5.1 Power requirement for each of two identical instruments

See table 11, Power budget.

### 3.4.6 Electrical ICD

The electrical ICD according to DRD44-1 is attached as Appendix B

3.4.6.1 Power connector J07 and J08

Power interface to the PDU is via 2 Cannon connectors Royal-D-9P:

- Signal names and pin connections in Appendix B.

### 3.4.7 Power Budget

The power budget for the main JEM-X subunits is given in table 11. This power budget is based on measurements on the EM-model.

| | | | | |
|---|---|---|---|---|
| DFEE + DAE | | | | |
| | V=26V | V=28V | V=28,5V | |
| Current | A | A | A | |
| M1=Turn-On mode | 1.01 | 0.94 | 0.92 | |
| M2=Stand-By | 1.04 | 0.97 | 0.94 | |
| M3=Operation | 1.05 | 0.98 | 0.95 | |
| | | | | |
| Power | W | W | W | |
| M1=Turn-On mode | 27.4 | 27.4 | 27.3 | |
| M2=Stand-By | 28.0 | 28.1 | 27.8 | |
| M3=Operation | 28.4 | 28.3 | 28.2 | |
| | | | | |
| DAE | | | | |
| Power | W | | | |
| All Modes | 5.6 | | | |

Table 11. JEM-X Power Consumption

The maximum power consumption at beginning of life is 28.4 W per Jem-X unit. Adding a 3% degradation due to ageing we arrive at an expected power consumption at end-of-life of 29.25 W for one unit or 58.5 W for both units together.

## 3.5 EMC-Design

### 3.5.1 Instrument Design Concept

The experiment consists of two units:

1: A detector in a pressurized enclosure together with front end electronics DAE. This enclosure is described 1.3.2.1. The entire enclosure, including the beryllium detector is electrically conducting.

2: The main electronics circuitry is contained in a box, which is milled from a solid aluminium block with an aluminium cover at the top and bottom. The high voltage supplies and the DC/DC converters are situated in this box.

Electrical connections between JEM-X and the satellite will be implemented in accordance with paragraph 4.5.2.3 (Electrical Interfaces) of the INTEGRAL EID-A.

Only one connection exists between instrument signal GND and structure GND. The most noise sensitive elements in the JEM-X instrument are the preamplifiers connected to the electrodes on the microstrip plate. The location of the connection between signal GND and structure GND are located inside the detector vessel in order to prevent capacitive pick up of noise signals from the vessel to the circuits inside.

### 3.5.2 Instrument Block Diagram

Figure 18 shows the instrument grounding scheme. An important feature in the grounding scheme is, that circuit GND is connected to structure in the DAE. This is necessary, because any noise voltage between the detector window and the micro-strip plate will be seen as a signal by the pre-amplifiers.

### 3.5.3 Susceptibility to EMC-Interference

JEM-X does not include items, that are susceptible to EMC-interference to a higher degree than what is normally expected for electronic circuits.

### 3.5.4 Possible High EMC-Emission

JEM-X will use switch-mode low voltage and high voltage power supplies.

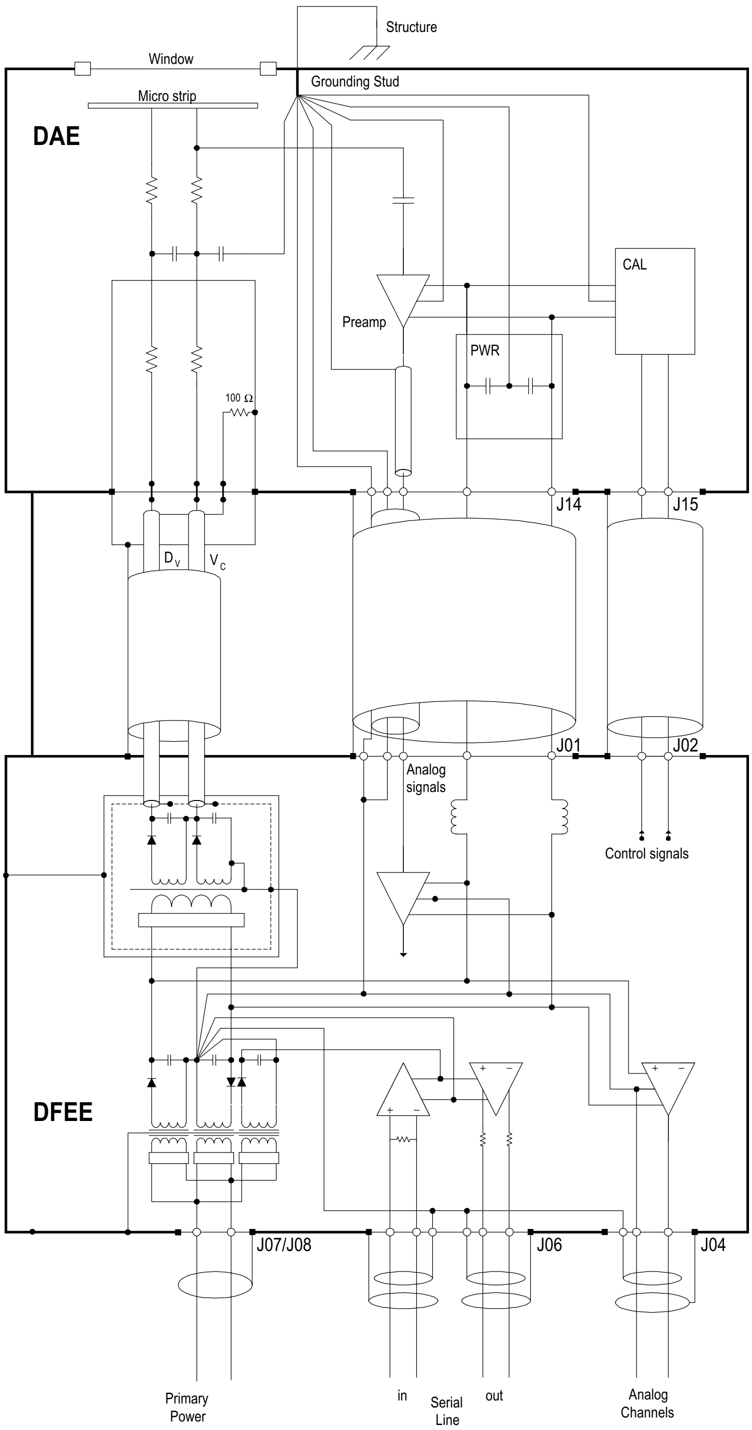



Figure 18 Instrument grounding scheme

## 3.6 Data handling interfaces.

### 3.6.1 Instrument data handling design definition.

The JEM-X on-board software will be distributed between the DFEE and the DPE processors.

The DFEE processor will interface to the detector read out electronics on one side and to the DPE on the other. The software in the DFEE processor will perform the following tasks:

- Software initialization and code corrections according to instructions from the DPE (on power-up)
- Detector read-out control
- Single event evaluation
- Identification of X-ray events from the radioactive sources
- Background rejection
- Event statistics collection
- Event buffering and transmission to DPE
- DFEE HK collection and transmission to DPE
- Hardware parameter control.
- Transmission of Memory Dump data according to requests received from the DPE

The DPE will interface to the DFEE on the one side and to the OBDH on the other. The IASW software supplied by the PI-team will perform the following tasks:

- Data reception from the front-end processor (Science data via High Speed link, all other data via Low Speed link)
- Data compression and build-up of science TM-packet data fields, last 430 bytes, (very last two bytes used for CSSW generated CRC)
- Generation of On-Request TM-packet data fields according to TC requests, last 430 bytes, (very last two bytes used for CSSW generated CRC)
- Housekeeping data acquisition and build-up of HK-packet data fields, about 262 bytes, leaving room for DPE internal HK data and On-Event Reports (80 bytes)
- Telemetry transfer to CSSW
- Telecommand reception, decoding and execution/rejection
- Safe storage of instrument parameters (H/W and S/W) as well as code correction sequences

The development of the on-board software will comply with ESA PSS-05-0. The DPE software will be written in ADA, but for reasons of processing speed the DFEE software will be written in assembler.

The software will be placed in ROM and downloaded to RAM before execution. Code, fixed constants and variable parameters will be placed in distinct areas in memory. It will be possible to uplink corrections to the code from the ground prior to execution. For the DFEE software the code corrections are stored in the DPE and transferred to the DFEE as part of the DFEE software initialization process on power-up.

### 3.6.2 Internal timing concept.

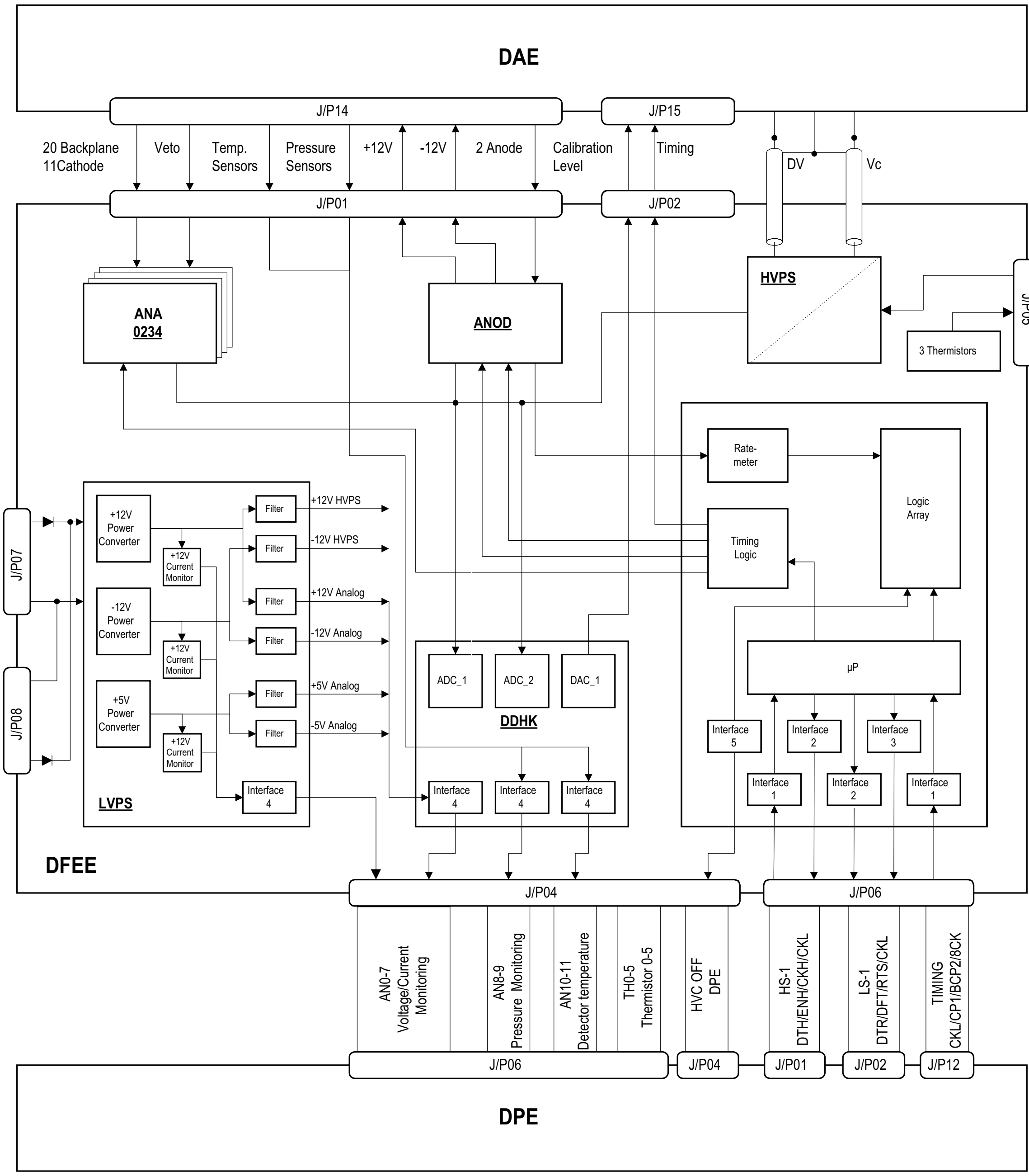
The DFEE will have an internal clock driven by a 8192 Hz signal derived from the 4.194304 MHz signal provided through the DPE. Thus the timing accuracy for the JEM-X is 122.07 microseconds. The DFEE clock will be reset every 8 seconds. The clock reset signal is derived from the BCP2 signal (1 Hz), which is stable with respect to the 4 MHz master signal. The BCP1 signal is used as a gate for the BCP2, limiting the reset frequency to 1/8 Hz.

The events transmitted from the DFEE to the DPE will be time stamped using two 16 bit words, one containing the reading of the DFEE clock (advancing every 122.07 microseconds) and another word counting the number of clock resets.

The DPE will read the “freeze register 1” in the Remote Bus Interface (RBI) every 8 s in synchronism with the clock reset operation in the DFEE. The DPE is therefore able to correlate the event time stamps from the DFEE to the OBT readings from the RBI.

Due to the existence of the "higher order time words" in the event timing, there will not be any 8 s ambiguity in the correlation between DFEE time and OBT.

### 3.6.3 Instrument level command diagram



### 3.6.4 Interfaces per instrument unit

3.6.4.1 DPE channels

1 discrete command line (DPE HVC OFF)
1 low speed serial line (TC)
1 high speed serial line (TM)
16 analogue lines (HK data)
10 thermistor lines (HK)
4 timing lines (4.194304 MHz, 8Hz, 1Hz, 1/8Hz)

3.6.4.2 RTU channels.

3 thermistor channels
1 discrete command line (S/C HVC OFF)

### 3.6.5 Definition of TC packet rate per instrument mode.

The nominal allocation of telemetry packets for JEM-X is 18 packets per polling cycle (8 seconds). Each packet has a total length 440 bytes of which 12 bytes are used for headers and CRC, leaving 428 bytes available for instrument data. Each JEM-X unit will use one (and only one) TM packet for HK information for every polling cycle. This leaves 16 packets for science. The 16 packets may be distributed evenly to the two instruments, this will typically be the case when observing source fields with low X-ray activity, or the packets may be distributed unevenly in order to exploit better the telemetry allocation, in case different formats are selected for the two instruments.

When observing intense X-ray sources JEM-X will generate data at higher data rates than the transmission allocation will allow. Then on-board data reduction must take place. This part of the on-board processing is designed to exploit effectively the available transmission capacity. Therefore JEM-X will fill the allocated TM capacity most of the time. Both the DFEE and the DPE software will be able to handle data congestion gracefully, for instance in case the data read-out from the DFEE or from the DPE hangs up.

On-Request telemetry packets will be used only for diagnostic purposes, and will not affect the average telemetry budget in a significant way.

If data are available each JEM-X unit will be able to support all packet rates between 1 and 191 packets per cycle as long as the DPE is on and the IASW is active. One packet per cycle is guaranteed to be a HK packet.

In case the DFEE is inactive the DPE will still fill part of the HK Package with meaningfull data. If the DFEE is inactive because the Low voltage is off, then the only valid data will be the DPE internal data and some thermistor data. If Low Voltage is On, but the DFEE CPU is Off, also the instrument HK monitored by the DPE will be valid.

Thus, the packet rate will be zero from a JEM-X unit in the OFF mode and it will be defined by the polling sequence in all other modes where the IASW is active. What response the CSSW will have to packet requests if the IASW is left in the inactive state (see the JEM-X state diagram in section 3.7.6.1) is beyond the control of the JEM-X software.

### 3.6.6 Data handling interface.

3.6.6.1 Housekeeping Connector J04

Housekeeping monitor channels are connected to the DPE via a Cannon connector Royal-D - 37S:

Signal names and Pin connections in Appendix B.

3.6.6.2 Serial communication connector J06

The serial communication channels are connected to the DPE via a Cannon connector Royal-D-37S:

Signal names and Pin connections in Appendix B.

3.6.6.3 Discrete commands connector J05

The discrete commands are connected to JEM-X via a Cannon connector Royal D-37:

Signal names and Pin connections in Appendix B.

# 3.7 Instrument Software and Interfaces

## 3.7.1 Instrument software architecture

The JEM-X On-board Software can be divided into two major components:

- The DFEE software, and
- The DPE IASW.

Each part of the software will run on a 1750A CPU.

The DFEE software consists of the following main components:

-Data Acquisition
Read the event data from the hardware.
--- In State: Science Data Acquisition
Perform event selection according to current Grey Filter Algorithm
Perform event selection according to signal amplitude and interaction type
Calculate XY-coordinates of event in detector
Identify X-ray calibration source events and accumulate spectra
Store time, energy and position for selected events in the output FIFO buffer
Compile event statistics
--- In State: Diagnostic Event Dump
Perform event classification according to current Grey Filter Algorithm
Perform event classification according to signal amplitude and interaction type
Calculate XY-coordinates of event in detector
Identify X-ray calibration source events and accumulate spectra
Store full event information (raw+derived data) in the output FIFO buffer
Compile event statistics
--- In State: Electronic Calibration
Store full event information (raw ADC data only) in the output FIFO buffer
Compile event statistics

-DFEE-DPE data transfer interface
Control the High Speed Serial line,
-Hardware control
Obtain hardware settings from the DPE and transmit to the hardware registers,
-High Voltage monitoring
Read the high precision HV data and transmit to the DPE via the low speed line,
-Software services
Synchronize the DFEE local clock with the OBT,
Obtain software parameters from the DPE and echo parameter values back
Transmit DFEE HK values to the DPE via the low speed line
Perform DFEE memory load and dump via the low speed line

The DPE IASW consists of the following components:

-Data Acquisition
Obtain event data blocks from the DFEE and store events in the event buffer,
-Data Format and Grey Filter selection according to the degree of filling of the event buffer
-Data compression, TM packet building and storage in TM-buffer
-HK monitoring
Obtain HK data directly or through DFEE, prepare HK-packets
-TC handling
Obtain TC packets, validate the contents and execute or reject
-Broadcast Packet monitoring
Obtain the Broadcast Packet, validate the contents and react to information on:
- Emergency and Switch-off Flags
- Eclipse/Radiation Belt Entry/Exit
- Radiation Monitor count rates
- ACS mode, On Target Flag and Slew Flag

- Telemetry allocation information

-Instrument state control
Control the execution of the state changing commands
Update the instrument state table,

-Software services
support the DFEE software, control the software parameters,
execute memory loads and dumps (both for DFEE and IASW).

### 3.7.2 Common Service Software (CSSW)

The JEM-X Onboard Software will use the CSSW. All of the CSSW services will be used.

### 3.7.3 Instrument specific application software (DPE IASW)

The event stream on the High Speed Line have characteristics which can be used for consistency checking and synchronization of the data stream:

- The HK Cycle Counter increments slowly (every 8 seconds)
- The HK Cycle Counter is also transmitted in LS HK
- Only the HK Cycle counter and the Timer Value can be zero

The IASW part of the program for JEM-X/DPE is composed of the following routines:

| Routine name | Addr. State | Main functions |
|---|---|---|
| DPE_IASW | AS0 | Initialisation of the IASW |
| IASW_MAIN | AS1 | Time synchronisation of actions of the program, reception and distribution of telecommands |
| IASW_TM | AS1 | Filtering of Telemetry Packets and On Event Messages |
| IASW_MODES | AS1 | Switching between modes of operation |
| IASW_EVENTS | AS1 | Handling of event data rescaling and compression |
| IASW_EVSORT | AS1 | Sorting of events collected in the buffer |
| IASW_HSL | AS1 | Receiving event-records from DFEE via High Speed Line |
| IASW_BUFFER | AS1 | Access to the large buffer of event-records |
| IASW_SUBBUFFER_1..10 | AS2 .. AS11 | Storing of up to 50000 event-records, there are 10 identical routines |
| IASW_SC_OUT | AS1 | Producing of Science TM Packets |
| IASW_REQ_OUT | AS1 | Producing of On Request TM Packets |
| IASW_HK | AS1 | Colecting of Housekeeping information |
| IASW_DFEE | AS1 | Dialog with DFEE via Low Speed Line |
| IASW_TIME | AS1 | Recalculation of DFEE time to the OBT scale |
| IASW_MRTU | AS1 | Facilitates the contact with Analog/Digital Converter |
| IASW_COMMON | AS1 | General purpose functions and definitions |
| IASW_STATE | AS1 | Autonomous actions of IASW (TBW - not yet implemented) |
| IASW_PATCHES | AS14 | Storing of RAM patches directed to DFEE |

IASW runs eight concurrent tasks:

| Name of the Task | Code in Routine | TID | Priority | Initial State | Stack Size |
|---|---|---|---|---|---|
| TASK_MAIN | IASW_MAIN | 1 | 15 | STARTED | 400 |
| TASK_TC | IASW_MAIN | 2 | 13 | STARTED | 1150 |
| TASK_HSL | IASW_HSL | 3 | 4 | STARTED | 500 |
| TASK_SC_OUT | IASW_SC_OUT | 4 | 3 | STARTED | 700 |
| TASK_DFEE_HK | IASW_HK | 5 | 11 | NOT_STARTED | 550 |
| TASK_DPE_HK | IASW_HK | 6 | 12 | NOT_STARTED | 350 |
| TASK_REQ_OUT | IASW_REQ_OUT | 7 | 10 | NOT_STARTED | 1100 |

| | | | | | |
|---|---|---|---|---|---|
| TASK_STATE | IASW_STATE | 8 | 14 | NOT_STARTED | 650 |

### 3.7.4 DFEE Software

The DFEE software is written in assembler. Task switching is not used. The various configurations of the DFEE software is handled by State changing commands that select interrupts and set software switches.

The main tasks of the DFEE On-Board Software are

- to capture the events,
- to determine the event class,
- to process the events,
- to transmit the events for further processing by the DPE software.

In this context four different operational states of the software must be distinguished:

- trigger system inactive,
- normal data taking,
- electronic calibration,
- diagnostic data dump.

The event trigger logic can be activated by four different classes of events:

- celestial x-rays,
- calibration source x-rays,
- background events,
- electronic calibration events.

The relation between the event classes and the operational states can be determined from the following schematic presentation:

| | Trigger System Inactive STATE < 10 | Normal Data Taking STATE = 10 | Electronic Calibration STATE = 20 | Diagnostic Data Dump STATE = 40 |
|---|---|---|---|---|
| Celestial X-rays | Not seen | Detect and transmit | Detect and reject | Detect and transmit |
| Calibration X-rays | Not seen | Detect and accumulate spectra | Detect and reject | Detect and transmit |
| Electronic Calibration Pulses | Not Generated | Not generated | Detect and transmit | Not generated |
| Particle events (background) | Not seen | Detect and reject | Detect and reject | Detect and transmit |

The description of the DFEE software is divided into the following sections:

- 3.7.4.1 Single Event Capture Routines
- 3.7.4.2 Event analysis Routines
- 3.7.4.3 Routines for processing counters
- 3.7.4.4 Description of the controllable parameters
- 3.7.4.5 The Software Interface between the DPE and the DFEE
- 3.7.4.6 Data exchange sequences between the DPE and the DFEE

<u>3.7.4.1 Single Event Capture</u>

When the interrupt system is active and an event trigger is detected an interrupt is generated and the interrupt handler will normally read in the event, store it in temporary storage and reactivate the interrupt system. The number of triggers will be counted in a double word counter [K5119+K5120].

3.7.4.1.1 Grey Filter event rejection.

During observations with high count rates it may not be possible to transmit all events to the ground. Some on-board rejection of events must take place. The “Grey Filter” mechanism is responsible for this rejection.The rejection takes place in the DFEE already during the handling of the the event trigger interrrupt in order to minimize the processing time waisted on useless events.

The Grey Filter consists of a string of 32 numbers which can assume the values one or zero. Running cyclically through this string, advancing one element for every event interrupt, we reject an event every time a one is encountered. Thus the transmission value of the grey filter can assume the values 1, 2, 3, ....., 30, 31, 32 divided by 32. (A zero transmission filter is not implemented). The values of the filter to be used is determined autonomously by an algorithm in the DPE software (the IASW), according to the degree of filling of the DPE data buffer and the time evolution of this filling. The instantaneous value of the grey filter is reported both in the housekeeping packet (“Used Grey Filter”) and in the science telemetry packets.

To minimize the effect of the recurrent pattern of length 32, the rejection takes place at the input where the interesting X-ray events are randomly distributed among a large number of particle background events (~1700 events/second). The number of rejected will be counted in a double word counter [K5121+K5122].

At the beginning of each new pointing (identified through the information in the Broadcast packet, see section 3.7.5.2.11) the grey filter will be initialized to 100% transmission.

3.7.4.1.2 Limitations imposed by the Temporary Event Buffer

In order to get the interrupt system back to active status as soon as possible only the actual reading of the event data will be performed with the interrupt disabled. As soon as the event has been read and transferred to one of the 5 slots in a Temporary Buffer, the interrupt system is reactivated. This means that the event analysis will be performed simultaneously with a possible arrival of new events.

The read-in of an event takes less than 100 microseconds whereas the analysis of an event can take up to 500 microseconds. At high counting rates the Temporary Buffer can therefore be filled. Events lost due to this condition will be counted in a single word counter [K5136].

When the instrument is in the Diagnostic Data Dump State all events (also the particle background events) will go through detailed processing and the condition of “Temporary Buffer Full” can be expected to occur frequently.

3.7.4.1.3 Interruption of event data read-in during Normal Data Taking.

In order to remove the large number of background events as quickly as possible from the data stream the read-in process contains one test of the data quality. Most particle background events will cause an overflow in the anode channel. Immediately after reading the anode signal it will be checked against a maximum allowed value and the read-in will be terminated if the upper limit condition is exceeded. This will keep the amount of time used on an event rejected in this way down to approx 50 microseconds. The rejects will be counted in the double word counter [K5123+K5124].

Note that this rejection mechanism is disabled during Diagnostic Data Dump.

The upper limit value value is adjustable from ground.

3.7.4.1.4 Data read-in during Electronic Calibration

The electronic calibration will normally be performed with the high voltage on to get as realistic a noise situation as possible. This means that normal events and background events must be prevented from filling up the data stream. This is achieved by keeping the interrupt system disabled most of the time. An electronic calibration event is then captured in the following way:

- enable interrupt
- generate a calibration pulse
- detect a trigger
- disable the interrupt
- read in the event.

It can happen that an outside event triggers the system before the pulse arrives at the amplifiers. Later analysis on board will remove most of these events from the data stream.

3.7.4.1.5 Reading of the HV monitoring values

The HV monitoring values are normally captured as a part of the read-out of a event trigger.

When the trigger system is disabled a special event trigger will be generated to allow the read-out of the HV values at least once every 8 seconds.

These values will be placed in the normal HK data block. [K5001+ K5002].

3.7.4.2. Event analysis

Once an event has been placed in the temporary buffer it will be analysed to determine its class. Depending upon the operational state of the software this analysis will have different aims:

- Normal Data Taking: extract X-ray events, reject events classified as background.
- Electronic Calibration: extract electronic calibration events, reject “real” events.
- Diagnostic Data Dump: extract and classify all events.

The extracted events will be placed in the output FIFO.

3.7.4.2.1 Normal Data Taking

The events to be classified as X-ray events have to pass several tests, of which the test on the anode signal upper limit have already been performed during data capture.

Further tests are:

- The ratio of the veto signal to the anode signal should be below an upper limit
- The ratio of the fast anode signal to the anode signal should be within a defined range
- The ratio of the backplane signal to the anode signal should be within a defined range
- The ratio of the cathode signal to the anode signal should be within a defined range
- Acceptable backplane footprint
- Acceptable cathode footprint

All condition limits are commandable from ground.

If an event fails one of the tests the event will be discarded. The number of events rejected according to the different criteria will be reported in a number of counters, reported in the HK Data. [K5125 to K5134].

When an event has passed all these tests the event position is calculated. If the position falls within one of the 4 footprints of the calibration sources, it will be classified as a X-ray calibration event and shunted to special analysis.

Normal events will be stored in the FIFO buffer. A fixed data format will be used:

- Event Start Mark (= F000 [Hex])
- HK Cycle Counter
- Timer value
- Anode value
- X position
- Y position

Each position is a 16-bit word.

3.7.4.2.1.1 X-ray calibration events

The X-ray calibration events will be acumulated in four spectra. For each of four radioactive calibration sources a 256 channel spectrum will be generated. These spectra will be transmitted via the HK blocks. In each HK block 8 channels will be transmitted from each of the four spectra. This means that a full spectrum will occupy 32 HK blocks. [K5200 to K5238 TBD].

A double buffer system will be used. This means that the collection time for each spectrum will be 32 HK cycles i.e. the time resolution in the X-ray calibration is 256 seconds.

3.7.4.2.2 Electronic Calibration

During the calibration state the analysis will try to identify the electronic calibration events and reject all other.

The electronic calibration consists of a number of pulses (commandable but nominally 100) send to the amplifiers for each of the calibration levels (commandable both in value and number of levels, nominally 10 levels evenly distributed over the operating range of the amplifiers).

When an event has been captured the signals from all selected channels (each channel commandable on/off) will be summed and compared to the expected value. The relation between the generated pulse and the expected signal has to be established during ground testing. If the difference exceeds the allowed limits the event will be rejected.

The limits are commandable from ground for each level. The on/off feature for each channel in the analysis allows the test to disregard dead or noisy channels during the test. All channels will be transmitted to the ground.

3.7.4.2.3 Diagnostic Data Dump

The event analysis in this state is similar to the analysis in Normal Data Taking. The only differences are that all input data as well as the results will be transmitted to ground and that also rejected events will be transmitted. This includes the X-ray calibration events.

This state can therefore be used to monitor and verify correct on-board data processing.

3.7.4.3. Processing counters

There are three ways to obtain information about the processing done by the DFEE software:

- the event data transmitted
- the JEM-X HK data
- system messages

The event data contains the accepted events, the HK block contains a series of counters indicating the number of events failing various tests and the system messages identifies unexpected or rare situations encountered during processing.

The HK counters contain processing information about the previous HK cycle i.e. the last 8 seconds.

The counters are:

- # of Event Triggers
- # of accepted avents
- # of events rejected by Grey Filter
- # of events rejected due to lack of space in Temporary Buffer
- # of events rejected by upper threshold
- # of events rejected by Veto Signal
- # of events rejected by Low Risetime
- # of events rejected by High Risetime
- # of events rejected by Too Many Hits in Back Plane
- # of events rejected by Too Many Hits in Cathode
- # of events rejected by Too High Signal in Back
- # of events rejected by Too Low Signal in Back
- # of events rejected by Too High Signal in Cathode
- # of events rejected by Too Low signal in Cathode
- # of events rejected due to output FIFO full condition

The counters are placed in the HK Block as [K5119 to K5136].

3.7.4.4 Controllable software parameters

The processing of the events are controlled by a number of parameters that can be adjusted from the ground. Except for the grey filter pattern, which may be changed autonomously by the IASW software, all of the parameters listed below are "engineering" parameters, i.e. once they have been adjusted they are not supposed to be changed as long as the instrument performs nominally. For the Normal Data Taking state the following parameters are used during the analysis of an event:

- Grey filter 32-bit pattern
- Slow anode upper limit
- Veto/Anode ratio upper limit
- Fast Anode/Slow Anode ratio lower limit
- Fast Anode/Slow Anode ratio upper limit
- Back Plane Low/High energy range shift
- Back Plane Stray upper limit low energy
- Back Plane Stray upper limit high energy
- Cathode Plane Low/High energy range shift
- Cathode Plane Stray upper limit low energy
- Cathode Plane Stray upper limit high energy
- Back Plane/Anode ratio lower limit
- Back Plane/Anode ratio upper limit
- Cathode Plane/Anode ratio lower limit
- Cathode Plane/Anode ratio upper limit

The "stray" limits are used to reject events where outlying (stray-) strips have too much signal.

For each of the 34 amplifier channels we also need

- channel offset
- channel gain

these are derived off line from the electronic calibration data.

In the analysis of the electronic calibration we need the following parameters:

- # of calibration levels.

For each level we need:

- # of pulses
- pulse voltage
- expected summed output.

For each of the four anode amplifier chains we need

- amplifier On/Off.

All of these parameters can be adjusted by commands from the ground. Other parameters used in the analysis like the X-ray calibration source positions are considered to be constants. They can however be modified by a DFEE memory patch [K17 DFEE_LOAD].

3.7.4.5 DFEE to DPE High Speed Link

The High Speed Link is unidirectional from the DFEE to the DPE. It is used to transfer a stream of event data blocks. It is expected that several blocks will be transmitted in every 8 second period.

The DPE will interrogate, every 125 ms, a special line which carries the Half-Full-Flag from the output FIFO in the DFEE. When the flag is detected the DPE reads a data block. The length of the data block is half of the buffer length (4096 words). There is no requirement to transmit only complete event blocks. The DPE software will correctly handle events split between two transfers on the High Speed Line.

Besides the normal events the HS stream will also contain “marker”-events used as time markers, grey filter indicators and fillers at the end of an observation. As the HS transfer is from a FIFO to a FIFO it is important to maintain synchronisation. When the special markers are sent via the HS line they will have the normal event length corresponding to the data taking mode in use.

There are three different HS formats used:

- 1. Normal Data Taking format,
- 2. Electronic Calibration format,
- 3. Diagnostic Dump format.

One HS block will contain about 680 events in Normal Data Taking format, about 110 events in Electronic Calibration format and about 100 events in Diagnostic Dump format.

3.7.4.5.1 Normal Data Taking Format.

Each event consists of 6 16-bit words.

1: Event Start Mark = F000[Hex]
2: HK Cycle Counter
3: Timer Value
4: Slow Anode Pulseheight
5: Back Plane Position
6: Cathode Plane Position

At the end of data taking period marker events will be used to fill the DFEE output FIFO in order to ensure that the last events are flushed to the DPE. Finally marker events will be used to indicate changes of the grey filter which may occur in the middle of an observation.

The format for the marker events is:

1: Event Start Mark = F000[Hex]
2: HK Cycle Counter
3: Timer Value
4: Marker event indicator = FFFF [Hex]
5: Type
  = 1  Filler
  = 2  Grey Filter change
6: Parameter
  if Type = 1 this word = 0000 [Hex]
  If Type = 2 this word = Grey Filter number

The filler type is used both for timing and for buffer flush at the end of an observation.

3.7.4.5.2 Calibration Format.

Each event consists of 37 16-bit words.

1: Event Start Mark = F000[Hex]
2: HK Cycle Counter
3: Timer Value
4: Slow Anode Pulseheight
5: Fast Anode Pulseheight
6: Veto signal
7-26: Back Plane signal 1 to 20 (20 words)
27-37: Cathode Plane signal 1 to 11 (11 words)

Marker events will be used as time markers and as fillers. A new type is used to indicate the change from one calibration level to the next.

The format is:

1: Event Start Mark = F000[Hex]
2: HK Cycle Counter
3: Timer Value
4: Marker event indicator = FFFF [Hex]
5: Type
  = 1 Filler
  = 3 Calibration change
6: Parameter
  If Type = 1 this word 0000 [Hex]
  If Type = 3 this word = Calibration amplitude
7: Parameter
  If Type = 1 this word 0000 [Hex]
  If Type = 3 # of triggers/level
8-37: these words = 0000 [Hex]

3.7.4.5.3 Diagnostic Dump Format.

Each event consists of 43 16-bit words.

1: Event Start Mark = F000[Hex]
2: HK Cycle Counter
3: Timer Value
4: Slow Anode Pulseheight
5: Back Plane Position
6: Cathode Plane Position
7: Risetime
8: Slow Anode Pulseheight
9: Fast Anode Pulseheight
10: Veto Signal
11-30: Back Plane signal 1 to 20 (20 words)
31-41: Cathode Plane signal 1 to 11 (11 words)
42: Event Status Word
43: Calibration Event Marker

If Event Status = 0 the event was accepted by the DFEE analysis. In this case the format contains the DFEE output (the first 6 words) + the corresponding DFEE input (the last 34 words). The two timer words are not duplicated. This means that this format can be seen as the sum of Format 1 and Format 2.

If the on-board analysis classifies this event as coming from one of the calibration radioactive sources the Calibration Event Marker is set to the number of the source. These are numbered 0, 1, 2, and 3. If the event is not so classified the Calibration Event Marker is set to -1.

If Event Status > 0 then the event was rejected by the DFEE analysis. In this case the positions and the risetime can be meaningless. If status > 5 the Risetime is OK, if status > 8 the Back Plane Position is OK, but the Cathode Plane Position is never correct when the Event Status > 0.

Marker events will be used as time markers and as fillers.

The format is:

1: Event Start Mark = F000[Hex]
2: HK Cycle Counter
3: Timer Value
4: Marker indicator = FFFF [Hex]
5: Type = 1 (Filler)
6-43: these words = 0000 [Hex]

3.7.4.6 Low Speed Link from the DPE to the DFEE.

The Low Speed Link is bidirectional. It is used to transmit infrequent messages back and forth. It is also used to transmit the DFEE HK data. The HK blocks comes once every 8 second period.

The Low Speed Link is half duplex only.

There are 8 different formats used to transfer requests and data from the DPE to the DFEE:

- 1. State Change Command
- 2. Parameter Change Command
- 3. Memory Uplink Command
- 4. Hardware Command
- 5. Memory Dump Request
- 6. Memory CRC Request
- 7. DFEE Status Request
- 8. HK Block Request.

The State Change Command moves the DFEE software between the major activities. The only state change accepted when in the Data Taking state is to stop, ie. STATE_SETUP.

Parameter Change Command and Hardware Commands will only be accepted in SETUP state.

Memory Uplink Commands will only be accepted in the MEMORY PATCH/DUMP state of the DFEE software. This state can only be reached from the SAFE state.

This allows two ways of changing the parameters that control the data analysis. Change of one or a few parameters will be done using Parameter Change Commandt. If a large set of parameters are to be changed this can be done by the Memory Uplink Command. The selection of which method to use will be determined by operational considerations.

To improve the reliability of the communication each command on the low speed link from the DPE to the DFEE is enclosed by an envelope consisting of two start words (=DDDD[Hex], DDDD[Hex]) preceeding the command and two termination words (=3333[Hex], 6666[Hex]) trailing the command.

No corresponding envelope is required for the response messages generated by the DFEE as the DPE knows beforehand the type and length of the response messages expected for each command.

3.7.4.6.1 State Change Command

This command can be executed autonomously by the IASW, as a consequence of information in the TC(15,1) Broadcast packet or as requested by a TC(5,5) Mode Change command from the ground.

This command consists of 4 16-bit words.

1: State Change Command Indicator = 1234 [Hex]
2: The State number wanted
3: State parameter
4: CRC check word

The State Parameter is used to specify the number of Calibration triggers/level for the CALIBRATION state and the number of Events to be transmitted for the DIAGNOSTIC state.

The correlation between the DFEE STATE and the (decimal) state number is:

| | |
|---|---|
| - SAFE | 1 |
| - MEMORY PATCH/DUMP | 2 |
| - SETUP | 5 |
| - DATA TAKING | 10 |
| - CALIBRATION | 20 |
| - DIAGNOSTIC | 40 |

This command will generate a Command Acknowledge from the DFEE.

3.7.4.6.2. Parameter Change Command

This command can be executed autonomously by the IASW, as a consequence of information in the TC(15,1) Broadcast packet or as requested by a TC(5,3) Load Task Parameter command from the ground.

This command consists of 5 16-bit words.

1: Parameter Change Command Indicator
    in case of Integer Parameter = 8642 [Hex]
    in case of Floating Parameter = 8765 [Hex]
2: # of Parameter to be changed
3: Parameter
    if integer = value
    if float = most significant part of value
4: Parameter
    if integer = 0
    if float = least significant part of value
5: CRC check word

This command will generate a Command Acknowledge from the DFEE.

3.7.4.6.3. Memory Uplink Command

This command can be executed autonomously by the IASW, as a consequence of information in the TC(15,1) Broadcast packet or as requested by a TC(6,1) Load Memory of DFEE command from the ground.

This command consists of 5 - 260 16-bit words.

1: Memory Uplink Command indicator = ABCD [Hex]
2: Start Address of the Block
3: Length of the Block
4 - 4+N: N Words (N=1 to 256)
5+N: CRC check word

This command will generate a Command Acknowledge from the DFEE.

3.7.4.6.4. Hardware Command

This command can be executed autonomously by the IASW, as a consequence of information in the TC(15,1) Broadcast packet or as requested by a TC(5,3) Load Task Parameter command from the ground.

This command consists of 4 16-bit words.

1: Hardware Command Indicator = AAAA [Hex]
2: Command Address
3: Command Value
4: CRC check word

The Hardware Command addressing system is:

| Command Address | Command Value | |
|---|---|---|
| 0 | 4 | HV_READY |
| 0 | 5 | HV_ON |
| 0 | 6 | HV_OFF |
| 1 | value of Anode Settings. Legal range, see below. | |
| 2 | value of Low Level Discriminator. Legal range: 0-255. | |

| | |
|---|---|
| 3 | value of HV_DELTA. Legal range: 0-4095. |
| 4 | value of HV_CATHODE. Legal range: 0-7. |

The Anode Settings is a 4-bit pattern (in bit 12 to 15), indicating the on-off status of the four anode sections. The bit values are inverted so a value 0000 [Bin] indicates that all anodes are on.

This command will generate a Command Acknowledge from the DFEE.

3.7.4.6.5. Memory Dump Request

This command can be executed autonomously by the IASW or as requested by a TC(6,2) Dump Memory of DFEE command from the ground.

This block consists of 4 16-bit words

1: Memory Dump Request Indicator = CADB [Hex]
2: Start Address of the Block
3: Length of the Block
4: CRC check word.

This request will generate a dump block from the DFEE.

3.7.4.6.6. Memory CRC Request

This command can be executed autonomously by the IASW, as a consequence of information in the TC(15,1) Broadcast packet or as requested by a TC(6,3) Calculate CRC of Memory of DFEE command from the ground.

This block consists of 4 16-bit words

1: Memory Dump Request Indicator = FEDC [Hex]
2: Start Address of the Block
3: Length of the Block
4: CRC check word.

This request will generate a CRC block from the DFEE.

3.7.4.6.7. DFEE Status Request

The DFEE Status Request will clear the error status.

This command can be executed as requested by a TC(5,3) Load Task Parameter command from the ground.

This block consists of 3 16-bit words

1: Status Request Indicator = 2323 [Hex]
2: Parameter (not used)
3: CRC check word

This request will generate a status block from the DFEE.

3.7.4.6.8. HK Block Request

This command can be executed as requested by a TC(5,3) Load Task Parameter command from the ground.

A HK Block Request will be issued by the DPE once every 8 seconds.

This block consists of 3 16-bit words

1: HK Block Request Indicator = 4711 [Hex]
2: TBD parameter
3: CRC check word

This request will generate a HK block from the DFEE.

3.7.4.7 Low Speed link data from the DFEE to the DPE

All data transfers or requests from the DPE to the DFEE will generate either a Command Acknowledge or an answer block back from the DFEE. There will be a delay between request and response of at least 100 microseconds.

3.7.4.7.1 Request Acknowledge

1. Packet identifier: F00F [Hex]
2. Request status value: 0: Request executed normally
   1: CRC error
   2: Request not recognized
   3: Request not valid
   4: State # or Parameter # not valid
   5: Parameter value out of range
3. CRC

3.7.4.7.2 DFEE Status Block

1. Packet identifier: 0F0F [Hex]
2. Last H/W command received
3. Last parameter change. Parameter #
4. System error #
5. HK cycle counter
6. Timer value
7. CRC

3.7.4.7.3 Memory CRC Block

1. Packet identifier: F1F7 [Hex]
2. Start address
3. Length
4. CRC

3.7.4.7.4 Memory Dump Block

1. Packet identifier: 0FF0 [Hex]
2. Start address
3. Length (N)
4 to 3+N: Memory block
4+N. CRC

3.7.4.7.5 Report Integer S/W parameter

1. Packet identifier: 1357 [Hex]
2. Parameter #
3. Value
4. CRC

3.7.4.7.6 Report Float S/W parameter

1. Packet identifier: 147A [Hex]
2. Parameter #
3 and 4. Value
5. CRC

3.7.4.7.7 Report all Integer S/W parameters

1. Packet identifier: BC01 [Hex]
2. Length = 100
3 to 102. 100 Integer parameter values
103. CRC

3.7.4.7.8 Report all Float S/W parameters

1. Packet identifier: BCEF [Hex]
2. Length = 100
3 to 202. 100 Float parameter values
203. CRC

3.7.4.7.9 DFEE HK data block

1. Packet identifier: 7777 [Hex]
2. Length = 57
3 to 59. 57 parameter words (see section on DFEE HK in 3.7.8.14)
60. CRC

3.7.4.8 Data exchange sequences between the DPE and DFEE

3.7.4.8.1 Housekeeping Sequence

Once per polling cycle the DPE will request HK data from the DFEE. The DFEE will collect the data from its hardware and software sources and transmit a HK data block to the DPE on the low speed serial line.

3.7.4.8.2 Calibration sequence

The calibration sequence is initiated via a STATE_CALIBRATE command from the ground. The DFEE will switch on the electronic calibration generator and generate 10 times 100 calibration pulses of increasing amplitude according to a parameter table. The calibration pulses will generate normal event triggers, but the data will not be analyzed in the DFEE, rather the full set of 34 raw detector outputs will be transferred to the DPE via the high speed link. After completion of the calibration sequence the DFEE will autonomously switch off the calibration generator and return to the SETUP state.

3.7.4.8.4 Diagnostic Sequence

The diagnostic sequence is initiated via a STATE_DATA_DUMP command from the ground. The DFEE will switch to its DATA_DUMP state in which all 34 raw detector outputs are send to the event output FIFO together with the results of the normal event processing (checking of rejection criteria, position determination). The START_DATA_DUMP command contains as a parameter the desired number of events to be processed in this mode. When the prescribed number of events have been recorded the DFEE will autonomously return to the SETUP state.

### 3.7.5 TC packet structure definition and content

The detailed TC packet definitions are given in the Satellite Data Base.

3.7.5.1 Hardware and Software parameter settings

a) Hardware settings:

-High Voltage ON/OFF. (Both DV and $V_C$)
-Set Detector Gas-gain Voltage, DV
-Set Detector Drift Voltage, $V_C$

-Enable/Disable Anode Strips,

-Set Event Discriminator level,

-Electronic Calibration Pulse Generator ON/OFF,
-Set Electronic Pulse Generator levels,
-Set Electronic Pulse Generator rate

b) Software parameter settings:

-Parameters for the event rejection criteria,

-Select Primary and Secondary Telemetry Formats

-Detector pulseheight to output channel conversion table
-Position linearization table, X-coordinate.
-Position linearization table, Y-coordinate.

-Ratemeter cut-off value to be used by the DFEE

A complete set of these parameters are stored in a dedicated area to be used in autonomous recovery after passage of the radiation belts and after eclipses. The parameters will be validated during uplink by the DFEE software so the setting table kept in the dedicated area will always be valid.

3.7.5.2 Telecommands

Each telecommand and telemetry packet carry an 11-bits target address called Application Identifier. To each of the units in the Integral system a range of APID is assigned. The Base APID defines the range of possible APIDs - BASE_APID .. BASE_APID+127.

| JEM-X | BASE_APID |
|---|---|
| "K" | 1100 0000 000 |
| "L" | 1101 0000 000 |

Table A Base APID for JEM-X**.**
Telecommands directed to IASW will have APID = BASE_APID+1. (EID-A, chapter 4.5.3.1)
IASW for JEM-X accepts and executes the following telecommands:

TC(5,3) - Load Task Parameters
TC(5,4) - Report Task Parameters
TC(5,5) - Mode Transition
TC(6,1) - Load Memory of DFEE
TC(6,2) - Dump Memory of DFEE
TC(6,3) - Calculate CRC of Memory of DFEE
TC(9,1) - Report TM Packet Generation Status
TC(9,4) - Enable Generation of Specific TM Packets
TC(9,5) - Disable Generation of Specific TM Packets
TC(13,1) - Test command
TC(15,1) - Broadcast Packet.

**WARNING! The DPE provides only limited verification of correctness of the sequence of telecommands.**

3.7.5.2.1 TC(5,3) - Load Task Parameters

The following description uses terms like: TID, FID, Param#n, which are described in IPSD, the location of the TID and FID parameters are illustrated in the following table[2].

| Header (3 words) | | | | |
|---|---|---|---|---|
| 00[Bin] | Chk-type | Ack=0000[Bin] | 5 | 3 |
| TID | | | FID | |
| Data Field (number of parameters depends on the TID and FID values) | | | | |

**Set DFEE's SW Integer Parameter TC_ID K5xxx**

TID = 0
FID = 1
Param #1 - SW Integer Parameter Identifier
Param #2 - SW Integer Parameters Value

The identifier is in a range 0..99. Its value corresponds to a position of the parameter in the Integer Parameters Table. The address of the table in the RAM of DFEE is D500(Hex).

**Set DFEE's SW Float Parameter TC_ID K5xxx**

TID = 0
FID = 2
Param #1 - SW Float Parameter Identifier
Param #2 - SW Float Parameter Value (bits 0..15)
Param #3 - SW Float Parameters Value (bits 16..31)

The identifier is in a range 0..99 Its value corresponds to a position of the parameter in the Float Parameters Table. The address of the table in the RAM of DFEE is D600[Hex].

[2] ALENIA, INT-RP-AI-0030, Issue 03, 22 Sep'97, „INTEGRAL Packet Structure Definition”.

**Anode Settings Command TC_ID K5xxx**

TID = 0
FID = 31
Param #1 - HW Setting value

Four Low Significant Bits of Param#1 sets the given anode ON (bit=0) or OFF (bit=1). The assignment of individual anode to a bit position is the following:

bit 12 - anode 1,
bit 13 - anode 2,
bit 14 - anode 3,
bit 15 - anode 4.

**Low Level of Discriminator Setting Command TC_ID K5xxx**

TID = 0
FID = 32
Param#1 - Low Level of Discriminator (range 0..255)

**Acceleration HV Setting Command TC_ID K5xxx**

TID = 0
FID = 33
Param#1 - Acceleration HV (range 0..4095)

**Drift HV Setting Command TC_ID K5xxx**

TID = 0
FID = 34
Param#1 - Drift HV (range 0..15)

**HV Ready Command TC_ID K5xxx**

TID = 0
FID = 4

**HV On Command TC_ID K5xxx**

TID = 0
FID = 5

**HV Off Command TC_ID K5xxx**

TID = 0
FID = 6

**Load into the DFEE the context stored in DPE memory TC_ID K5xxx**

TID = 0
FID = 7

**Save DFEE context in DPE memory TC_ID K5xxx**

TID = 0
FID = 8

**Setting of the flag „Automatic Recovery Enable" TC_ID K5xxx**

TID = 1
FID = 12
Param #1 = 0 for OFF (default), =1 for ON

Setting this flag enables the procedure of automatic recovery of HV and data taking after Radiation Belts or Eclipse.

**Set Operator overrides for Broadcast Packet data TC_ID K5xxx**

TID = 1
FID = 18
Param#1 16 bit flags „Disable Check"
When a bit is set to 1, the corresponding condition will not be read from BCPKT.
Its value will instead be determined by the corresponding bit Error Condition.
Param#2 16 bit flags „Error Condition"
Value of a bit is used only when the corresponding Disable Check bit is set.

| Bit # | BCPKT data overridden by Disable Check = 1 | Meaning of Error Condition = 1 |
|---|---|---|
| 0 | OTF | OTF=0 (Not On Target) |
| 1 | AOCS Mode | not Inertial Pointing Mode |
| 2 | AOCS Submode | (not used) |
| 3 | ESAM | ESAM=1 |
| 4 | Radiation Monitor Counter #1 | value exceeds a limit |
| 5 | Radiation Monitor Counter #2 | --"-- |
| 6 | Radiation Monitor Counter #3 | --"-- |
| 7 | Radiation Belts Entry/Exit Times | Radiation Belts condition true |
| 8 | Eclipse Entry/Exit Times | Eclipse condition true |
| 9 | Data Rate Share | Data Rate = 16 (otherwise Data Rate = 8) |
| 10 | Imminent Instrument Switch Off | I.I.Sw.Off = 1 |
| 11..15 | Spare | |

**Set Operator overrides for mRTU data TC_ID K5xxx**

TID = 1
FID = 19
Param#1 16 bit flags „Disable Check"
When a bit is set to 1, the corresponding condition will not be read from mRTU.
Its value will instead be determined by the corresponding bit Error Condition.
Param#2 16 bit flags „Error Condition"
Value of a bit is used only when the corresponding Disable Check bit is set.

| Bit # | mRTU data overridden by Disable Check = 1 | Meaning of Error Condition = 1 |
|---|---|---|
| 0 | Detector Pressure #1 | value out of range |
| 1 | Detector Pressure #2 | --"-- |
| 2 | Detector Temperature #1 | --"-- |
| 3 | Detector Temperature #2 | --"-- |
| 4 | +5V digital (voltage) | --"-- |
| 5 | +5V digital (current) | --"-- |
| 6 | +5V analog (voltage) | --"-- |
| 7 | -5V analog (voltage) | --"-- |
| 8 | +12V (voltage) | --"-- |
| 9 | +12V (current) | --"-- |
| 10 | -12V (voltage) | --"-- |
| 11 | -12V (current) | --"-- |
| 12..15 | Spare | |

**Enable automatic generation of Lost Synchro. Diagnostic TM TC_ID K5xxx**

TID = 3
FID = 1
Param#1 =0 - disable, (default)
=1 - enable.

See chapter "Lost HSL Synchro. Diagnostic Telemetry" for further explanations.

**Energy Linearisation Table Setting TC_ID K5xxx**

TID = 4
FID = 44
Param #1 - starting address inside the table (accepted values: 0, 64, 128, 192)
Param #2..#65 - 64 values loaded into the table

For loading of a full table, which is 256 words long, four commands are needed. Each of the 256 values represents upper value of the corresponding energy channel. The numbers should be sorted in increasing order, last value should be equal to 4095. Loaded table becomes effective only after expansion - see the next command.

**Command - "Expand Energy Linearisation Table" TC_ID K5xxx**

TID = 4
FID = 45

To be effective the energy linearisation table must be expanded to another table - 4056 8-bit words long in which each entry represents energy channel number (0..255) assigned to an energy (0..4095).

**Set the Grey Filter TC_ID K5xxx**

TID = 4
FID = 43
Param #1 if in the range 0..31 - indication to the Grey Filter to be used,
if equal to FFFF[Hex] - means that DPE should set Grey Filter automatically (default)

**Set the parameters for automatic Grey Filter selection procedure TC_ID K5xxx**

TID = 4
FID = 46

| | | |
|---|---|---|
| Param #1 | - Extra Low Level | (default 5%) |
| Param #2 | - Normal Low Level | (default 20%) |
| Param #3 | - Normal High Level | (default 50%) |
| Param #4 | - Extra High Level | (default 80%) |

In the current algorithm (since IASW ver.1.27) the value of Extra Low Level is not used, but still must be set properly in the command.

**Set period of automatic generation of SW Diagnostic reports TC_ID K5xxx**

TID = 1
FID = 15
Param #1 - Period of generation of SW Diagnostic TM Packets expressed as a number of BCP1 periods (8 sec each).
If set to 0 (default) - no automatic reports will be produced.

**Set thresholds for Radiation Monitor Count Rates. TC_ID K5xxx**

TID = 1
FID = 17
Param #1 - Higher value (for rad.belts entering) of Radiation Monitor Count Rate #1
Param #2 - Lower value (for rad.belts exiting) of Radiation Monitor Count Rate #1
Param #3 - Higher value (for rad.belts entering) of Radiation Monitor Count Rate #2
Param #4 - Lower value (for rad.belts exiting) of Radiation Monitor Count Rate #2
Param #5 - Higher value (for rad.belts entering) of Radiation Monitor Count Rate #3
Param #6 - Lower value (for rad.belts exiting) of Radiation Monitor Count Rate #3

3.7.5.2.2 TC(5,4) - Report Task Parameters

| Header (3 words) | | | | |
|---|---|---|---|---|
| 00[Bin] | Chk-type | Ack=0000[Bin] | 5 | 4 |
| TID | | | FID | |
| Data Field (number of parameters depends on the TID and FID values) | | | | |

TIDs, FIDs and format in most cases are the same as for TC(5,3). Only SW parameters can be queried, no HW Settings Report is provided with use of TC(5,4). Actual HW Settings are reported in the housekeeping packets. As a response to TC(5,4) a TM(5,4) packet is generated. Normally one TC(5,4) generates one TM(5,4), there are two exceptions:
- SW Diagnostic (TM(5,4)/TID=1/FID=16) can be produced automatically with a programmed period,
- HSL Lost Synchro. Diagnostic (TM(5,4)/TID=3/FID=1) can be produced automatically as a response on the event of losing synchronization.

**Report DFEE's SW Integer Parameters Table**

Question: TID = 0
FID = 11

Answer: TID = 0
FID = 11
Param #1..#100 - Set of Integer Parameters (1 integer parameter = 1 word)

**Report DFEE's SW Float Parameters Table**

Question: TID = 0
FID = 12

Answer: TID = 0
FID = 12
Param #1..#200 - Set of Float Parameters (1 float parameter = 2 words)

**Report of the flag „Automatic Recovery Enable"**

Question: TID = 1
FID = 12

Answer: TID = 1
FID = 12
Param #1 - „Automatic Recovery Enable" flag (0=OFF, 1=ON)

**Report Operator overrides for Broadcast Packet data**

Question: TID = 1
FID = 18

Answer: TID = 1
FID = 18
Param#1 16 bit flags „Disable Check"
Param#2 16 bit flags „Error Condition"

**Report Operator overrides for mRTU data**

Question: TID = 1
FID = 19

Answer: TID = 1
FID = 19
Param#1 16 bit flags „Disable Check"
Param#2 16 bit flags „Error Condition"

**Get diagnostic dump of HSL input buffer**

Question: TID = 3
FID = 1

Answer: TID = 3
FID = 1
Param#1..205 - see chapter "Lost HSL Synchro. Diagnostic Telemetry"

**Report IASW Version:**

Question: TID = 1
FID = 11

Answer: TID = 1
FID = 11
Param #1 - Major part of the Version Number
Param #2 - Minor part of the Version Number

**Report the Grey Filter**

Question: TID = 4
FID = 43

Answer: TID = 4
FID = 43
Param #1 - indication to the Grey Filter actually used (range 0..31),

**Report the parameters for automatic Grey Filter selection procedure**

Question: TID = 4
FID = 46
Answer: TID = 4
FID = 46
Param #1 - Extra Low Level
Param #2 - Normal Low Level
Param #3 - Normal High Level
Param #4 - Extra High Level

**Report period of automatic generation of SW Diagnostic reports**

Question: TID = 1
FID = 15

Answer: TID = 1
FID = 15
Param #1 - Period of automatic generation of the SW Diagnostic reports

**Report thresholds for Radiation Monitor Count Rates.**

Question: TID = 1
FID = 17

Answer: TID = 1
FID = 17
Param #1 - Higher value (for rad.belts entering) of Radiation Monitor Count Rate #1
Param #2 - Lower value (for rad.belts exiting) of Radiation Monitor Count Rate #1
Param #3 - Higher value (for rad.belts entering) of Radiation Monitor Count Rate #2
Param #4 - Lower value (for rad.belts exiting) of Radiation Monitor Count Rate #2
Param #5 - Higher value (for rad.belts entering) of Radiation Monitor Count Rate #3
Param #6 - Lower value (for rad.belts exiting) of Radiation Monitor Count Rate #3

3.7.5.2.3 TC(5,5) - Mode Transition

| Header (3 words) | | | | |
|---|---|---|---|---|
| 00[Bin] | Chk-type | Ack=0000[Bin] | 5 | 5 |
| TID | | | FID | |
| Data Field (number of parameters depends on the TID and FID values) | | | | |

TC(5,5) is used to switch between states - the major actions of JEM-X. Format of this command provides a set of parameters (see IPSD). MODE (8-bit) codes the target state. Param.#1 (8-bit) and Params.#2..#5 (16-bit) are present or not, depending on the target state.

Target state = SAFE
MODE = 1

Target state = MEMORY OPERATIONS
MODE = 2

Target state = SETUP
MODE = 5

Target state = DATA TAKING
MODE = 10
Param #1 = 0 (not used)
Param #2 = Primary Format Code
Param #3 = Secondary Format Code
[ Param #4 = Grey Filter for switching to Secondary Format ]
[ Param #5 = Grey Filter for switching back to Primary Format ]

Parameters #4 and #5 are optional. Grey Filter threshold levels will remain unchanged if parameters are missing.
The Grey Filter thresholds should comply: Param#4 < Param#5.

Target state = CALIBRATION
MODE = 20
Param #1 = 0 (not used)
Param #2 = Number of events per calibration level

Target state = DIAGNOSTIC DUMP
MODE = 40
Param #1 = 0 (not used)
Param #2 = Number of events to be dumped

Target state = DATA TAKING (test data mode)
MODE = 11

When this state is commanded, the DFEE will be set in DATA TAKING and the DPE will let the event data on the HSL pass through to the telemetry without modifications. This data mode could be usefull also in-flight if anomalies occur in the instrument.

Target state = CALIBRATION (test data mode)
MODE = 21
Param #1 = 0 (not used)
Param #2 = Number of events per calibration level

Target state = DIAGNOSTIC DUMP (test data mode)
MODE = 41
Param #1 = 0 (not used)
Param #2 = Number of events to be dumped

For coding of Primary and Secondary Imaging Formats use numerical codes:

| Code of the Format | Format |
|---|---|
| 1 | Full Imaging |
| 2 | Spectral-timing |
| 3 | Restricted Imaging |
| 4 | Timing |
| 5 | Spectrum |
| 90 | Test |

3.7.5.2.4 TC(6,1) - Load Memory

| Header (3 words) | | | | |
|---|---|---|---|---|
| 00[Bin] | Chk-type | Ack=0000[Bin] | 6 | 1 |
| TID | | | FID | |
| Data Field (number of parameters depends on the TID and FID values) | | | | |

Program accepts only commands with MID=255, which is interpreted as DFEE RAM identifier. Load Memory commands are stored in DPE in order of occurrence. This information is used in the process of automatic recovering of interrupted data taking. There is also a TC(5,3)-Load DFEE Context, which loads all stored memory patches to DFEE.
See IPSD for further details.

3.7.5.2.5 TC(6,2) - Dump Memory

| Header (3 words) | | | | |
|---|---|---|---|---|
| 00[Bin] | Chk-type | Ack=0000[Bin] | 6 | 2 |
| TID | | | FID | |
| Data Field (number of parameters depends on the TID and FID values) | | | | |

The program accepts only commands with MID=255, which is interpreted as DFEE RAM identifier. Length of the dump is not limited to the TM packet size, one dump can cover the whole range of addresses - 8000..FFFF(Hex). DPE itself will decompose the long dump into a series of TM(6,2) packets.
See IPSD for further details.

3.7.5.2.6 TC(6,3) - Calculate Memory CRC

| Header (3 words) | | | | |
|---|---|---|---|---|
| 00[Bin] | Chk-type | Ack=0000[Bin] | 6 | 3 |
| TID | | | FID | |
| Data Field (number of parameters depends on the TID and FID values) | | | | |

Program accepts only commands with MID=255, which is interpreted as DFEE RAM identifier.
See IPSD for further details.

3.7.5.2.7 TC(9,1) - Report TM Packet Generation Status

| Header (3 words) | | | | |
|---|---|---|---|---|
| 00[Bin] | Chk-type | Ack=0000[Bin] | 9 | 1 |
| TID | | | FID | |
| Data Field (number of parameters depends on the TID and FID values) | | | | |

The following TM Packets can be controlled: TM(5,4), TM(6,2), TM(6,3), TM(9,1).
See IPSD for further details.

3.7.5.2.8 TC(9,4) - Enable Generation of Specific TM Packets
See IPSD for details.

3.7.5.2.9 TC(9,5) - Disable Generation of Specific TM Packets
See IPSD for details.

3.7.5.2.10 TC(13,1) - Test command
This is a No Operation Command. Its only action is incrementing of the counter of telecommands received.

3.7.5.2.11 TC(15,1) - Broadcast Packet
The Broadcast Packet (BCPKT) is analyzed as soon as it is received by DPE. Some specific content of the BCPKT can cause a so called "shutdown" - stopping of data taking. Automatic recovery of data taking is possible, but only if the flag "Automatic Recovery Enabled" is set.

The reaction to the On Target Flag is performed independently of the value of "Automatic Recovery Enabled" flag. See chapters: "Shutdown/Recovery scheme" and "Analysis of Eclipse and Radiation Belts Entry/Exit Times" for further details.

**Data Rate Share**. This value is used in the algorithm for calculating of the Grey Filter, used to moderate the JEM-X data rate.

**OTF-On Target Flag**.
The OTF is used in combination with the Pointing ID to determine the start of a new observation. We will recognize the acquicsition of a new target (distinct from any temporary flickering of the On Target Flag during a pointing) by the following logic: Whenever the (validated) On Target Flag makes a transition from zero to one the current value of the Pointing ID parameter in the Broadcast Packet will be compared with the Pointing ID value stored on the previous occasion of the On Target Flag zero-to-one transition. If the stored value and the current value of the Pointing ID is the same, no action will be taken by the IASW. If the values are different, then the DPE and the DFEE data buffers will be flushed and the new value of the Pointing ID will be stored for future reference.

**AOCS Mode**. When equal to IPM (Inertial Pointing Mode) - enables interpretation of OTF (as described above). For all other values the content of the OTF is ignored.

**AOCS Sub Mode**. Ignored.

**Radiation Monitor Count Rate (#1,#2,#3)**. If any of the three counters exceeds the TBD threshold (adjustable individually for each of them through a Load Task Parameter TC(5,3)(TID=1, FID=17)), it is interpreted as the entrance into the radiation belts. Exit from radiation belts is assumed when all counters are below thresholds. Thresholds defining exit from radiation belts will be lower than those defining entering into radiation belts (hysteresis). Interpretation of these data is affected by DRMC flag.
Entrance into the area of high radiation will result in stopping data taking in soft mode, switching off HV, and setting DFEE to Safe mode.

**DRMC-Disregard Radiation Monitor Count Rates**. Radiation Monitor Count Rates are considered valid only when DRMC=0 (Disregard Radiation Monitor Count Rates). Otherwise (DRMC=1) Radiation Monitor Count Rates are assumed low.

**ESAM-Emergency Safe Acquisition Mode**. Reaction on this signal as in case of high radiation.

**Instrument Imminent Switch-Off**. Data taking is stopped in soft mode, HV is turned off. Next DPE stores context of DFEE, to be able to recover data taking. DFEE is left in Safe state, waiting for turning off the low voltage supply.

**Ground Station Hand-Over Flag**. Ignored.

**Pointing ID**. Used in the On Target Flag logic as described above.

**Radiation Belts Crossing Start Time, Radiation Belts Crossing Exit Time and Eclipse Entry Time**. All valid time-type fields (not equal to zero) from BCPKT will be stored separately. The purpose is to have good data for comparison with the current OBT in case of interrupted connection Earth - S/C. Time-type data are recalculated at the very beginning from BCPKT format to 48-bit format. The program uses internally only 48-bit format coding for On Board Time.

Entrance into the radiation belt will result in stopping data taking in soft mode, switching off HV, and setting DFEE to SAFE.

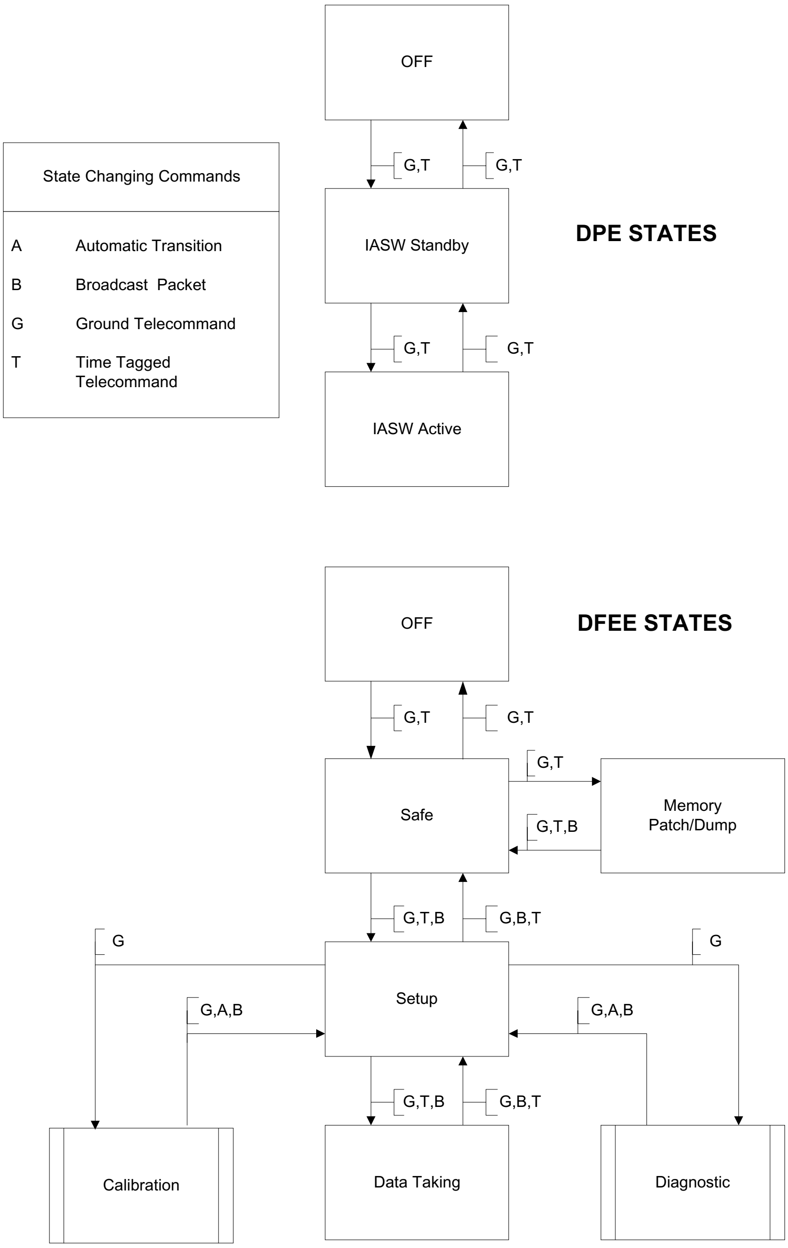
At exit from the radiation belt the DFEE state prior to the entry may be be restored autonomously - this assumes that the “Autonomous Recovery Flag has been set on - the default value for this flag is off.

When entering into eclipse region, data taking is stopped in soft mode and the HV is turned off. Next, the DPE stores the context of DFEE, to be able to recover data taking after the eclipse. The DFEE is left in SAFE state, waiting for the turn-off of the low voltage.

Recovery after eclipse exit takes place under ground control.

3.7.5.3 The JEM-X Operational States

The operational states for the JEM-X instrument and their interrelations are illustrated in the following flowchart.



## JEM-X State Tables

### DPE States

| Name | DPE Power | CSSW | IASW | DFEE power |
|---|---|---|---|---|
| OFF | OFF | - | - | OFF |
| IASW STANDBY | ON | Active | Inactive | OFF |
| IASW ACTIVE | ON | Active | Active | OFF/ON |

### DFEE States

| Name | DFEE power | DFEE S/W | High Voltage | Event Interrupt | Calib. Gener. |
|---|---|---|---|---|---|
| OFF | OFF | - | - | - | - |
| SAFE | ON | Active | OFF | OFF | OFF |
| MEMORY (DUMP/PATCH) | ON | Active | OFF | OFF | OFF |
| SETUP | ON | Active | ON/OFF | OFF | OFF |
| DATA TAKING | ON | Active | ON | ON | OFF |
| CALIBRATION | ON | Active | ON/OFF | ON | ON |
| DIAGNOSTIC | ON | Active | ON | ON | OFF |

## The JEM-X DFEE State-Changing Commands

| Name | Function | Prerequisites | TC-type | TC-subtype | Ground / Autonomous | Parameters | Comments |
|---|---|---|---|---|---|---|---|
| Low Voltage On | OFF to SAFE | DPE: IASW_ACTIVE DFEE temperature in limits | 5 | 5 | G+A | No | After Eclipse |
| State_SETUP | SAFE to SETUP | Outside radiation belts Rad. Monit. below limit | 5 | 5 | G+A | No | After [1]Eclipse or Radiation Belt Passage |
| State _DATA_TAKING | SETUP to DATA TAKING | Outside radiation belts Rad. Monit. below limit | 5 | 5 | G+A | No | After [1]Eclipse or Radiation Belt Passage |
| State_CALIBRATE | SETUP to CALIBRATE | Outside radiation belts Rad. Monit. below limit | 5 | 5 | G | 1: Number of events/level | |
| State_DATA_DUMP | SETUP to DIAGNOSTIC | Outside radiation belts Rad. Mont. below limit | 5 | 5 | G | 1: Number of events desired | |
| State_SETUP | DIAGN. or DATA TK. or CALIBR. to SETUP | None | 5 | 5 | G+A | No | Eclipse or Rad. Belt Entry Switch-off Imminent |
| State_MEMORY | SAFE to ME-MORY | None | 5 | 5 | G | No | |
| State_SAFE | SETUP to SAFE | None | 5 | 5 | G+A | No | Eclipse or Rad. Belt Entry Switch-off Imminent |
| Low Voltage Off | SAFE to OFF | None | 5 | 5 | G | No | |

### 3.7.6 TC parameter description

**List of DFEE integer software parameters** (number refers to position in int-parameter block)

0 to 33 Analog channel offset values
*A substantial voltage offset is imposed on each of 34 analog channels in order to be able to handle correctly the negative signals resulting from the use of the capacitive readout. These offset must be removed from the signals on-board before they can be used in the calculation of event positions*.

34 Calibration Frequency
*This parameter controls the frequency of the electronic calibration pulses.*

35 Anode upper limit
*The most important particle event rejection criterion is the upper limit for the anode pulse amplitude.*

36 High voltage Cut off count rate
*The count rate limit for software controlled High Voltage switch-off.*

**List of DFEE float software parameters** (number refers to position in float-parameter block)

0 Veto reject level
*The maximum allowable value for the ratio of the signal from the veto electrode to that of the anode (Anode Slow signal).*

1 Risetime high limit
*The maximum allowable value for the ratio of the signal in the Fast Anode chain to that of the anode (Anode Slow signal).*

2 Risetime low limit
*The minimum allowable value for the ratio of the signal in the Fast Anode chain to that of the anode (Anode Slow signal).*

3 Back plane high limit
*The maximum allowable value for the ratio of the sum of the signals from the backplane electrodes to that of the anode (Anode Slow signal).*

4 Back plane low limit
*The minimum allowable value for the ratio of the sum of the signals from the backplane electrodes to that of the anode (Anode Slow signal).*

5 Cathode high limit
*The maximum allowable value for the ratio of the signal from the veto electrode to that of the anode (Anode Slow signal).*

6 Cathode low limit
*The minimum allowable value for the ratio of the sum of the signals from the cathode electrodes to that of the anode (Anode Slow signal).*

7 Back plane low hit level
*The lower threshold for a back plane signal to be counted as a valid "hit".*

8 Back plane high hit level
*The upper threshold for a back plane signal to be accepted as a valid "hit".*

9 Back plane energy cut
*The upper threshold for the sum of the back plane signals.*

10 Cathode low hit level
*The lower threshold for a cathode signal to be counted as a valid "hit".*

11 Cathode high hit level
*The upper threshold for a cathode signal to be accepted as a valid "hit".*

12 Cathode energy cut
*The upper threshold for the sum of the cathode signals.*

13 to 47 Analog channel gain values
*Each of 34 analog channels will have a slightly different gain value. These gain differences must be removed from the signals on-board before they can be used in the calculation of event positions*.

All the above parameters are "Engineering" parameters which may need to be adjusted during the verification phase - but only in case of anomalies may they need readjustment later in the flight.

All Hardware parameters and single Software parameters are directly adjustable using TC(5,3) commands. Multiple adjustments af larger sets of parameters can be handled by the DFEE memory upload commands. DFEE memory upload commands are, however, not in accordance with the PSD as these commands are not memory load commands proper. The DFEE memory is only accessible through commands via the DPE.

The only HW or SW parameters controlled for every observation are the Primary and Secondary data formats. All other parameters can be considered static after initial adjustment during the commissioning phase.

### 3.7.7 TM Packet Structure and Content

3.7.7.1 TM allocation management

The JEM-X software will seek to optimize the usage of the available telemetry. The DPE IASW will interrogate the Broadcast Packet for the current TM allocation. Nominally, the TM allocation is 18 packets per polling cycle in total for the two JEM-X instruments early in the mission (at solar maximum conditions) and 16 packets per cycle later in the mission (at solar min). Each JEM-X instrument will transmit one HK-packet per polling cycle as long as the corresponding DPE is powered on, but otherwise the two instruments may be set up with different packet rates as long as the total allocation is respected.

The packet length is 440 bytes. The packet header occupies 6 bytes and the terminating CRC occupies 2 bytes. This leaves 432 bytes or 216 words per packet for the data field.

Prior to a new observation each JEM-X unit will be given a telemetry allocation and also instructed about which telemetry formats to use. The typical situation will be that both units are requested to use the "Full Imaging Format" as the primary format. Then, as the secondary format, which will be used if the count rate exceeds what can be handled in the full format, one unit may be set up to use "Restricted Imaging", the other "Spectral Timing". Should the count rate exceed also the capacity of the secondary format, then the grey filtering process will be activated.

**Grey Filtering**

If the input data rate exceeds the rate at which data can be transmitted the DPE software will autonomously select an alternative format or, if the telemetry capacity problem persists for the alternative format, activate the "grey filtering" event rejection process in the DFEE, whereby a certain fraction of the DFEE input triggers are rejected. The grey filter process can operate with 32 different transmission fractions. The 32 filters are numbered from 0 to 31, and the filter transmission fraction, $F$, is calculated as:

$F = (N+1) / 32$

where $N$ is the filter number.

3.7.7.2 Format for time stamping of the telemetry packets.

Time information is given at the beginning of each packet. A 40 bit format is used beginning in bit 8 of the first word. The least significant bit (of the third word) is counting in units of 1/65536 s. In this way the least significant bit of the second word will be counting in units of 1 s, making the format compatible in this respect with a standard, two-word, data field header.

The precision of the timing of the individual X-ray events in JEM-X is 1/8192 s. Therefore the least significant 3 bits of the 40 bit time should be considered as spare bits and are not to be used in the data analysis.

<table>
<tr><td colspan="5">Packet Header</td></tr>
<tr><td>Version no. [3]</td><td>type [1]</td><td>fla g [1]</td><td colspan="2">APID [11]</td></tr>
<tr><td>sequ.fl.[2]</td><td colspan="4">sequence count [14]</td></tr>
<tr><td colspan="5">packet length [16]</td></tr>
<tr><td colspan="5">Data Field Header</td></tr>
<tr><td>packet type [4]</td><td colspan="2">subtype[4]</td><td colspan="2">Note: NONSTANDARD time [8] (unit 65536 s)</td></tr>
<tr><td colspan="5">time [16] (unit 1 s)</td></tr>
<tr><td colspan="4">time [13] (unit 1/8192 s)</td><td>spare [3]</td></tr>
<tr><td colspan="5">Data Field</td></tr>
<tr><td colspan="5">data 215*[16]</td></tr>
</table>

JEM-X Science-TM packet header layout with nonstandard Data Field Header.

3.7.7.3 Full Imaging Format

APID: 110 0100 1000 [Bin], =1608 (JEM-X unit 1)
110 1100 1000 [Bin], =1736 (JEM-X unit 2)

In the Full Imaging Format each event is described in two (or three) words:

| X position bits 0-7 | Y position bits 8-15 | Energy bits 0-7 | Delta time relative to prev. event. (The value 255 is a flag, indicating that an extra word follows). bits 8-15 | Delta time extension (Only present if 8 bits are insufficient) |
|---|---|---|---|---|
| 8 bits | 8 bits | 8 bits | 8 bits (time unit 1/8192 s) | (16 bits) **Note 1** |

**Full Imaging Format**

| # | Content | Word | Bit pos | Length bits | Comment |
|---|---|---|---|---|---|
| 1 | Type Subtype = 0000 1000 [Bin] | 0 | 0 | 8 | |
| 2 | OBT of 1.st event | 0 | 8 | 40 | format: see 3.7.7.2 |
| 3 | No. of events in packet | 3 | 0 | 16 | Variable event format ! |
| 4 | Grey filter # for first event in packet. | 4 | 0 | 16 | **Note 2** |
| 5 | Event data ( - 105 events) | 5-215 | 0 | 3676 | |
| 6 | CRC | 216 | 0 | 16 | Provided by CSSW |

**Note 1.** *If two events are separated by more than 8 s then the delta-time cannot be described in 16 bits. In this case the timing information for the remaining events in this packet will be lost. The delta time extension will contain FFFF[Hex].This situation should only occur when the data stream from the DFEE for one reason or another stops for a period. If no events have been received for a full Housekeeping-cycle the unfilled packet will be transmitted. This will be the situation when the data transmission from the DFEE to the DPE has terminated completely.*
**Note 2.** *If a change of Grey filter occurs in the middle of a packet the position of the change will be indicated by inserting a marker event (a grey filter change report) with the X and Y positions equal to zero (this cannot happen for a real event) and with the new grey filter number taking the place of the energy value in the upper 8 bits of the second word. The lower 8 bits of the second word shall contain the normal delta-time information. These marker events are included in the event count indicated in the packet header.*

3.7.7.4 Restricted Imaging Format

APID: 110 0101 1000 [Bin] =1624 (JEM-X unit 1)
110 1101 1000 [Bin] =1752 (JEM-X unit 2)

The restricted imaging format may be used when the count rate exceeds the value which can be transmitted using the full imaging format. In this format the timing information for the individual events is discarded. As compensation, count rate packets will be generated whenever the restricted imaging format is in use. The countrate packet is described in section 3.7.7.5.

When the restricted imaging format is in use, about 2580 events (TBC) are collected in a buffer in the DPE. The events in the buffer are sorted according to their position in the image, using as a key the integer value: 256X+Y. (Both X and Y are scaled to the range 1 to 255).

The image data are then transmitted in 8 TM-packets. For the first event in each packet the full X/Y position is given, and for the following events only the distance between event positions in the 65536 position array. The delta-positions are encoded in 5 bits. In cases where the 5 bits do not suffice, an additional 8 bit word is added. (Note that the value 31 in the 5 bit delta position is not a delta-value but a flag indicating that an ekstra 8 bit word follows). If even the 8 bit extension does not suffice to bridge the gap to the next event position a second, 16-bit extension word will be used.

For each event a 3 bit energy value is also given. The 3 bit energy values are derived from the 8 bit values used in the full imaging and spectral-timing formats.

**Event format in Restricted Imaging**

| Delta position ( ) ) | Energy | Delta pos. extension ( ) ’) Only present if 5 bits does not suffice. ( ) is set to 31) | 2. Delta position extension Only present if 8 bits does not suffice. ( ) ’ is set to 255) |
|---|---|---|---|
| 5 bits | 3 bits | (8 bits) | (16 bits) |

A timeout function for the collection of the 2580 events (TBC) needed for one image will be initiated whenever data collection for a new image is started. If, after 32 seconds, less than the required number of events has been collected, the available image data will anyway be transmitted. This function assures that we do not wait indefinitely transmitting the last part of the data if the event data stream from the detector or from the DFEE is interrupted. Under normal circumstances the restricted imaging will only be invoked when the countrate exceeds the capacity of the full imaging format, - 100 counts/s.

**Restricted Imaging Format**

| # | Content | Word | Bit pos | Length bits | Comment |
|---|---|---|---|---|---|
| 1 | Type Subtype=0001 1000 [Bin] | 0 | 0 | 8 | |
| 2 | OBT of first event in image | 0 | 8 | 40 | OBT format: see 3.7.7.2 |
| 3 | Length of time interval covered by image | 3 | 0 | 16 | precision: 1/2048 s |
| 4 | No. of events in packet | 4 | 0 | 16 | |
| 5 | Grey filter, first event in image. | 5 | 0 | 16 | **Note 1** |
| 6 | Grey filter, last event in image | 6 | 0 | 16 | **Note 1** |
| 7 | XY pos for first event in packet. | 7 | 0 | 16 | 8 bits X pos +8 bits Y pos. |
| 8 | XY pos for last event in packet. | 8 | 0 | 16 | 8 bits X pos +8 bits Y pos |
| 9 | Sequence # of packet in image (8000[hex] added for last packet) | 9 | 0 | 16 | |
| 10 | Event data ( - 320 events) | 10-215 | 0 | 3296 | |
| 11 | CRC | 216 | 0 | 16 | Provided by CSSW |

**Note 1.** *There is no way to indicate in this Restricted Imaging Format which events in the image have been recorded with a specific greyfilter value. However, in the corresponding countrate packet the time-evolution of the grey filter values can be followed.*

3.7.7.5 Count Rate Format

APID: 110 0111 1000 [Bin] = 1656 (JEM-X unit 1)
110 1111 1000 [Bin] = 1784 (JEM-X unit 2)

The countrate format cannot be used by itself. It will be automatically invoked when the restricted imaging or one of the two spectral formats are required. The countrate packets will appear in between the packets of the invoking format.Each time bin is 125 ms wide.

In order to assure that the time bins in a count rate packet always align with other data (spectra transmitted in spectral format and time bins in other count rate packet blocks) the time bins will always begin when the DFEE time counter has zeroes in the lower 10 bits. This happens every 125 ms. The DFEE time counter is reset via a logic based on the BCP2 pulse, and therefore there will be a fixed relation between the OBT and all time bin start times.

**Countrate Format**

| # | Content | Word | Bit pos | Length bits | Comment |
|---|---|---|---|---|---|
| 1 | Type Subtype = 0011 1000 [Bin] | 0 | 0 | 8 | |
| 2 | OBT of first time bin | 0 | 8 | 40 | format: see 3.7.7.2<br>Lower 14 bits always 0! |
| 3 | 8 greyfilter specifiers (see below) | 3 | 0 | 128 | |
| 4 | # of time bins in this packet | 11 | 0 | 16 | . |
| 5 | Count rate in first time bin | 12 | 0 | 16 | |
| 6 | Delta-count rates (see text) | 13-215 | 0 | 3248 | |
| 7 | CRC | 216 | 0 | 16 | Provided by CSSW |

The delta-countrates in the packet are coded into 8 bits (-127 to +126 with negative numbers in two-complement notation). If 8 bits does not suffice for a particular time bin, then a marker of +127 is placed in the first 8 bit followed by the full 16 bit countrate (not the difference!). The 16 bit value is placed in the buffer without any gap, even if it is not word aligned.

**Format for greyfilter specifiers**

| Bit pos | Length (bits) | Content |
|---|---|---|
| 0 | 5 | Greyfilter number |
| 5 | 11 | Time bin number in packet where greyfilter takes effect<br>The time bin number will allways be zero for the first specifier.<br>The subsequent specifiers are only valid if time bin number is nonzero |

3.7.7.6 Spectral Timing Format

APID: 110 0101 0000 [Bin] = 1616 (JEM-X unit 1)
110 1101 0000 [Bin] = 1744 (JEM-X unit 2)

In this format the imaging data for each event are discarded. The format is only suited for observations where one, strong source dominates the scene. The time difference between events are encoded in 8 bits. If that happens to be insufficient a value of 255 is given in the 8 bits and a full 16 bit word is added to encode the time difference. The energy information is encoded in 8 bits.

**Event format in Spectral/Timing**

| Energy | Delta time (0 to 254) | Delta time extension.<br>(If the delta time is larger than 254 ) |
|---|---|---|
| 8 bits | 8 bits (time unit 1/8192 s) | (16 bits) |

**Spectral/Timing Format**

| # | Content | Word | Bit pos | Length bits | Comment |
|---|---|---|---|---|---|
| 1 | Type Subtype = 0001 0000[Bin] | 0 | 0 | 8 | |
| 2 | OBT of first event | 0 | 8 | 40 | format: see 3.7.7.2 |
| 3 | No. of events in packet | 3 | 0 | 16 | No. of events is variable due to variable event format |
| 4 | Grey filter # for first event | 4 | 0 | 16 | **Note 1** |
| 5 | Event data ( - 210 events) | 5-215 | 0 | 3376 | |
| 6 | CRC | 216 | 0 | 16 | Provided by CSSW |

**Note 1.** *If a change of Grey filter occurs in the middle of a packet the position of the change will be indicated by inserting a marker event with an energy value of zero and the new grey filter number will be inserted in place of the Delta time. Such marker events will be included in the event count indicated in the packet header.*

3.7.7.7 Timing Format

APID: 110 0110 0000 [Bin] = 1632 (JEM-X unit 1)
110 1110 0000 [Bin] = 1760 (JEM-X unit 2)

In this format only the timing data for each event is retained. The format is only suited for observations where one, strong source dominates the scene. The time difference between events are encoded in 6 bits. If that happens to be insufficient a value of 63 is given in the 6 bits and a full 16 bit word is added to encode the time difference. It is inconvenient to mix the 6-bit and the 16 bit data items. We have therefore chosen to place the 16-bit delta-time extensions at the end of the packet data field - they will be placed in reverse order, so the first extension is placed in word 215, the next in word 214 and so on.

Note that up to 20 bits of each packet will be left unused. A count rate data item will not be inserted if there is less than 22 bits free in the packet as there would then be insufficient space to store a possible delta-time extension.

**Event format in Timing**

| Delta time (Time unit =1/8192 s) | Delta time extension. (Only present if 6 bits does not suffice) These will be placed in reverse order at the rear of the packet. In this way we avoid to break the sequence of 6 bit values used for normal delta times. |
|---|---|
| 6 bits | (16 bits) |

**Timing Format**

| # | Content | Word | Bit pos | Length bits | Comment |
|---|---|---|---|---|---|
| 1 | Type Subtype = 0010 0000 [Bin] | 0 | 0 | 8 | |
| 2 | OBT of first event | 0 | 8 | 40 | format: see 3.7.7.2 |
| 3 | No. of events in packet | 3 | 0 | 16 | No. of events is variable due to the variable event format |
| 4 | Grey filter # for first event in packet. | 4 | 0 | 16 | **Note 1** |
| 5 | Event data ( - 550 events) | 5-215 | 0 | 3376 | |
| 6 | CRC | 216 | 0 | 16 | Provided by CSSW |

**Note 1.** *Changes in the grey filter cannot be guaranteed to happen only at packet boundaries. But if a change occurs in the middle of a packet the position of the change will be indicated by inserting a marker event with a Delta time equal 63 and a Delta time extension word equal to FFE0[Hex] plus the number of the new grey filter. This would correspond to a Delta time of more than 8 seconds which is extremely unlikely to occur since this format will only be used at event rates well in excess of 100 counts/s. Such marker events will be included in the event count indicated in the packet header.*

3.7.7.8 Spectrum Format

APID: 110 0110 1000 [Bin] = 1640 (JEM-X unit 1)
110 1110 1000 [Bin] = 1768 (JEM-X unit 2)

In this format only the energy information is transmitted. The format is only suited for observations where one, strong source dominates the scene. Spectra with 64 energy channels are transmitted at a rate of 8 spectra per second. The 6-bit channel numbers are derived from the 8 bit energy value used in the Full Imaging format by masking away the lower two bits. The 125 ms integration time intervals are aligned with the time bins used in the Count Rate format (see 3.7.7.5).

The content of each of the 64 spectral channels are allocated 4 bits in this format. Should a channel contain more than 14 counts the 4-bit value will be set to 15, and the full count value (truncated to 8 bits if necessary) will be placed in the next free 8 bit overflow field of this spectrum block.

**Spectrum Format**

| # | Content | Word | Bit pos | Length bits | Comment |
|---|---|---|---|---|---|
| 1 | Type Subtype = 0010 1000 [Bin] | 0 | 0 | 8 | |
| 1 | OBT of start of first spectrum | 0 | 8 | 40 | format: see 3.7.7.2 |
| 2 | # of spectra in packet | 3 | 0 | 16 | May be less than 10 for last packet. |
| 3 | Spectrum Block #1 | 4 | 0 | 336 | |
| 4 | Spectrum Block #2 | 25 | 0 | 336 | |
| 5 | Spectrum Block #3 | 46 | 0 | 336 | |
| 6 | Spectrum Block #4 | 67 | 0 | 336 | |
| 7 | Spectrum Block #5 | 88 | 0 | 336 | |
| 8 | Spectrum Block #6 | 109 | 0 | 336 | |
| 9 | Spectrum Block #7 | 130 | 0 | 336 | |
| 10 | Spectrum Block #8 | 151 | 0 | 336 | |
| 11 | Spectrum Block #9 | 172 | 0 | 336 | |
| 12 | Spectrum Block #10. | 193 | 0 | 336 | |
| 23 | CRC | 216 | 0 | 16 | Provided by CSSW |

**Format for each spectrum block**

| # | Content | Word | Bit pos | Length bits | Comment |
|---|---|---|---|---|---|
| 1 | Grey filter for first event in spectrum | 0 | 0 | 16 | |
| 2 | 64 channel energy spectrum (4 bits/ch) | 1 - 16 | 0 | 256 | |
| 3 | 8 overflow fields (8 bits each) | 17 - 20 | 0 | 64 | |

3.7.7.9 Calibration Format

APID: 110 0100 0001 [Bin] = 1601 (JEM-X unit 1)
110 1100 0001 [Bin] = 1729 (JEM-X unit 2)

In this format all the 34 ADC read-outs from the JEM-X detector analog chains are transmitted as raw values. Marker events are used in this format to signal new values for the calibration amplitude and for the "Events per step" parameter. These "amplitude marker events are included in the calibration data packets. The amplitude marker events events are flagged by a value of "0xFFFF" for the slow anode signal and a value of "3" for the fast anode signal. The new calibration amplitude value is given in place of the Veto signal, and the number of events per amplitude step instead of the first of the Backplane signals. Another type of "dummy" event is used if needed as a filler for the last calibration data packet. These filler events have "0xFFFF" for the slow anode signal and "1" for the fast anode signal.

**Event Format for Calibration**

| # | Content | Word | Bit pos | Length bits | Comment |
|---|---|---|---|---|---|
| 1 | delta OBT rel. to first event in packet | 0 | 0 | 16 | precision: 1/8192 s |
| 2 | Slow Anode signal | 1 | 0 | 16 | |
| 3 | Fast Anode signal | 2 | 0 | 16 | |
| 4 | Veto signal | 3 | 0 | 16 | |
| 5 | 20 x Backplane signals | 4-23 | 0 | 320 | |
| 6 | 11 x Cathode signals | 24-34 | 0 | 176 | |

**TM-Format for Calibration**

| # | Content | Word | Bit pos | Length bits | Comment |
|---|---|---|---|---|---|
| 1 | Type Subtype = 0000 0001 [Bin] | 0 | 0 | 8 | |
| 2 | OBT of 1.st event | 0 | 8 | 40 | format: see 3.7.7.2 |
| 3 | Calibrator amplitude | 3 | 0 | 16 | |
| 4 | Events per amplitude step | 4 | 0 | 16 | |
| 5 | Anode switch status | 5 | 0 | 16 | in bits 12-15 |
| 6 | Data for 6 events | 6-215 | 0 | 3360 | |
| 7 | CRC | 216 | 0 | 16 | Provided by CSSW |

3.7.7.10 Diagnostic Dump Format

APID: 110 0100 0010 [Bin] = 1602 (JEM-X unit 1)
110 1100 0010 [Bin] = 1730 (JEM-X unit 2)

In this format all the 34 ADC read-outs from the detector analog chains are given as raw values. In addition the result of the DFEE analysis: i.e.the rejection cause or the final "Full Imaging Format" data.

**Event Format for Diagnostics**

| # | Content | Word | Bit pos | Length bits | Comment |
|---|---|---|---|---|---|
| 1 | HK cycle counter | 0 | 0 | 16 | prec: 8 s |
| 2 | DFEE timer value | 1 | 0 | 16 | prec: 1/8192 s |
| 3 | Slow Anode signal | 2 | 0 | 16 | |
| 4 | Calculated Back Plane position | 3 | 0 | 16 | |
| 5 | Calculated Cathode position | 4 | 0 | 16 | |
| 6 | Calculated Risetime | 5 | 0 | 16 | |
| 6 | Slow Anode signal | 6 | 0 | 16 | |
| 7 | Fast Anode signal | 7 | 0 | 16 | |
| 8 | Veto signal | 8 | 10 | 16 | |
| 9 | Backplane signals (20) | 9 | 0 | 320 | |
| 10 | Cathode signals (11) | 29 | 0 | 176 | |
| 11 | Processing status word | 40 | 0 | 16 | 0 if accepted<br>1 to 10 if rejected,<br>(see following text) |
| 12 | Calibration X-ray event marker:<br>FFFF[Hex]: Not a calibration event, 0-3: Calibration event | 41 | 0 | 16 | Marks event from one out of four calibration sources |

The low byte of the “Processing Status” is zero for an accepted event and can take on the following following values according to the rejection cause for rejected events:

1: High Anode signal
2: High Veto value ( / Veto signal / Slow Anode signal)
3: Low Risetime value (Risetime / Fast Anode signal / Slow Anode signal)
4: High Risetime value
5: Too many its in Back Plane
6: Too many hits in Cathode Plane
7: Too high value of Back Plane ratio ( / Back Plane signal / Slow Anode signal)
8: Too low value of Back Plane ratio
9: Too high value of Cathode ratio ( / Cathode signal / Slow Anode signal)
10: Too low value of Back Plane ratio

The high byte of this word is reserved for indication of possible alternative event processing routes.

**TM-Format for Diagnostic**

| # | Content | Word | Bit pos | Length bits | Comment |
|---|---|---|---|---|---|
| 1 | Type/Subtype = 0000 0010 [Bin] | 0 | 0 | 8 | |
| 1 | OBT of 1.st event | 0 | 8 | 40 | format: see 3.7.7.2 |
| 2 | Spare | 3 | 0 | 32 | |
| 4 | Anode Switch Status | 5 | 0 | 16 | in bits 12-15 |
| 4 | Event data (5 events) | 5-214 | 0 | 3360 | |
| 5 | CRC | 216 | 0 | 16 | Provided by CSSW |

3.7.7.11 DPE Memory Dump Format

APID: 110 0000 0110 [Bin] = 1542 (JEM-X unit 1)
110 1000 0110 [Bin] = 1670 (JEM-X unit 2)

The detailed format is determined by CSSW.

3.7.7.12 DFEE Memory Dump Format

APID: 110 0000 0110 [Bin] = 1542 (JEM-X unit 1)
110 1000 0110 [Bin] = 1670 (JEM-X unit 2)

The detailed format is determined by CSSW.

Memory dumps from the DFEE will be routed via a designated area in the DPE memory.

3.7.7.13 Housekeeping Telemetry

The Housekeeping TM packet contains three parts: the IASW HK part, the On Event Messages and the CSSW HK part. This chapter describes the IASW part of the HK packet. In general it consists of four blocks of information:
- Variables describing the state of IASW,
- DPE housekeeping - readouts from analog input lines,
- Latest DFEE housekeeping,
- Latest BCPKT block.

| Start (byte.bit#) | Size (bits) | Content |
|---|---|---|
| State of IASW | | |
| ADDR1=0 | 16 | EVENT SIZE (0, 5, 36 or 42) |
| ADDR1+2 | 8 | ACTUAL SHUTDOWN LEVEL |
| ADDR1+3 | 8 | WANTED SHUTDOWN LEVEL |
| ADDR1+4 | 8 | PRIMARY FORMAT |
| ADDR1+5 | 8 | SECONDARY FORMAT |
| ADDR1+6 | 16 | ACTIVE FORMAT (=1 - primary, =2 - secondary) |
| ADDR1+8 | 8 | COMMANDED GREY FILTER |
| ADDR1+9 | 8 | USED GREY FILTER |
| ADDR1+10 | 16 | HSL BUFFER SIZE (number of words actually in the buffer) |
| ADDR1+12 | 16 | HSL BUFFER INDEX (position of taking data from the buffer) |
| ADDR1+14 | 16 | TIME SINCE READOUT (time in units of 8s from the last HSL readout) |
| ADDR1+16 | 16 | EVENTS TRANSFERRED (no of events received in last BCP1 period) |
| ADDR1+18 | 8 | HSL SYNC. STATUS (nonzero when synchronization is lost) |
| ADDR1+19 | 8 | HSL READ ACTIVE (nonzero when DPE wants to read HSL) |
| ADDR1+20 | 16 | EVENTS IN BUFFER (number of events stored in the DPE's buffer) |
| ADDR1+22 | 32 | TOTAL EVENTS (total number of events read) |
| ADDR1+26 | 16 | MEMORY PATCHES (number of DFEE mem. patches stored in DPE) |
| ADDR1+28 | 48 | PARAMETERS OBT (time of last modification of DFEE's parameters) |
| ADDR1+34 | 16 | Spare#1 = 16#1111# |
| mRTU Housekeeping | | |
| ADDR2=36 | 16 | ANA8 - Detector pressure #1 |
| ADDR2+2 | 16 | ANA9 - Detector pressure #2 |
| ADDR2+4 | 16 | ANA10 - Detector temperature, TH8 |
| ADDR2+6 | 16 | ANA11 - Detector temperature, TH9 |
| ADDR2+8 | 16 | ANA0 - Voltage +5V Digital supply |
| ADDR2+10 | 16 | ANA1 - Current +5V Digital supply |
| ADDR2+12 | 16 | ANA2 - Voltage +5V Analog supply |
| ADDR2+14 | 16 | ANA3 - Voltage -5V Analog supply |
| ADDR2+16 | 16 | ANA4 - Voltage +12V |
| ADDR2+18 | 16 | ANA5 - Current +12V |
| ADDR2+20 | 16 | ANA6 - Voltage -12V |
| ADDR2+22 | 16 | ANA7 - Current -12V |
| ADDR2+24 | 16 | Connector J01Temperature TH0 |
| ADDR2+26 | 16 | CPU Board Temperature TH1 |
| ADDR2+28 | 16 | LVPS Cooling Bridge Temperature TH2 |
| ADDR2+30 | 16 | DDHK Board Temperature TH3 |

| | | |
|---|---|---|
| ADDR2+32 | 16 | Motherboard at ANOD Connector Temperature TH4 |
| ADDR2+34 | 16 | Motherboard at ANA2 Board Temperature TH5 |
| ADDR2+36 | 16 | ANA12 - FIFO Flag |
| ADDR2+38 | 16 | ANA13 - HV Power Supply Temperature, TH7 |
| ADDR2+40 | 16 | ANA14 - HV Power Supply Temperature, TH8 |
| ADDR2+42 | 16 | ANA15 - Spare |
| ADDR2+44 | 16 | Spare#2 = 16#7777# |
| DFEE Housekeeping | | |
| ADDR3=82 | 16 | HK Cycle Counter |
| ADDR3+2 | 16 | DFEE State |
| ADDR3+4 | 8 | Low Level Discriminator |
| ADDR3+5 | 8 | Anode configuration |
| ADDR3+6 | 16 | HV Acc. Voltage |
| ADDR3+8 | 16 | HV Drift Voltage |
| ADDR3+10 | 4 | HV Drift Setting |
| ADDR3+10.4 | 12 | HV Acc. Setting |
| ADDR3+12 | 16 | # of Event Triggers |
| ADDR3+14 | 16 | # of Accepted Events |
| ADDR3+16 | 16 | # of Events rejected by grey filter |
| ADDR3+18 | 16 | # of Events rejected due to lack of buffer space |
| ADDR3+20 | 16 | # of Events rejected due to FIFO full |
| ADDR3+22 | 16 | # of Events rejected by upper threshold |
| ADDR3+24 | 16 | # of Events rejected by Veto Signal |
| ADDR3+26 | 16 | # of Events rejected by Low Risetime |
| ADDR3+28 | 16 | # of Events rejected by High Risetime |
| ADDR3+30 | 16 | # of Events rejected by Too Many Hits in Back Plane |
| ADDR3+32 | 16 | # of Events rejected by Too Many Hits in Cathode Plane |
| ADDR3+34 | 16 | # of Events rejected by Too High Signal in Back Plane |
| ADDR3+36 | 16 | # of Events rejected by Too Low Signal in Back Plane |
| ADDR3+38 | 16 | # of Events rejected by Too High Signal in Cathode Plane |
| ADDR3+40 | 16 | # of Events rejected by Too Low signal in Cathode Plane |
| ADDR3+42 | 16 | Calibration spectrum partition number |
| ADDR3+44 | 32 x 16 | 32 words of calibration spectrum |
| ADDR3+108 | 4 x 4 | 4 bits wrap for #of Event Triggers<br>4 bits wrap for #of Events rejected by grey filter<br>4 bits wrap for #of Events rejected by Too High Signal in Back Plane<br>4 bits wrap for #of Events rejected by Veto Signal |
| ADDR3+110 | 16 | Hardware Trigger Counter (Also enabled when DFEE is in SETUP state) |
| ADDR3+112 | 16 | Spare#3 = 16#AAAA# |
| BCPKT Packet | | |
| ADDR4=196 | 34 x 16 | (see [5] for description of Broadcast Packet format) |
| ADDR4+68 | 16 | Spare#4 = 16#FFFF# |
| State of IASW (continuation) | | |

| | | |
|---|---|---|
| ADDR5=266 | 16 | 16 bit flags:<br>bit#0 - debugging flag "Don't use LSL"<br>bit#1 - debugging flag "Don't use analog signal Half FIFO Full"<br>bit#2 - debugging flag "Don' use HSL"<br>bit#3 - debugging flag "Don't reject telecommands because of wrong state"<br>bit#4 - debugging flag "Don't disregard HSL data in case of error"<br>bit#5 - debugging flag "Do automatic reset of serial module after HSL_FIFO_FULL_ERROR"<br>bit#6..10 - not used,<br>bit#11 - flag "Buffer Locked",<br>bit#12 - semaphore for Big Buffer,<br>bit#13 - flag “Auto Recovery Enabled”<br>*bit#14 - Super-User Mode,*<br>*bit#15 - arm flag for Super-User command,* |
| ADDR5+2 | 16 | Counter of OEMs rejected because of filtering, |
| ADDR+4 | 16 | DFEE State expected in IASW, |
| ADDR+6 | 16 | 16 bit flags "Disable Check" for BCPKT |
| ADDR+8 | 16 | 16 bit flags "Error Condition" for BCPKT |
| ADDR+10 | 16 | 16 bit flags "Disable Check" for mRTU |
| ADDR+12 | 16 | 16 bit flags "Error Condition" for mRTU |
| ADDR+14 | 8 | Counter of activity of Task MAIN |
| ADDR+15 | 8 | Counter of activity of Task TC |
| ADDR+16 | 8 | Counter of activity of Task HSL |
| ADDR+17 | 8 | Counter of activity of Task SC_OUT |
| ADDR+18 | 8 | Counter of activity of Task DFEE_HK |
| ADDR+19 | 8 | Counter of activity of Task MRTU |
| ADDR+20 | 8 | Counter of activity of Task REQ_OUT |
| ADDR+21 | 8 | Counter of activity of Task STATE |
| | | |
| Total = 288 | | |
| Max = 290 | | |

3.7.7.14 On Event Message Telemetry

Each On Event Message occupies 5 words in the Housekeeping TM Packet.

| Start (word# . bit#) | Size (bits) | Content |
|---|---|---|
| 0 . 0 | 32 | Time |
| 2 . 0 | 6 | Field#1 |
| 2 . 6 | 2 | Class (0-Event, 1-Exception, 2-Major anomaly, 3-Failed TC Report) |
| 2 . 8 | 8 | Identifier |
| 3 . 0 | 16 | Field#2 |
| 4 . 0 | 16 | Field#3 |

Identifier specifies a group of messages. For more detailed specification whithin the group Field#1 is used. The two fields - Identifier and Field#1 together forms Message Cathegory. The idea of cathegory is important because of filtering of OEMs generation. For each of the possible cathegories the time of last issue is stored. Next, if there is a request of generation of the OEM of a given cathegory, coming from inside the IASW part of program, the time is checked and too frequent generation is blocked. OEM of a given cathegory can be issued again only 10 seconds after the previous one. Fields#2 and #3 carry some additional informations, specific to the cathegory of OEM. They are equal to 0 when not used.

| Ident. | Field#1 | Class | Description |
|---|---|---|---|
| Group - Telecommand rejected<br>Field #2 - TC packet header (contains packet counter in bits 3-15)<br>Field #3 - TC packet header:<br>bits 0-7: spare = 0<br>bits 8-11: packet type<br>bits 12-15: packet subtype | | | |
| 128 | 1 | Failed TC Report | Wrong field TYPE or SUBTYPE |
| 129 | 2 | Failed TC Report | Wrong field TID or FID |
| 130 | 3 | Failed TC Report | Wrong field MID |
| 131 | 4 | Failed TC Report | Wrong field ADDRESS |
| 132 | 5 | Failed TC Report | Wrong field LENGTH or wrong length of the TC itself |
| 133 | 6 | Failed TC Report | Some other errors in the text of TC |
| 134 | 7 | Failed TC Report | DPE is busy - TC input queue is full |
| 135 | 8 | Failed TC Report | HW Command illegal because of shutdown in progress |
| 136 | 9 | Failed TC Report | State change illegal because of shutdown in progress |
| 137 | 10 | Failed TC Report | Execution started but failed |
| 138 | 31 | Failed TC Report | Wrong command „Set Super-user priv.” (fire without arm)<br>(Fields #2 and #3 are not used) |
| Group - Problems with HSL | | | |
| 151 | 1 | Major anomaly | Overflow |
| 158 | 8 | Major anomaly | CRC error |
| 159 | 9 | Major anomaly | Timeout |
| 154 | 11 | Event | Loss of synchronization |

| Ident | field#1 | Class | Description |
|---|---|---|---|
| Group - Problems with LSL<br>Field #2 - indicator word of the command<br>Field #3 - indicator word of the answer | | | |
| 161 | 1 | Major anomaly | Overrun |
| 162 | 2 | Event | Framing error |
| 163 | 3 | Event | Parity error |
| 169 | 9 | Event | Timeout |
| Group - Problems with Analog Acquisition | | | |
| 175 | 5 | Major anomaly | Error |
| 177 | 7 | Major anomaly | Busy |
| 179 | 9 | Major anomaly | Timeout |
| Group - Problems with communication with DFEE | | | |
| 180 | 0 | Major anomaly | Unexpected answer from DFEE<br>Field#2 - indicator word of the command<br>Field#3 - indicator word of the answer |
| 181<br>..<br>185 | 1 .. 5 | Event | Request Acknowledge with the code 1..5<br>Field#2 - indicator word of the command<br>Field#3 - indicator word of the answer |
| 186 | 6 | Event | Request Acknowledge with some other code<br>Field#2 - indicator word of the command<br>Field#3 - Request Acknowledge Code |
| 188 | 8 | Event | CRC error<br>Field#2 - indicator word of the command<br>Field#3 - indicator word of the answer |
| 189 | 9 | Event | Unexpected DFEE state reported in HK<br>Field#2 - expected state<br>Field#3 - reported state |
| 190 | 10 | Event | Discontinuity in DFEE HK Cycle Counter<br>(possibly DFEE reset)<br>Field#2 - expected CC,<br>Field#3 - reported CC. |
| 191 | 11 | Event | “Load DFEE Context” unsuccessfull - CRC check failed |
| Group - Problems with BCP1 | | | |
| 201 | 1 | Major anomaly | BCP1 shorter than 7.5 sec |
| 202 | 2 | Major anomaly | No BCP1 after 8.5 sec |
| Group - Unexpected behaviour of IASW<br>Field#2 contains id# of the task issuing the OEM | | | |
| 211 | 1 | Exception | Unexpected exception |
| 212 | 2 | Major anomaly | Problems with buffer software |
| 213 | 3 | Major anomaly | Problems with TC queue software |
| 214 | 4 | Major anomaly | Problems with storing patches of DFEE’s RAM in the DPE |
| Group - Unexpected behaviour of CSSW<br>Field#2 contains id# of the task issuing the OEM | | | |
| 221 | 1 | Exception | Unexpected exception |
| 222 | 2 | Major anomaly | No RTC events |
| Group - Events when autonomous action of IASW | | | |

| | | | |
|---|---|---|---|
| 231 | 1 | Event | Shutdown initiated<br>Field#2 - actual level<br>Field#3 - target level |
| 232 | 2 | Event | Shutdown failed<br>Field#2 - actual level<br>Field#3 - target level |
| 233 | 3 | Event | Recovery initiated<br>Field#2 - actual level<br>Field#3 - target level |
| 234 | 4 | Event | Recovery failed<br>Field#2 - actual level<br>Field#3 - target level |
| 235 | 5 | Event | New pointing - restart of data mode<br>Field #2 and #3 - New Pointing ID |
| 239 | 9 | Event | Super-user mode initiated |
| Group - Problems with Telemetry<br>Field#2 contains APID of TM Packet which is source of problems | | | |
| 240 | 1 | Event | TM Packet lost |

3.7.7.15 Software Diagnostic Telemetry

SW Diagnostic is generated on request in form of TM(5,4)/TID=1/FID=16. It can also be produced periodically in the same form.

This TM packet contains set of counters of events, which are interesting for diagnostic ot the software. Each issue of this report clears the counters, so each report shows counts made between reports.

| Start (word#) | Events counted |
|---|---|
| Group - TC | |
| 0 | Constant 16#1111# |
| 1 | Received TC |
| 2 | Corrupted TC |
| 3 | Rejected TC |
| 4 | Timeout when reading TC |
| 5 | Timeout of BCP1 |
| 6 | BCP1 too short |
| 7 | No RTC |
| Group - ADC | |
| 8 | Constant 16#2222# |
| 9 | ADC readout |
| 10 | ADC error |
| 11 | ADC busy |
| 12 | ADC timeout |
| Group - LSL | |
| 13 | Constant 16#3333# |
| 14 | Command sent |
| 15 | LSL error |
| 16 | CRC eror |
| 17 | LSL timeout |
| 18 | Aborted communication request |
| Group - HSL | |
| 19 | Constant 16#4444# |
| 20 | HSL readout |
| 21 | CRC error |
| 22 | HSL timeout |
| 23 | HSL overflow |
| 24 | HSL lost synchronization |
| 25 | Constant 16#5555# |

3.7.7.16 Lost HSL Synchronization. Diagnostic Telemetry

This diagnostic TM is generated on request in form of a TM(5,4)/TID=3/FID=1. It can also be produced automatically at each synchronization loss. The automatic mode can be enabled/disabled using a TC(5,3)/TID=3/FID=1. By default the automatic mode is off.

The content of the diagnostic TM packet shows a fragment of HSL input buffer, where a loss of synchronization was encountered.

| Word # | Content |
|---|---|
| 0 | Event size+1 (6, 37, or 43).<br>(+1 is because in HSL buffer each event record is preceeded by the Event Marker = F000). |
| 1 | Number of words in the HSL input buffer. Usually it is about 4096. |
| 2 | Buffer index, pointing to the place, where synchronization was lost.<br>Buffer is indexed starting with 0. |
| 3 | Offset of the dump. This shows the place in the HSL buffer where the dump start. |
| 4..203 | Dump of a fragment of HSL input buffer - up to 200 words. |

This diagnostic TM is produced from the data stored in a dedicated buffer, in which the HSL buffer is latched, when a synchronization loss occur on the HSL. Initially this buffer is empty, so there is no sense to ask for it before observing On Event Message informing about a loss of HSL synchronization.

### 3.7.8 TM parameter description

Refer to the SDB.

### 3.7.9 CPU and memory budget

DPE CPU MA31750A

Usage: 65% of 80 kword ROM
20 % of 2 Mword RAM

DFEE CPU MA31750A

Usage: 60% of 8 kword ROM
75 % of 32 kword RAM

### 3.7.10 JEM-X Autonomous Functions

3.7.10.1 Hardware Autonomous Functions

3.7.10.1.1 DFEE Undervoltage Protection

A protection circuit will inhibit the DFEE Low Voltage Converters from starting up until the input voltage exceeds 22 V. The same circuit will also switch off the power converters if the input voltage sinks below 18.5 V after the power converters have been started up. This circuit is incorporated to prevent excessive currents to be drawn through the supply line filters.

The undervoltage protection mechanism cannot be inhibited.

3.7.10.1.2 JEM-X High Voltage Switch-Off by Internal Ratemeter

A hard wired ratemeter will switch off the high voltage to the JEM-X detector if the trigger counts exceeds 65535 over an 8 second period.

The ratemeter sensitivity is adjustable through the setting of the discriminator providing the input for the ratemeter (and the event trigger signal for instrument). This ratemeter will function even if the DFEE is in the SETUP state, since it is the raw trigger signals which are counted, not the processed triggers.

The disappearence of the high voltage will be detected by the DFEE software, which will report the HV-status to the DPE at the next transfer of the DFEE housekeeping data. The DPE IASW will then set the DFEE to the SAFE state.

Autonomous recovery will not be invoked following a internal ratemeter induced switch off.

The hardware switch-off mechanism can be inhibited.

3.7.10.2 Software Autonomous Functions

3.7.10.2.1 JEM-X High Voltage Switch-Off by Software Ratemeter

A software ratemeter will switch off the high voltage to the JEM-X detector if the processed trigger counts exceeds a predefined limit (default value 32767) over an 8 second period. Note that this ratemeter is only active when the DFEE is in the Normal Data Taking mode.

The ratemeter sensitivity is adjustable through the choice of the limiting count and the setting of the discriminator providing the input for the instrument event trigger. The Grey Filter value does not affect the software ratemeter sensitivity.

The DFEE software will report the high count condition to the DPE at the next transfer of the DFEE housekeeping data. The DPE IASW will then set the DFEE to the SAFE state.

Autonomous recovery may be invoked following a software ratemeter induced switch off.

The software switch-off mechanism can be inhibited.

3.7.10.2.2 Autonomous Transition to DFEE SAFE state (shut-down) according to Broadcast Packet

The DPE IASW will set the DFEE to the SAFE state when the Broadcast Packet indicates this to be necessary, such as at Radiation Belt Entry, Eclipse Entry, Radiation Monitor count rates out of range or Satellite Emergencies (ESAM, Instrument Switch-off Imminent).

A copy of the parameter values used by the DFEE is always kept in the DPE memory, to assure a full recovery of the current DFEE state following a power switch-off.

DFEE Autonomous recovery may be invoked following a Broadcast Packet induced transition to SAFE.

3.7.10.2.3 Autonomous Recovery from a shut-down.

The DPE IASW may restore the working state of the DFEE to a previously existing state when the condition causing the shut-down has disappeared. This includes the restoration of the detector high voltage values to their previous values. During this recovery any updates to the DFEE software which are available in the DPE will be implemented before setting the high voltage and, possibly, the transfer to the Normal Data Taking mode.

3.7.10.2.4 Change of format for the Science Telemetry

The JEM-X science telemetry will be allowed to switch between two different telemetry formats according to the instantaneous count rate - actually, according to the degree of filling of the Large Data Buffer in the DPE.

3.7.10.2.5 Grey Filter adjustment

The event rate which can be transmitted through the JEM-X telemetry allocation is very limited, and we will frequently encounter situations where more events are recorded than can be tranmitted. We will then try to adjust an unbiased filtering mechanism (the Grey Filter) so as to achieve a stable situation with the Large Data Buffer in the DPE about half full.

3.7.10.2.6 Autonomous termination of DFEE CALIBRATION mode.

The CALIBRATION mode of the DFEE is self terminating, after a defined number of events the DFEE will revert to the SETUP mode.

3.7.10.2.7 Autonomous termination of DFEE DIAGNOSTIC mode.

The DIAGNOSTIC mode of the DFEE is self terminating, after a defined number of events the DFEE will revert to the SETUP mode.

# 3.8 GSE Interfaces

### 3.8.1 Mechanical GSE

N/A

### 3.8.2 Electrical GSE

3.8.2.1 Hardware

The Electrical Ground Support Equipment is designed to be flexible in the way it will be configured for the following stages of JEM-X instrument development and checkout. Three major test configurations are planned:
-for instrument development and calibration - Level A,
-for DPE software development and stand-alone checkout - Level B,
-to support integration and final testing - Level C.

3.8.2.2 LEVEL A - Instrument development and manufacturing.

The EGSE at this level is mainly devoted to support the instrument development (hardware and DFEE software) phase. For development the instrument is connected to the EGSE instead of to the DPE and spacecraft PDU and/or RTU units, as shown in Figure cxxii.

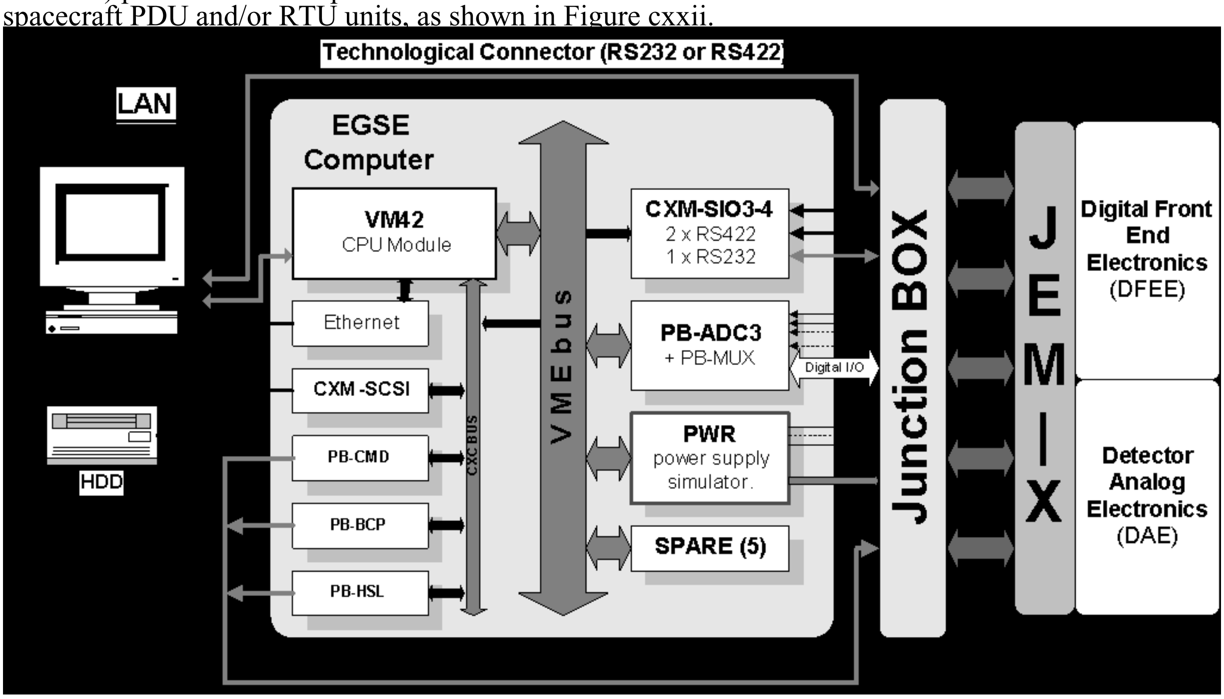



Figure 21 Level A EGSE architecture block diagram

Depending of each phase of testing the standard computer platform ( VME ) can be configured with various additional boards such as:

1. CXM-SIO3-4 board ( Serial Line Interface Simulator)

The serial interface simulator support bi-directional synchronous/asynchronous data transmissions using balanced digital voltage interface (RS-422). Two kind of links are simulated:
-low-speed link, to provide a rate up to 64 Kbit/sec.
-technological links (two serial ports: RS-422 and RS-232)

2. PB-HSL board (High-Speed Link simulator)

The uni-directional synchronous serial interface simulator receives data from the instrument at a rate of up to 5 Mbit/sec transmission rate using balanced digital voltage interface (RS-422).

3. PB-ADC3 and PB-MUX boards ( Analogue & Thermistor HK channels)These boards are providing Housekeeping data acquisition and monitoring functions. Both, the DPU and the RTU acquisition lines are simulated.
- 16 analogue inputs ( res. 12 bit ),
- 16 Thermistor YSI 44908 channels.

4. PB-CMD board (Discrete command lines)

The TC pulse generation controller and associated electrical interface for generation of High Power Telecommand On/Off pulses. The four separate lines are simulated. To facilitate verification of instrument interfaces it is possible to set an amplitude and pulse period to its maximum, normal and minimum values.
Specifications:
Number of lines: 4
Pulse Amplitude: 12 - 16 [V]
Pulse Width: 10 - 20 [ms]
Imax 300 [mA]

5. PB-BCP (DPE Timing Lines simulator).

The timing line simulator consists of four lines as this ones issued from DPE. Timing interface provides:
INST_CLK 4.19 MHz clock
BCP1 8 Hz timing pulses
BCP2 1 Hz timing pulses
CLK8N 1/8 Hz timing pulses

6. PWR module ( Power supply simulator).

This module is responsible for the provision of all power to the instrument or heater as would be provided by flight PDU. For his purpose PWR module consists of a programmable controlled DC/DC converter with current limiting and over-voltage protection. The PWR module is equipped with a built-in self test procedure.
Features of the PWR module:
Output power : 40 W (max.).
Output voltage: 24 - 32 V ( nom. 28V)
Load current: 1.2 A (max.)
Output current and voltage monitoring (resolution 8bit)
Spare hardware slots are available to allow extra instrument interfaces and system modules to be incorporated without design impact. Each interface simulator includes its own servicing task to allow for flexible configuration and fast software upgrade.

### 3.8.2.3 LEVEL B - Instrument integration, calibration and testing.

This level is required to verify the complete instrument parameters fields, including the worst test conditions and final calibrations.
Additionally, the EGSE in this configuration will be used for DPE software development and debugging.
The INTEGRAL SIS" is also planned to be used at this level. Figure cxxiv shows the EGSE architecture

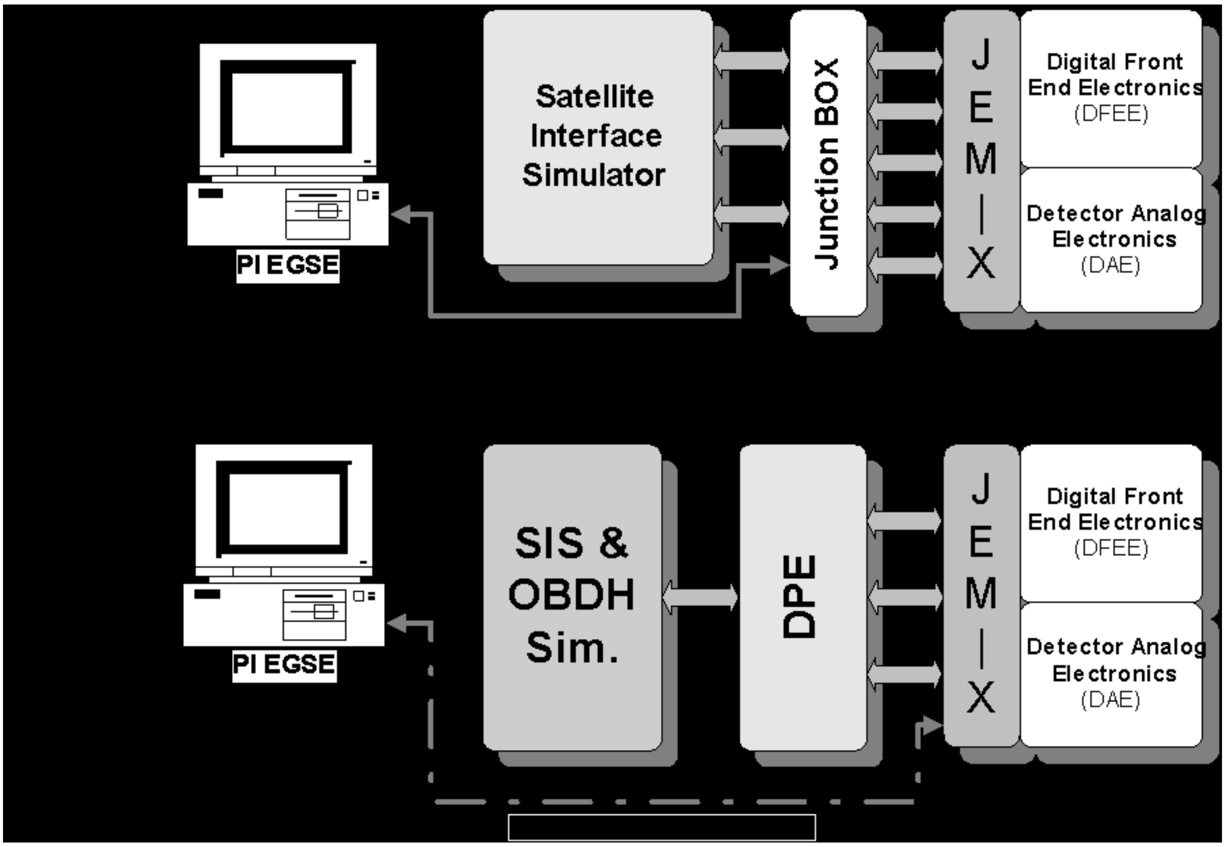



Figure 22 Level B JEM-X EGSE configurations

.

Two stages of testing configuration are planned:
a) - JEM-X will be connected to DPE simulator
b) - JEM-X will be connected to DPE

Final tests before delivery will be performed in configuration "B".

3.8.2.4 LEVEL C - S/C integration.

At the integration test level the EGSE will be mainly aimed to verify the compatibility of subsystems and capability of the instrument to perform the pre-programmed operations.
It is expected that the EGSE will be able to support:

- preparing and sending commands to instrument (via MAIN EGSE subsystem),

- receiving and storing down link telemetry data (via MAIN EGSE using LAN connection),
- monitoring of the on board HK parameters contained in telemetry data, e.g. acquisition, comparison against references and reporting.
- monitoring and on line presentation of the DFEE HK parameters ( via technological connector)

It is planned that up to the final stage of integration tests both instruments will be connected to EGSE using the technical connections e.g. galvanic isolated RS-422/RS-232 serial link.
The EGSE will be designed in such a way that any failure in any test configuration will never propagate to the item under test.

3.8.2.5 Software.

The EGSE software has been written in high order programming language. The "C" and "C++" object oriented language has been used. However, some part of software, like drivers, handlers, act. was written in assembler language.The programs used in various EGSE configurations consists of two main parts:

1. "OS/9 part" running on powerful VME-bus computer PEP-VM42 (Motorola 68040 CPU + 68360).
2. "Windows part" running on PENTIUM CPU based PC.

The "OS/9 Part" perform all necessary real time processing relevant to the I/O boards (interface simulators). An application software is built by a number of concurrent tasks in charge of performing the following functions:

1. I/O VME modules set-up - perform the set-up of the I/O simulators modules according to the command sent by operator's test sequence.
2. Real-time processing - perform all necessary real time processing relevant to I/O modules

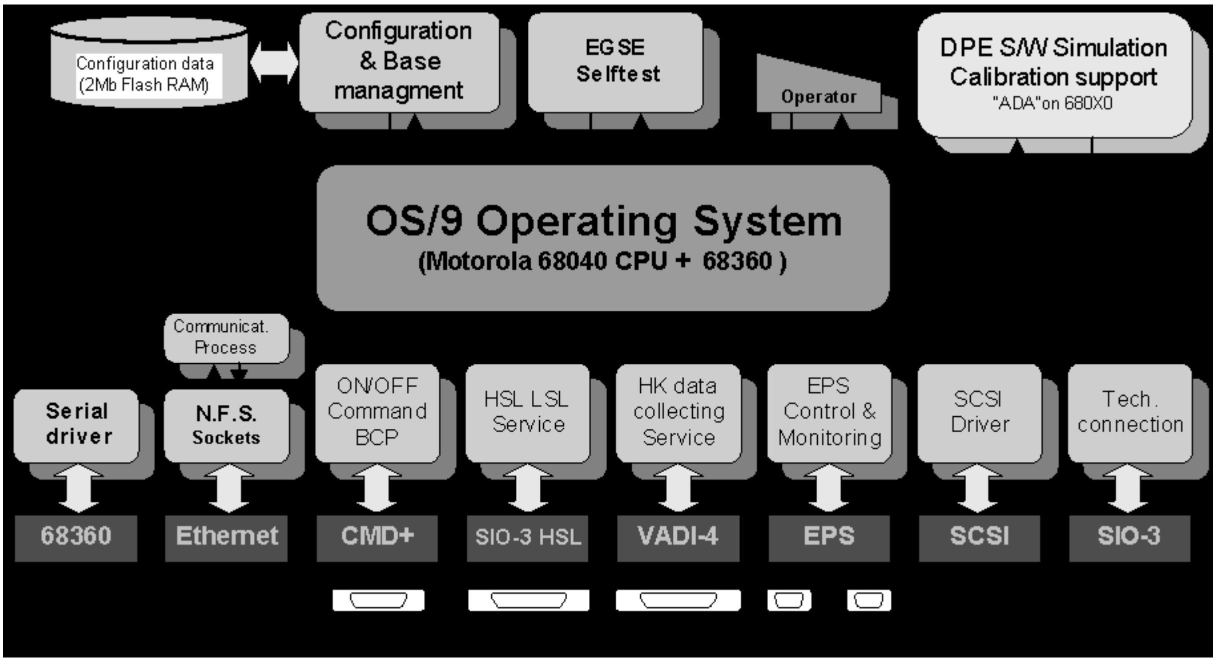



Figure 23 EGSE software structure (OS/9 part)

data acquisition (HK channels scanning), data time-stamping, interface health monitoring, correlation of acquired data to dedicated responses (alarm events triggering), data blocks collecting and pre-formatting.
3. Host Computer(s) interfacing - perform the interface with the Host Computer(s) via serial direct connection and/ or LAN interface according to TCP/IP protocol logical link. Communication process in order to acquire set-up commands, transmits to the host data, simulator status and error messages.
Figure cxxv shows the software logical structure of this part and its relations with hardware .

The "Windows part" is based on a common Basic Software Platform (DOS / Windows / Windows NT) and provides the following main task:
1. Graphical User Interface All operation performed by user (operator) can be done like in the other regular "Windows" applications. All test results are displayed with techniques optimised for human perception (e.g., tables, colour graphic pictures, histograms, diagrams, bar graph, act.)
2. Tests preparation end execution. The specialised script language has been written. The built-in interpreter allows the operator to run prepared test sequence.
3. Data Monitoring and Displaying. A dedicated HK Channels Database set-up facility allowing the operator to easily describe the data channel sets that will be monitored. When test results exceeds predefined values an event alarm is displayed. (numerical and graphical presentation)
4. Data archiving (calibration and test data ), The data received from tested instrument can be

stored at run-time.

5. Test results presentation and report generation. It will be possible to produce all test related documents on the system, directly accessing or including data and graphics produced during the test process. (Instrument Data and EGSE Event log Database).

6. Data Base Management,

7. Instrument Development Support, (technical connection)

8. "OS/9 platform" Communication,

9. EGSE self-test and diagnostic, The basic checkout kernel for each testing level will carry out subsystem or module main test (answer: GOOD or FILED). Only in case of detection of errors (or operator request) detailed testing or calibration procedures (and/or child processes) will be performed.

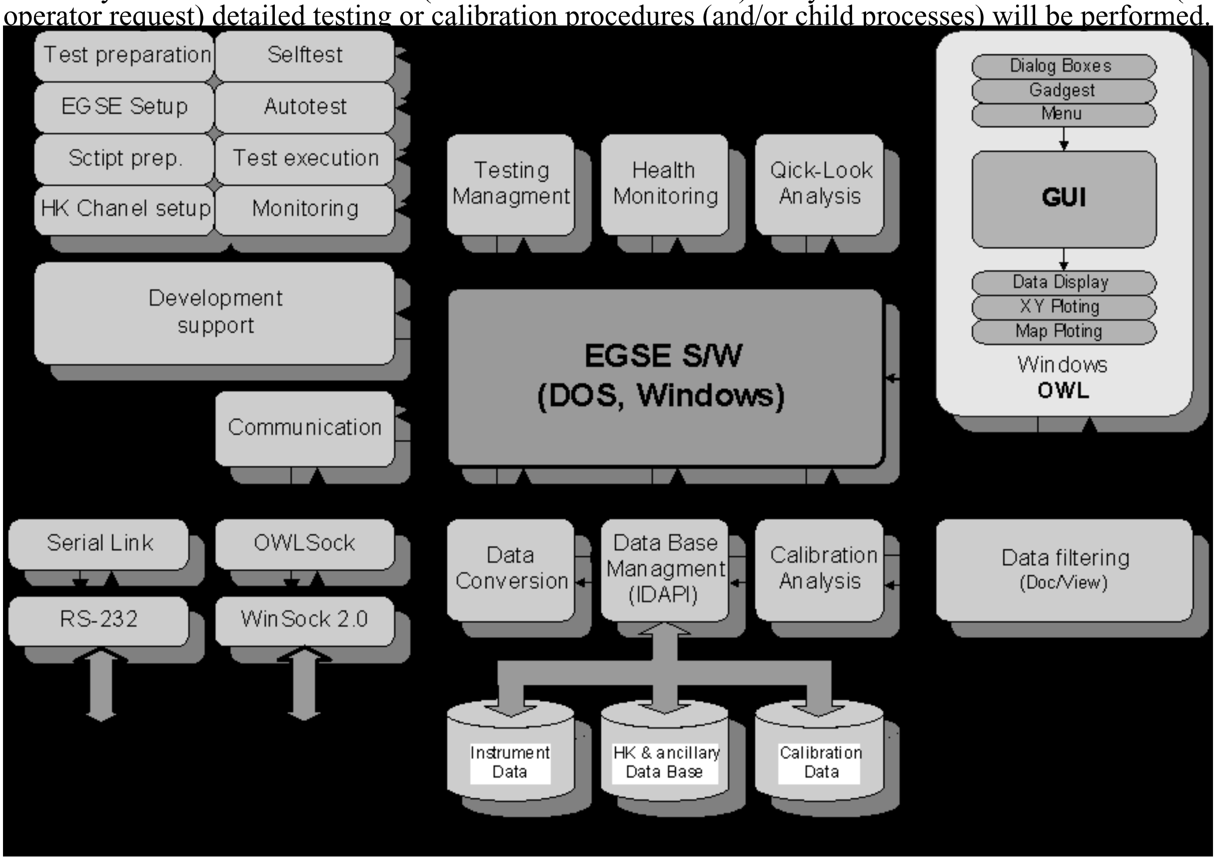



Figure 24 EGSE software structure (IBM/PC - "Windows" part)

The software will be structured such that it could be adapted to several testing levels. Functions which needs flexible adaptation during the test will be changeable without S/W recompilation. The general view of this part of EGSE software structure is shown on Figure cxxvi

## 3.9 ISSW - Instrument specific software

The ISSW is the software to handle the instrument specific parts of the data. The software shall be installed at the ISDC, following the ISDC requirements. The software development will follow PSS-05.

The software is briefly described in the following. It is described in more detail in the separate documents for the User Requirements (ISDC-URD), the Logical Model (ISDC-LMD) and the Architectural Design Document (ADD). The software will be documented according to PSS-05.

Parts of the following developments will be done by the ISDC.

### 3.9.1 Instrument health monitoring

The health monitoring software will examine the House Keeping HK data stream. The process will be automatic, and will be able to alert the operator in case of faults detected. The process will run at the Mission Operation Centre (MOC) and the software will be developed by the MOC according to specifications provided by the Instrument Team. The issues will at least be:

- conversion of HK parameters to physical units
- examination of HK parameters for excess of threshold settings.
- possibility to display HK parameters through interactive control, or automatic, if an alert (outside threshold) has arisen.
- produce alert to operator if alert flag is set.
- examination of status of execution of telecommands.

### 3.9.2 Instrument performance monitoring

The performance monitoring software will provide a deeper analysis of the telemetry stream for the purpose of monitoring the scientific and technical performance of the instrument. It will use both the House Keeping data stream, event data from the calibration sources included in the science telemetry, and it will use data from previous observations. This combination will give a more complete description of the instrument performance than the health monitoring and will allow looking for transients on different timescales.

Events from the on-board calibration sources will be used for a continuous calculation of gain and response, by collecting the spectra from each calibration source in the HK data strem.

The process will be automatic, and will be able to alert the operator in case of alarming trends. The issues will at least be:

- conversion of HK parameters to physical units
- examination of HK parameters for excess of threshold settings.
- examination of gain and response obtained from a continuous calibration (see Preprocessing)
- examination of internal calibration source, gain monitoring
- examination of changes in performance parameters compared to previous observations
- possibility to display of HK and calibration parameters through interactive control, or automatic, if an alert (outside threshold) has arisen.
- produce alert to operator if alert flag is set.
- store performance parameters as part of instrument history.
- determination of internal calibration source spectra, gain history

### 3.9.3 Preprocessing software

The JEM-X preprocessing software (removal of instrument signatures) will at least cover the following issues:

- bad event examination
- position linearization
- gain variation correction
- energy channel linearization
- energy calibration

- detector efficiency correction

Further, the pre-processing software shall estimate the background

- output in FITS events format (OGIP "standard", eg. RDF format).

### 3.9.4 Quick Look analysis

The QL software will run on all of the JEM-X data to monitor that the scientific goals of the observation is met, and to check that that the objects at which the observation was aimed are actually in the field of view. It will also allow observers to detect interesting astronomical events in the field of view. The software will probably resemble the Standard Analysis software, but will use simpler algorithms when possible and fewer bins in histograms to provide faster display of results. It is expected, that the ISDC provides tools for displaying the images. The software will at least cover the following issues:

- quick image reconstruction
- image storing in FITS files using available auxiliary information.
- background determination.
- quick source position determination.
- quick timing analysis
- quick spectral analysis
- comparison with simulation if applicable

Some of these issues are not relevant for all instrumental modes.

### 3.9.5 Standard analysis software

The Standard Analysis software will run on all of the JEM-X software and will produce a set of standard data products to be delivered to the observer with the raw data. The software will contain many of the elements of the Quick Look analysis, but possibly use a higher number of bins and the optimal algorithms when applicable:

- image reconstruction with refined image reconstruction in areas of interest
- image storing in FITS files using auxiliary information.
- background determination.
- background modeling
- source position determination
- source identification using sky catalogues
- timing analysis
- spectral analysis and spectral modeling of sources in field of view

Some of these issues are not relevant for all instrumental modes.

The timing and spectral analysis is only possible to the extend where images are still possible to construct. The requirements are at least several hundred counts/s for the source in question. In case the source is dominating all other point sources, the system can be analysed as a usual collimated detector.

Having produces lightcurves, spectra or images, it is assumed that already existing software packages will be used for detailed analysis.

### 3.9.6 Simulation software

The JEM-X simulation software package is available in a preliminary form. The package will contain the following:

estimating software

- estimates of count-rates, using eg. PIMMS similar software detailed simulation
- Monte-Carlo ray-tracing
- storage of simulated shadowgrams in FITS files (event files).
- Production of files to simulation runs of software, both ISDC relevant software and ESOC simulator software (see 3.9.7).

### 3.9.7 Simulation files

The JEM-X team will produce the sets of files specified in general terms in EID-A section 7.5.3.3. The set will be split in files according to mode.

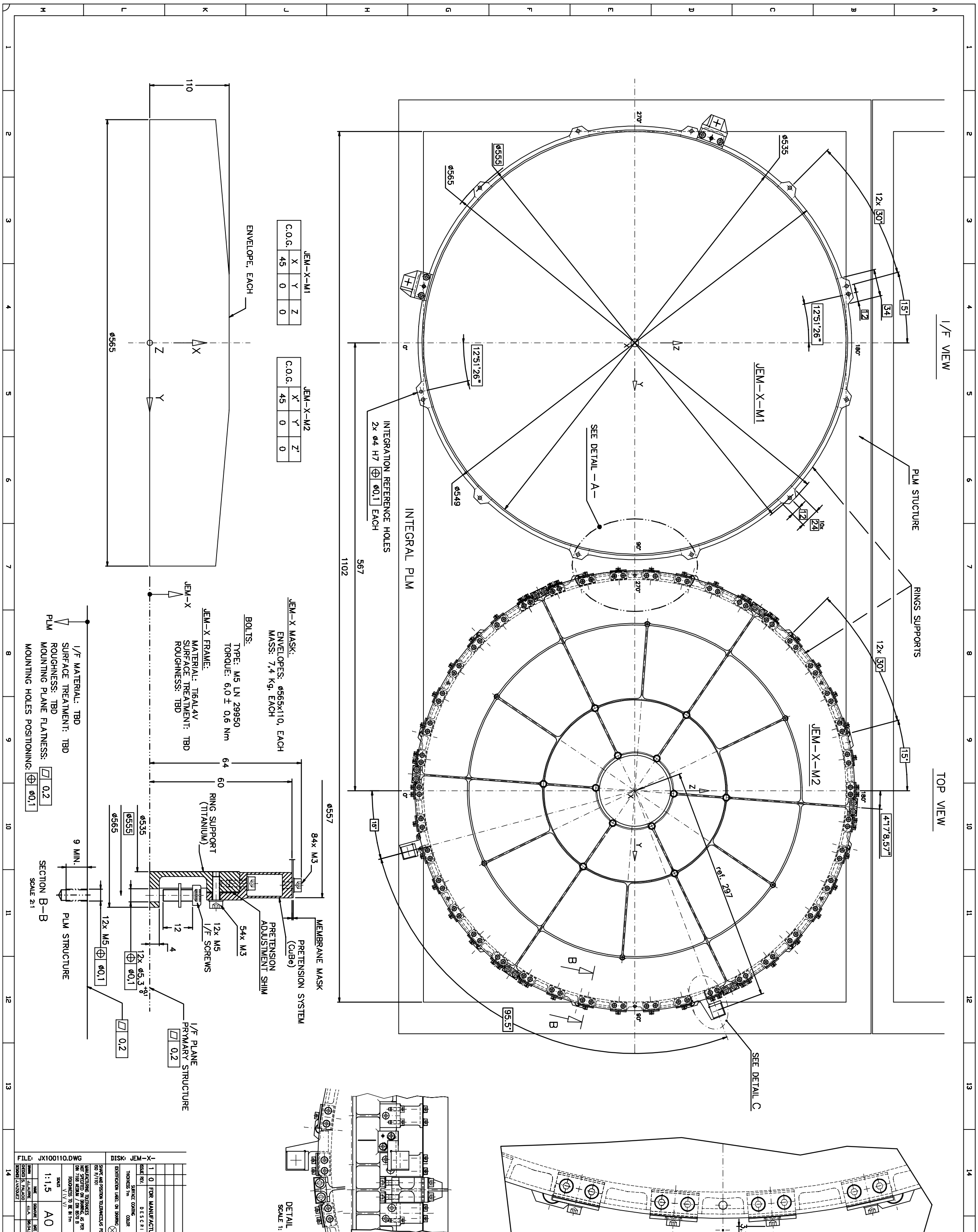
# APPENDIX A

**Mechanical Interface Control Document (MICD) according DRD-42-1.**

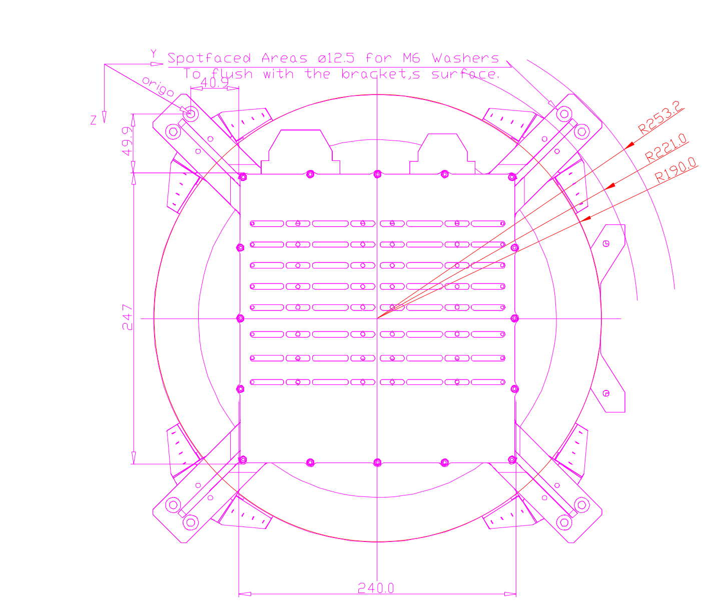
The drawings can also be downloaded in PDF format from the DSRI JEMX FTP server as:

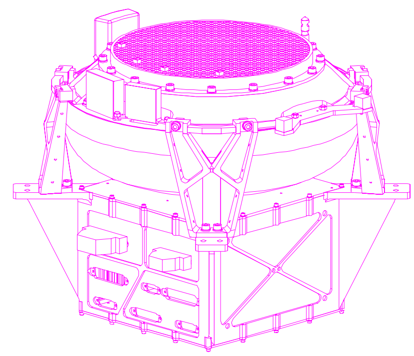
| | |
|---|---|
| j-det-i.pdf | JEM-X #130010 rev. B (Detector/DFEE assembly) |
| J-mask-i.pdf | IN-JX-SR-DW-100-00 (Coded mask assembly) |

Please note, that the drawings found in this appendix are not to scale.

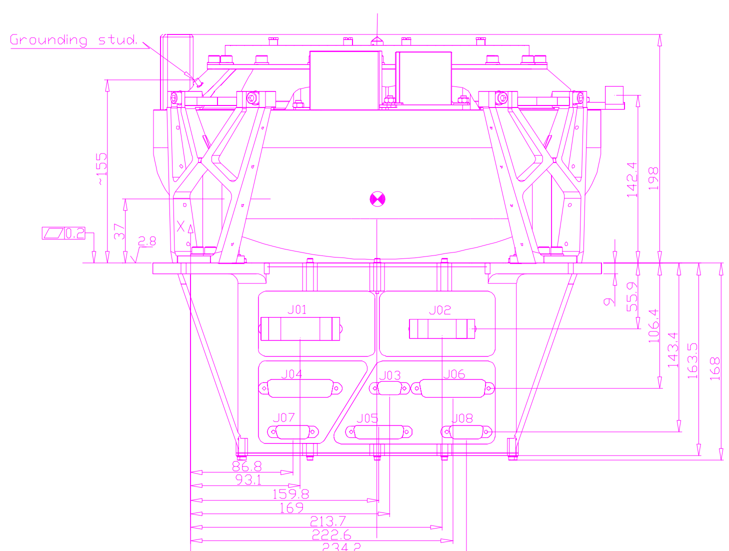

I/F VIEW
TOP VIEW
JEM-X-M1
JEM-X-M2
INTEGRAL PLM
PLM STUCTURE
RINGS SUPPORTS
SEE DETAIL -A-
SEE DETAIL C
INTEGRATION REFERENCE HOLES
2x Ø4 H7 ⊕ Ø0,1 EACH
ENVELOPE, EACH
JEM-X MASK:
ENVELOPES: Ø565x110, EACH
MASS: 7,4 Kg. EACH
BOLTS:
TYPE: M5 LN 29950
TORQUE: 6,0 ± 0,6 Nm
JEM-X FRAME:
MATERIAL: Ti6AL4V
SURFACE TREATMENT: TBD
ROUGHNESS: TBD
I/F MATERIAL: TBD
PLM SURFACE TREATMENT: TBD
ROUGHNESS: TBD
MOUNTING PLANE FLATNESS: ▱ 0,2
MOUNTING HOLES POSITIONING: ⊕ Ø0,1
MEMBRANE MASK
PRETENSION SYSTEM (CuBe)
PRETENSION ADJUSTMENT SHIM
RING SUPPORT (TITANIUM)
12x M5 I/F SCREWS
54x M3
84x M3
I/F PLANE PRYMARY STRUCTURE
PLM STRUCTURE
SECTION B-B SCALE 2:1
DETAIL A SCALE 2:1
DETAIL C SCALE 1:1
PRETENSION SYSTEM
FILE: JX100110.DWG
SENER
UNIVERSIDAD DE VALENCIA
INTEGRAL
JEM-X MASK INTERFACES
FOR MANUFACTURING

Bottom view:



Side view:




## Mechanical Properties:

All bolts and nuts will be tightened according to ESA PSS-03-206 issue 1, page 18-10 (friction coefficient = 0.1), strenght grade 8.8 or strength class 70.

Mass:
Flight Model unit = 27.43 kg

CoG: in coordinates (37,158,173)
MoI: X-axis = 0.5 kg*m2
Y-axis = 0.51 kg*m2
z-axis = 0.51 kg*m2

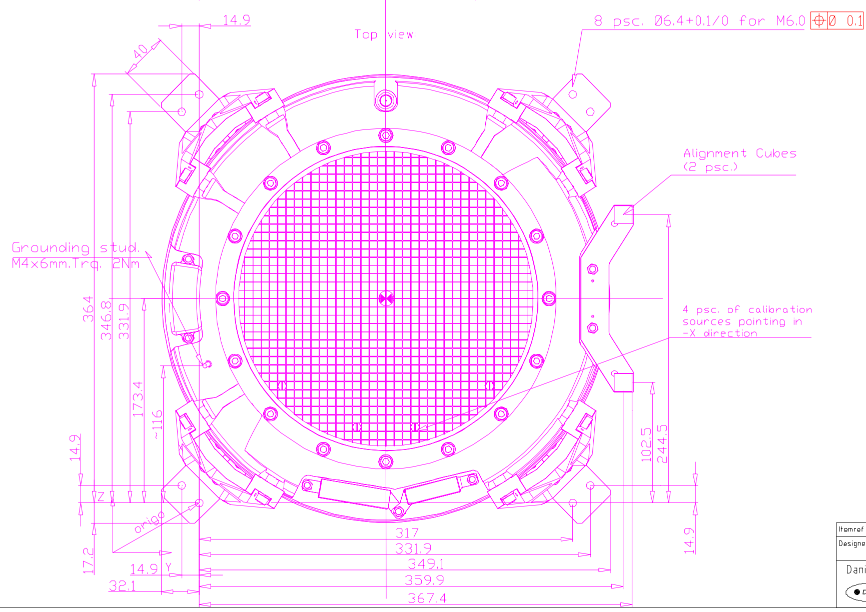
## Electrical properties:

Power:
Detector = 5.5W
DFEE = 22.5W

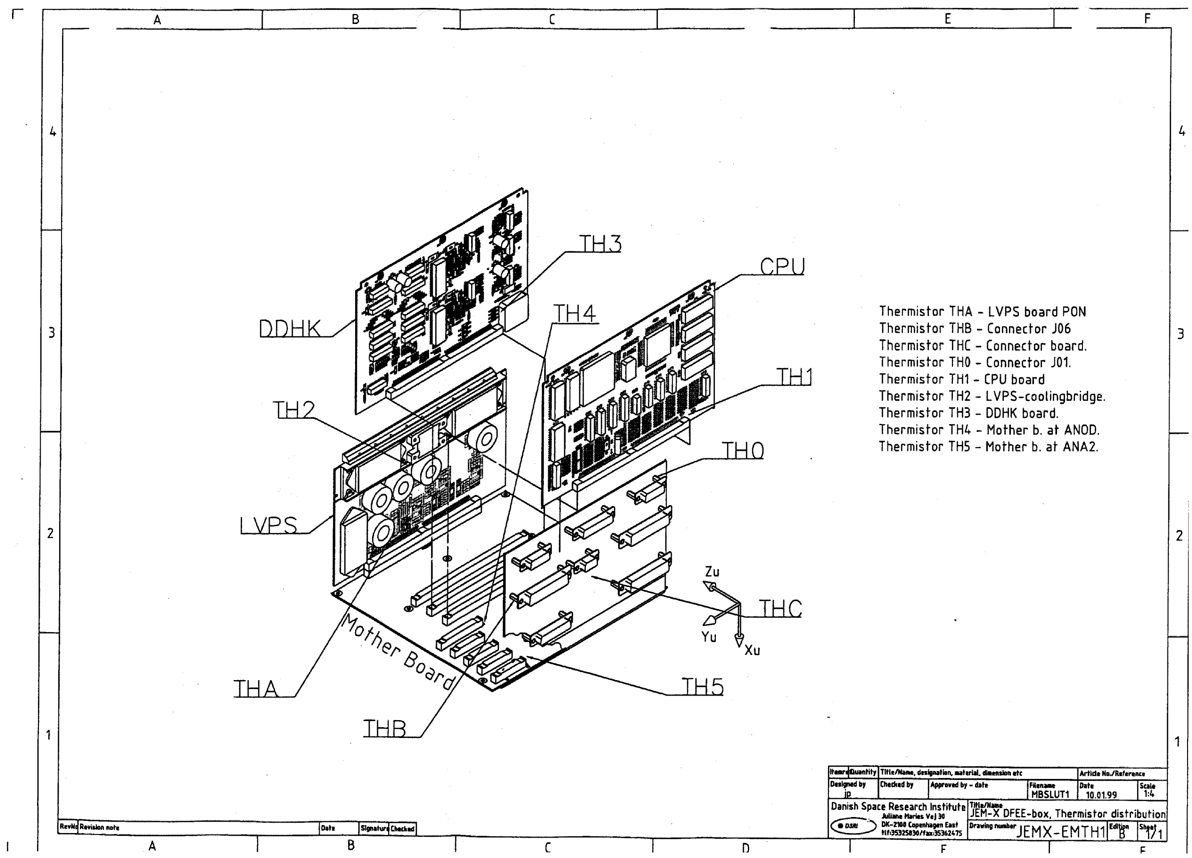
## Thermal properties:

Thermal surfaces: The DFEE surface are painted with Chemglaze Z306 (emission coefficient = 0.85). The Detector dome has emission coefficient = 0.10.
The radiative areas between the Detector dome and the DFEE top-plate has emission coefficient = 0.80.
Thermistor position are shown on drawings: JEMX-EMTH1/B/1; Hybrico N543, see following pages.

Top view:

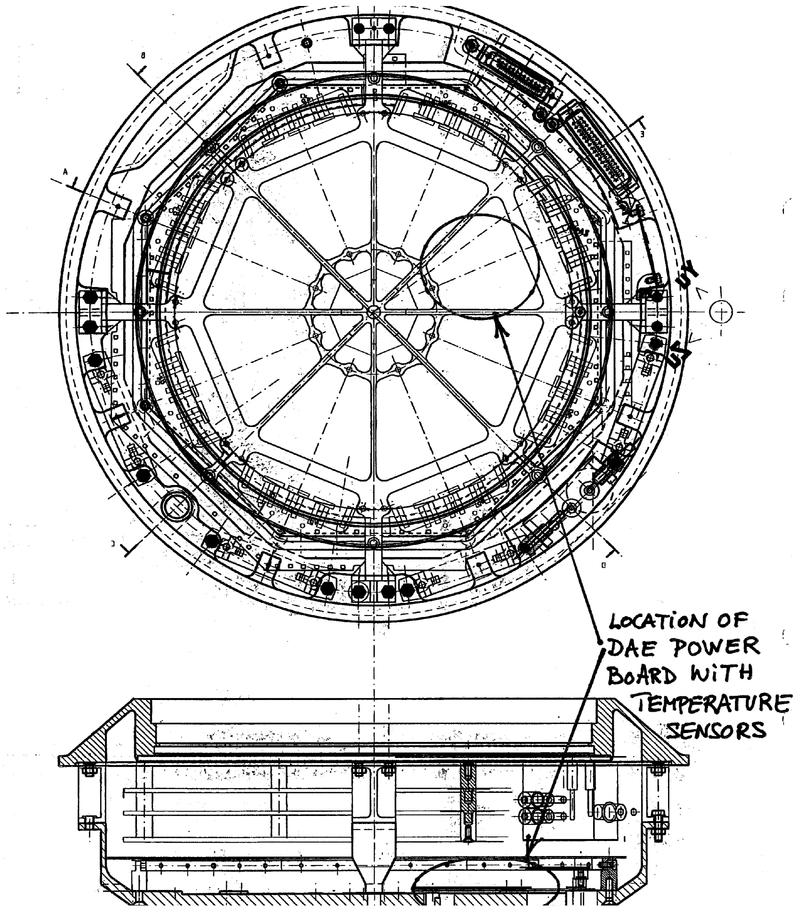



| Itemref | Quantity | Title/Name, designation, material, dimension etc | | Article No./Reference | |
|---|---|---|---|---|---|
| Designed by PC | | Checked by JP | Approved by - date NL-22.12.99 | Filename saml_det | Date 22.12.99 | Scale |
| Danish Space Research Institute, Juliane Maries Vej 31, DK-2100 Copenhagen East, tlf:35325830/fax:35362475 (DSRI) | | Title/Name Jem-X; Inteface Control Drawing, -FM | | | |
| | | Drawing number JEM-X; No. 130100 | | Edition B | Sheet 1/1 |




Figur 3

Figure showing the location of 9 of the 11 thermosensors (THA, THB, THC and TH0-5) located inside the DFEE box. The last two sensors in this box, TH6 and TH7, are located in High Voltage Supply, which occupies the space next to the LVPS Board.




Figur 4

Figure showing the location inside the detector of the DAE power board which carries the two thermosensors and the two pressuresensors located inside the detector. Both thermosensors measures the same temperature, the temperature of the DAE electronics and the detector gas.

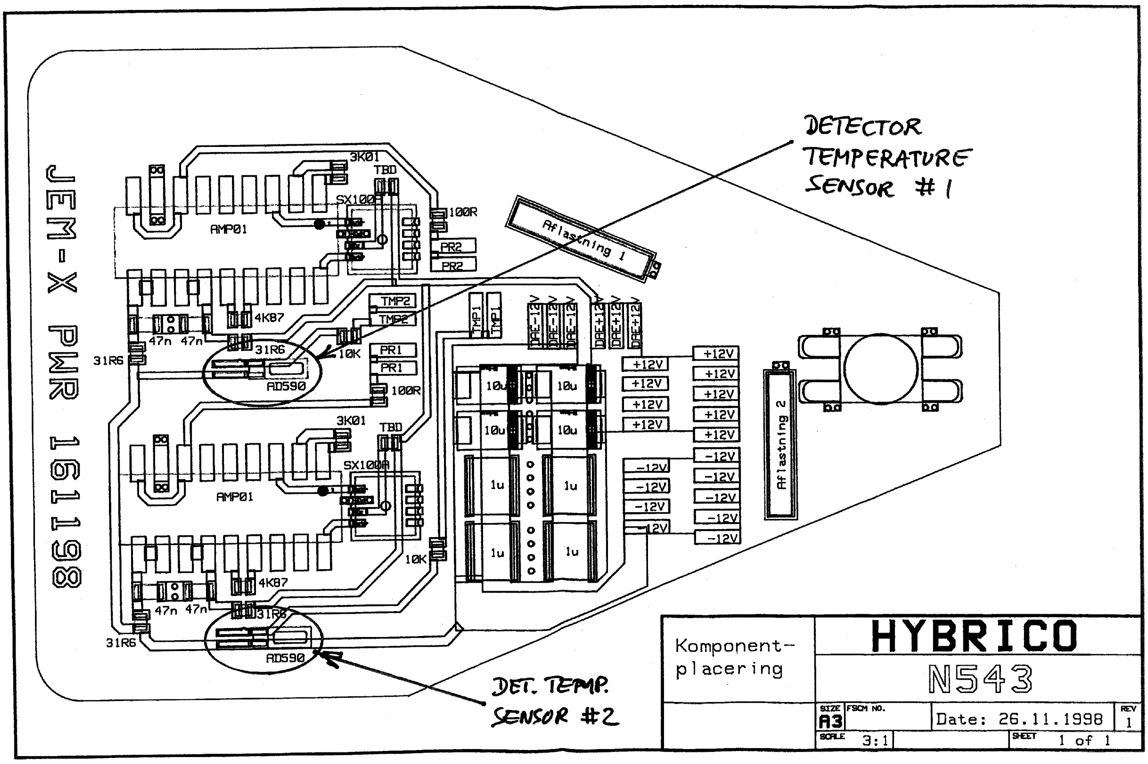



Figure showing the location on the DAE power board of the two AD590 thermosensors. The pressure sensors are the 8-pin IC's marked SX1000.

**APPENDIX B**

**Electrical Interface Control Document (EICD) according to DRD44-1.**

**Introduction**

S **Purpose**

The purpose of this document is to establish the Electrical I/F characteristics of JEM-X.

JEM-X consists of:

The Detector Unit (DAE) and the Electronics Unit (DFEE). The two units are delivered integrated as one unit (JEM-X). JEM-X has two different electrical interfaces:

- External from the DFEE to the S/C via the DPE, RTU and PDU
- Internal between the DFEE and the DAE.

**List of Acronyms**

| | |
|---|---|
| DAE | Detector Analog Electronics |
| DFEE | Digital Front End Electronics |
| DPE | Data Processing Electronics |
| EGSE | Electrical Ground Support Equipment |
| EICD | Electrical Interface Control Document |
| EID | Experiment Interface Document |
| ESA | European Space Agency |
| HS | High Speed |
| I/F | Interface |
| JEM-X | Joint European X-Ray Monitor |
| LS | Low Speed |
| PDU | Power distribution Unit |
| RTU | Remote Terminal Unit |
| S/C | Spacecraft |

S **Applicable Documents**

Experiment Interface Document (EID) - Part A

## S Connector Definition

**3.1** The DFEE has the following connector types:

### 3.1.1 DFEE connectors for external interfaces

| ID. | Connector type | Comments | To |
|---|---|---|---|
| J04 | ESA/SCC-3401-002-01B-DDMA-50S-NMB-FO | House Keeping | DPE |
| J05 | ESA/SCC-3401-002-01B-DBMA-25P-NMB-FO | Command | RTU |
| J06 | ESA/SCC-3401-002-01B-DDMA-50S-NMB-FO | Serial Communication | DPE |
| J07 | ESA/SCC-3401-002-01B-DAMA-15P-NMB-FO | Main Power | PDU-M |
| J08 | ESA/SCC-3401-002-01B-DAMA-15P-NMB-FO | Redundant Power | PDU-R |

### 3.1.2 DFEE connectors for internal interfaces.

| ID. | Connector type | Comments | To |
|---|---|---|---|
| J01 | ESA/SCC-3401-002-01B-DDMA-50S-NMB-FO | Analog Signals | DAE |
| J02 | ESA/SCC-3401-002-01B-DBMA-25S-NMB-FO | Control Signals | DAE |
| J03 | ESA/SCC-3401-002-01B-DEMA-9P-NMB-FO | Test | Test Computer |

**3.2** The DAE has the following connector types:

### 3.2.1 DAE connectors for internal interfaces.

| ID. | Connector type | Comments | To |
|---|---|---|---|
| HV | Ceramaseal Hermetic Type FDTH 12 kV | High Voltage | DFEE |
| J14 | Ceramaseal Hermetic D Type | Analog Signals | DFEE |
| J15 | Ceramaseal Hermetic D Type | Control Signals | DFEE |

## S Connector Interconnection

The interconnections from the DFEE to the DPE, RTU and PDU are shown in the Interconnection Block Diagram in annex 1.

## S External Interface Pin Allocation

The tables in annex 2 show the pin allocation for the DFEE unit connectors to the DPE, RTU and

PDU.

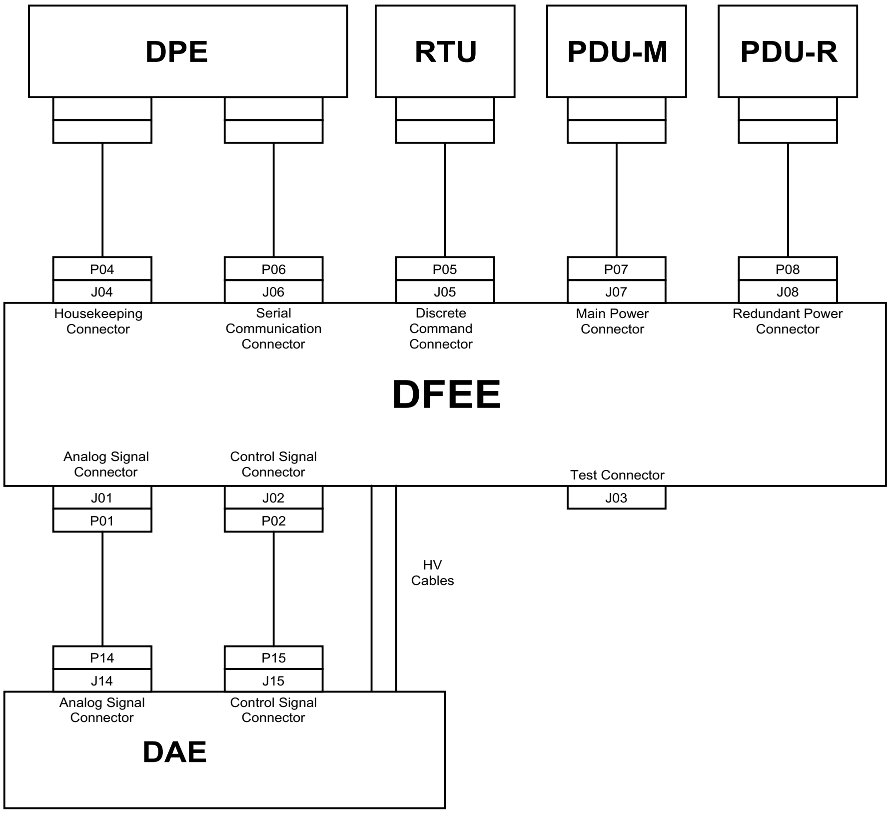
### S Internal Interface Pin Allocation.

The tables in annex 3 show the pin allocation between the DFEE unit connectors and the DAE.

### S Interface Circuits.

The Interface Circuits are shown in Annex 4

**Annex 1. Connector Interconnections.**



## Annex 2. External Interface Pin Allocation.

| Unit: DFEE | | Function: Housekeeping | | Checked by: | | | | | | | | | Issue | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Connector Identification: J04 | | | | Connector type: ESA/SCC-3401-02-01B-DDMA-50S-NMB-FO | | | | | | | | | | | | |
| Pin Number | Signal Type | Signal Name | Signal Description | Electrical Type | Current (mA) | Source Impedance (Kohm) | Load Impedanc (Kohm) | Frequency (Hz) | Voltage (V) | Load Capacity to GND (pF) | Source Capacity to GND (pF) | Rise Time (uS) | Pulse Width (uS) | Sensitivity | Specific Harness Requirements | To Unit |
| 1 | | ANA0+ | +5V Digital monitor | ANA | | | | | | | | | | | TP26 | DPE |
| 18 | | ANA0 - | +5V Digital monitor RTN | ANA | | | | | | | | | | | TP26 | DPE |
| 2 | | ANA1+ | +5V Current monitor | ANA | | | | | | | | | | | TP26 | DPE |
| 19 | | ANA1 - | +5V Current monitor RTN | ANA | | | | | | | | | | | TP26 | DPE |
| 3 | | ANA2+ | +5V Analog monitor | ANA | | | | | | | | | | | TP26 | DPE |
| 20 | | ANA2 - | +5V Analog monitor RTN | ANA | | | | | | | | | | | TP26 | DPE |
| 4 | | ANA3+ | -5V Analog monitor | ANA | | | | | | | | | | | TP26 | DPE |
| 21 | | ANA3 - | -5V Analog monitor RTN | ANA | | | | | | | | | | | TP26 | DPE |
| 5 | | ANA4+ | +12V Analog monitor | ANA | | | | | | | | | | | TP26 | DPE |
| 22 | | ANA4 - | +12V Analog monitor RTN | ANA | | | | | | | | | | | TP26 | DPE |
| 6 | | ANA5+ | +12V Current monitor | ANA | | | | | | | | | | | TP26 | DPE |
| 23 | | ANA5 - | +12V Current monitor RTN | ANA | | | | | | | | | | | TP26 | DPE |
| 7 | | ANA6+ | -12V Analog monitor | ANA | | | | | | | | | | | TP26 | DPE |
| 24 | | ANA6 - | -12V Analog monitor RTN | ANA | | | | | | | | | | | TP26 | DPE |
| 8 | | ANA7+ | -12V Current monitor | ANA | | | | | | | | | | | TP26 | DPE |
| 25 | | ANA7 - | -12V Current monitor RTN | ANA | | | | | | | | | | | TP26 | DPE |
| 9 | | ANA8+ | Pressure monitor 1 | ANA | | | | | | | | | | | TP26 | DPE |
| 26 | | ANA8 - | Pressure monitor 1 RTN | ANA | | | | | | | | | | | TP26 | DPE |
| 10 | | ANA9+ | Pressure monitor 2 | ANA | | | | | | | | | | | TP26 | DPE |
| 27 | | ANA9 - | Pressure monitor 2 RTN | ANA | | | | | | | | | | | TP26 | DPE |
| 11 | | ANA10+ | Detector temperature 1 | ANA | | | | | | | | | | | TP26 | DPE |
| 28 | | ANA10 - | Detector temperature 1 RTN | ANA | | | | | | | | | | | TP26 | DPE |
| 12 | | ANA11+ | Detector temperature 2 | ANA | | | | | | | | | | | TP26 | DPE |
| 29 | | ANA11 - | Detector temperature 2 RTN | ANA | | | | | | | | | | | TP26 | DPE |
| 17 | | | NC | | | | | | | | | | | | | |
| 13 | Thermistor | YSI_TH0 | Thermistor 0 | ANA | | | | | | | | | | | TP26 | DPE |
| 14 | Thermistor | YSI_TH0_RTN | Thermistor 0 RTN | ANA | | | | | | | | | | | TP26 | DPE |
| 30 | Thermistor | YSI_TH1 | Thermistor 1 | ANA | | | | | | | | | | | TP26 | DPE |
| 31 | Thermistor | YSI_TH1_RTN | Thermistor 1 RTN | ANA | | | | | | | | | | | TP26 | DPE |
| 42 | Thermistor | YSI_TH2 | Thermistor 2 | ANA | | | | | | | | | | | TP26 | DPE |
| 43 | Thermistor | YSI_TH2_RTN | Thermistor 2 RTN | ANA | | | | | | | | | | | TP26 | DPE |
| 15 | Thermistor | YSI_TH3 | Thermistor 3 | ANA | | | | | | | | | | | TP26 | DPE |
| 16 | Thermistor | YSI_TH3_RTN | Thermistor 3 RTN | ANA | | | | | | | | | | | TP26 | DPE |
| 44 | Thermistor | YSI_TH4 | Thermistor 4 | ANA | | | | | | | | | | | TP26 | DPE |
| 45 | Thermistor | YSI_TH4_RTN | Thermistor 4 RTN | ANA | | | | | | | | | | | TP26 | DPE |
| 46 | Thermistor | YSI_TH5 | Thermistor 5 | ANA | | | | | | | | | | | TP26 | DPE |
| 47 | Thermistor | YSI_TH5_RTN | Thermistor 5 RTN | ANA | | | | | | | | | | | TP26 | DPE |
| 32 | | | NC | | | | | | | | | | | | | |
| 33 | | | NC | | | | | | | | | | | | | |
| 48 | | REL0 | DPE HVC off | DIG | | | | | | | | | | | TP26 | DPE |
| 49 | | REL0_RTN | DPE HVC off RTN | DIG | | | | | | | | | | | TP26 | DPE |
| 50 | | | NC | | | | | | | | | | | | | |
| 34 | | ANA12+ | HF FIFO FLAG (HFF0+) | DIG | | | | | | | | | | | TP26 | DPE |
| 35 | | ANA12- | HF FIFO FLAG RTN (HFF0-) | DIG | | | | | | | | | | | TP26 | DPE |
| 36 | | ANA13+ | HVPS Temperature 1 | ANA | | | | | | | | | | | TP26 | DPE |
| 37 | | ANA13- | HVPS Temperature 1 RTN | ANA | | | | | | | | | | | TP26 | DPE |
| 38 | | ANA14+ | HVPS Temperature 2 | ANA | | | | | | | | | | | TP26 | DPE |
| 39 | | ANA14- | HVPS Temperature 2 RTN | ANA | | | | | | | | | | | TP26 | DPE |
| 40 | | ANA15+ | Spare AN. Channel | ANA | | | | | | | | | | | TP26 | DPE |
| 41 | | ANA15- | Spare AN. Channel RTN | ANA | | | | | | | | | | | TP26 | DPE |

| **Unit: DFEE** | **Function: Discrete Command** | | | **Checked by:** | | | | | | | | | **Issue** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Connector Identification: J05** | | | | **Connector type: ESA/SCC-3401-002-01B-DBMA-25P-NMB-FO** | | | | | | | | | | | | |
| Pin Number | Signal Type | Signal Name | Signal Description | Electrical Type | Current (mA) | Source Impedance (Kohm) | Load Impedanc (Kohm) | Frequency (Hz) | Voltage (V) | Load Capacity to GND (pF) | Source Capacity to GND (pF) | Rise Time (uS) | Pulse Width (uS) | Sensitivity | Specific Harness Requirements | [illegible] |
| 1 | | | NC | | | | | | | | | | | | | |
| 2 | | | NC | | | | | | | | | | | | | |
| 3 | | | NC | | | | | | | | | | | | | |
| 4 | | | NC | | | | | | | | | | | | | |
| 5 | | | NC | | | | | | | | | | | | TP26 | R |
| 18 | | | NC | | | | | | | | | | | | TP26 | R |
| 6 | ON/OFF | | S/C HVC off A | DIG | | | | | | | | | | | TP26 | R |
| 19 | ON/OFF | | S/C HVC off RTN A | DIG | | | | | | | | | | | TP26 | R |
| 7 | | | NC | | | | | | | | | | | | | |
| 8 | Thermistor | YSI_THA | Thermistor A | ANA | | | | | | | | | | | TP26 | R |
| 21 | Thermistor | YSI_THA_RTN | Thermistor A RTN | ANA | | | | | | | | | | | TP26 | R |
| 9 | Thermistor | YSI_THB | Thermistor B | ANA | | | | | | | | | | | TP26 | R |
| 22 | Thermistor | YSI_THB_RTN | Thermistor B RTN | ANA | | | | | | | | | | | TP26 | R |
| 10 | Thermistor | YSI_THC | Thermistor C | ANA | | | | | | | | | | | TP26 | R |
| 23 | Thermistor | YSI_THC_RTN | Thermistor C RTN | ANA | | | | | | | | | | | TP26 | R |
| 11 | | | NC | | | | | | | | | | | | | |
| 24 | | | NC | | | | | | | | | | | | | |
| 12 | | | NC | | | | | | | | | | | | | |
| 13 | | | NC | | | | | | | | | | | | | |
| 14 | | | NC | | | | | | | | | | | | | |
| 15 | | | NC | | | | | | | | | | | | | |
| 16 | | | NC | | | | | | | | | | | | | |
| 17 | | | NC | | | | | | | | | | | | | |
| 20 | | | NC | | | | | | | | | | | | | |
| 25 | | | NC | | | | | | | | | | | | | |

| Unit: DFEE | Function: Serial Communication | | | Checked by: | | | | | | | | | Issue | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Connector Identification: J06 | | | | Connector type: ESA/SCC-3401-002-01B-DDMA-50S-NMB-FO | | | | | | | | | | | | |
| Pin Number | Signal Type | Signal Name | Signal Description | Electrical Type | Current (mA) | Source Impedance (Kohm) | Load Impedanc (Kohm) | Frequency (Hz) | Voltage (V) | Load Capacity to GND (pF) | Source Capacity to GND (pF) | Rise Time (uS) | Pulse Width (uS) | Sensitivity | Specific Harness Requirements | To Unit |
| 1 | | | NC | | | | | | | | | | | | | |
| 2 | RS422HSL | DTH0+ | 5Mb/s Data | DIG | | | | | | | | | | | | DPE |
| 35 | RS422HSL | DTH0- | 5Mb/s Data RTN | DIG | | | | | | | | | | | | DPE |
| 3 | RS422HSL | ENH0+ | Data Enable | DIG | | | | | | | | | | | | DPE |
| 36 | RS422HSL | ENH0- | Data Enable RTN | DIG | | | | | | | | | | | | DPE |
| 4 | | | NC | | | | | | | | | | | | | DPE |
| 37 | | | NC | | | | | | | | | | | | | DPE |
| 5 | RS422HSL | CKH0+ | 5MHZ Clock | DIG | | | | | | | | | | | | DPE |
| 38 | RS422HSL | CKH0- | 5MHZ Clock RTN | DIG | | | | | | | | | | | | DPE |
| 6 | | | NC | | | | | | | | | | | | | |
| 7 | RS422LSL | DTR0+ | 64Kb/s Transmit | DIG | | | | | | | | | | | | DPE |
| 40 | RS422LSL | DTR0- | 64Kb/s Transmit RTN | DIG | | | | | | | | | | | | DPE |
| 8 | RS422LSL | DTF0+ | 64Kb/s Receive | DIG | | | | | | | | | | | | DPE |
| 41 | RS422LSL | DTF0- | 64Kb/s Receive RTN | DIG | | | | | | | | | | | | DPE |
| 9 | RS422LSL | RTSN+ | Request To Send | DIG | | | | | | | | | | | | DPE |
| 42 | RS422LSL | RTSN- | Request To Send RTN | DIG | | | | | | | | | | | | DPE |
| 10 | RS422LSL | CLK0+ | 64KHz Clock | DIG | | | | | | | | | | | | DPE |
| 43 | RS422LSL | CLK0- | 64KHz Clock RTN | DIG | | | | | | | | | | | | DPE |
| 11 | | | NC | | | | | | | | | | | | | |
| 12 | | | NC | | | | | | | | | | | | | |
| 13 | RS422HSL | INST_CLK+ | 4MHz Timing | DIG | | | | | | | | | | | | DPE |
| 46 | RS422HSL | INST_CLK- | 4MHz Timing RTN | DIG | | | | | | | | | | | | DPE |
| 14 | RS422LSL | EXT_BCP2+ | 1Hz Timing | DIG | | | | | | | | | | | | DPE |
| 47 | RS422LSL | EXT_BCP2- | 1Hz Timing RTN | DIG | | | | | | | | | | | | DPE |
| 15 | RS422LSL | EXT_CLK8N+ | 8Hz Timing | DIG | | | | | | | | | | | | DPE |
| 48 | RS422LSL | EXT_CLK8N- | 8Hz Timing RTN | DIG | | | | | | | | | | | | DPE |
| 16 | RS422LSL | EXT_BCP1+ | 1/8z Timing | DIG | | | | | | | | | | | | DPE |
| 49 | RS422LSL | EXT_BCP1- | 1/8z Timing RTN | DIG | | | | | | | | | | | | DPE |
| 17 | | | NC | | | | | | | | | | | | | |
| 18 | | | NC | | | | | | | | | | | | | |
| 19 | | | NC | | | | | | | | | | | | | |
| 20 | | | NC | | | | | | | | | | | | | |
| 21 | | | NC | | | | | | | | | | | | | |
| 22 | | | NC | | | | | | | | | | | | | |
| 23 | | | NC | | | | | | | | | | | | | |
| 24 | | | NC | | | | | | | | | | | | | |
| 25 | | | NC | | | | | | | | | | | | | |
| 26 | | | NC | | | | | | | | | | | | | |
| 27 | | | NC | | | | | | | | | | | | | |
| 28 | | | NC | | | | | | | | | | | | | |
| 29 | | | NC | | | | | | | | | | | | | |
| 30 | | | NC | | | | | | | | | | | | | |
| 31 | | | NC | | | | | | | | | | | | | |
| 32 | | | NC | | | | | | | | | | | | | |
| 33 | | | NC | | | | | | | | | | | | | |
| 34 | | | NC | | | | | | | | | | | | | |
| 39 | | | NC | | | | | | | | | | | | | |
| 44 | | | NC | | | | | | | | | | | | | |
| 45 | | | NC | | | | | | | | | | | | | |
| 50 | | | NC | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |

**Unit: DFEE** **Function: Main Power** **Checked by:** **Issue**

**Connector Identification: J07** **Connector type: ESA/SCC-3401-002-01b-DAMA-15P-NMB-FO**

| Pin Number | Signal Type | Signal Name | Signal Description | Electrical Type | Current (mA) | Source Impedance (Kohm) | Load Impedanc (Kohm) | Frequency (Hz) | Voltage (V) | Load Capacity to GND (pF) | Source Capacity to GND (pF) | Rise Time (uS) | Pulse Width (uS) | Sensitivity | Specific Harness Requirements | To Unit |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | NC | | | | | | | | | | | | | |
| 2 | | PBUSN | 28V Power Bus 1 | DC | | | | 0 | 28 | | | | | | TP24 | PDU |
| 10 | | PBUSN_RTN | 28V Power Bus 1 RTN | DC | | | | 0 | 0 | | | | | | TP24 | PDU |
| 3 | | PBUSN | 28V Power Bus 1 | DC | | | | 0 | 28 | | | | | | TP24 | PDU |
| 11 | | PBUSN_RTN | 28V Power Bus 1 RTN | DC | | | | 0 | 0 | | | | | | TP24 | PDU |
| 4 | | | NC | | | | | | | | | | | | | |
| 5 | | | NC | | | | | | | | | | | | | |
| 6 | | | NC | | | | | | | | | | | | | |
| 7 | | | NC | | | | | | | | | | | | | |
| 8 | | | NC | | | | | | | | | | | | | |
| 9 | | | NC | | | | | | | | | | | | | |
| 12 | | | NC | | | | | | | | | | | | | |
| 13 | | | NC | | | | | | | | | | | | | |
| 14 | | | NC | | | | | | | | | | | | | |
| 15 | | | NC | | | | | | | | | | | | | |

**Unit: DFEE** **Function: Redundant Power** **Checked by:** **Issue**

**Connector Identification: J08** **Connector type: ESA/SCC-3401-002-01b-DAMA-15P-NMB-FO**

| Pin Number | Signal Type | Signal Name | Signal Description | Electrical Type | Current (mA) | Source Impedance (Kohm) | Load Impedanc (Kohm) | Frequency (Hz) | Voltage (V) | Load Capacity to GND (pF) | Source Capacity to GND (pF) | Rise Time (uS) | Pulse Width (uS) | Sensitivity | Specific Harness Requirements | To Unit |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | NC | | | | | | | | | | | | | |
| 2 | | PBUSR | 28V Power Bus 2 | DC | | | | 0 | 28 | | | | | | TP24 | PDU |
| 10 | | PBUSR_RTN | 28V Power Bus 2 RTN | DC | | | | 0 | 0 | | | | | | TP24 | PDU |
| 3 | | PBUSR | 28V Power Bus 2 | DC | | | | 0 | 28 | | | | | | TP24 | PDU |
| 11 | | PBUSR_RTN | 28V Power Bus 2 RTN | DC | | | | 0 | 0 | | | | | | TP24 | PDU |
| 4 | | | NC | | | | | | | | | | | | | |
| 5 | | | NC | | | | | | | | | | | | | |
| 6 | | | NC | | | | | | | | | | | | | |
| 7 | | | NC | | | | | | | | | | | | | |
| 8 | | | NC | | | | | | | | | | | | | |
| 9 | | | NC | | | | | | | | | | | | | |
| 12 | | | NC | | | | | | | | | | | | | |
| 13 | | | NC | | | | | | | | | | | | | |
| 14 | | | NC | | | | | | | | | | | | | |
| 15 | | | NC | | | | | | | | | | | | | |

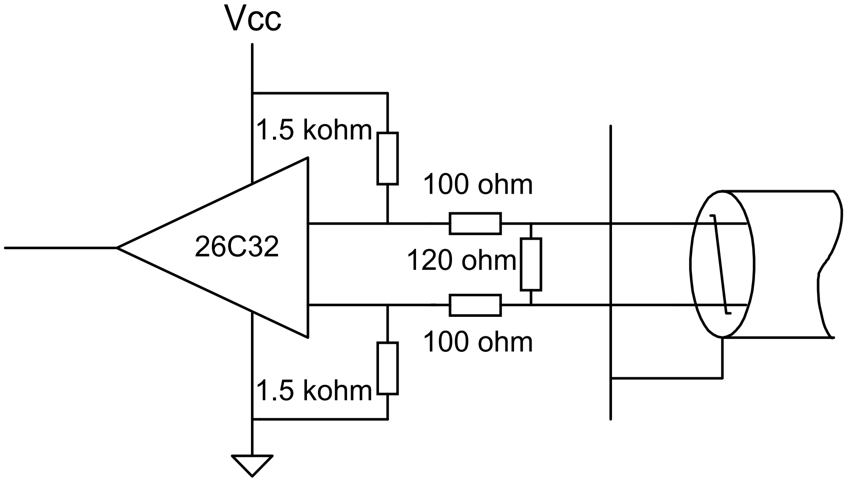
## Annex 3. Internal Interface Pin Allocation.

| Unit: DFEE | | Function: Analog Signal | | Checked by: | | | | | | | | | | Issue | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Connector Identification: J01 | | | | Connector type: ESA/SCC-3401-02-01B-DDMA-50S-NMB-FO | | | | | | | | | | | | | |
| Pin Number | Signal Type | Signal Name | Signal Description | Electrical Type | Current (mA) | Source Impedance (Kohm) | Load Impedanc (Kohm) | Frequency (Hz) | Voltage (V) | Load Capacity to GND (pF) | Source Capacity to GND (pF) | Rise Time (uS) | Pulse Width (uS) | Sensitivity | Specific Harness Requirements | To Unit | Connector |
| 1 | | BACK0 | Backplane Signal 0 | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 2 | | BACK1 | Backplane Signal 1 | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 3 | | BACK2 | Backplane Signal 2 | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 4 | | BACK3 | Backplane Signal 3 | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 5 | | BACK4 | Backplane Signal 4 | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 6 | | BACK5 | Backplane Signal 5 | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 7 | | BACK6 | Backplane Signal 6 | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 8 | | BACK7 | Backpiane Signal 7 | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 9 | | BACK8 | Backplane Signal 8 | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 10 | | BACK9 | Backplane Signal 9 | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 11 | | BACK10 | Backplane Signal 10 | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 12 | | BACK11 | Backplane Signal 11 | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 13 | | BACK12 | Backplane Signal 12 | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 14 | | BACK13 | Backplane Signal 13 | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 15 | | BACK14 | Backplane Signal 14 | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 16 | | BACK15 | Backplane Signal 15 | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 17 | | BACK16 | Backplane Signal 16 | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 18 | | BACK17 | Backplane Signal 17 | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 19 | | A_GND | Analog Ground | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 20 | | BACK18 | Backplane Signal 18 | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 21 | | A_GND | Analog Ground | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 22 | | BACK19 | Backplane Signal 19 | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 23 | | A_GND | Analog Ground | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 24 | | ANOD0 | Anode Signal 0 | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 25 | | A_GND | Analog Ground | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 26 | | ANOD1 | Anode Signal 1 | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 27 | | A_GND | Shield | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 28 | | VETO | Veto Signal | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 29 | | A_GND | Analog Ground | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 30 | | PR1 | Pressure Transducer 1 | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 31 | | A_GND | Analog Ground | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 32 | | PR2 | Pressure Transducer 2 | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 33 | | A_GND | Analog Ground | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 34 | | CATH0 | Cathode signal 0 | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 35 | | CATH1 | Cathode signal 1 | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 36 | | CATH2 | Cathode signal 2 | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 37 | | CATH3 | Cathode signal 3 | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 38 | | CATH4 | Cathode signal 4 | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 39 | | CATH5 | Cathode signal 5 | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 40 | | CATH6 | Cathode signal 6 | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 41 | | CATH7 | Cathode signal 7 | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 42 | | CATH8 | Cathode signal 8 | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 43 | | CATH9 | Cathode signal 9 | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 44 | | CATH10 | Cathode signal 10 | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 45 | | TMP1 | Temperature Transducer 1 | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 46 | | TMP2 | Temperature Transducer 2 | ANA | | | | | | | | | | | TP26 | DAE | J14 |
| 47 | | DAE+12V | +12V til DAE | DC | | | | 0 | | | | | | | TP26 | DAE | J14 |
| 48 | | DAE+12V | +12V til DAE | DC | | | | 0 | | | | | | | TP26 | DAE | J14 |
| 49 | | DAE-12V | -12V til DAE | DC | | | | 0 | | | | | | | TP26 | DAE | J14 |
| 50 | | DAE-12V | -12V til DAE | DC | | | | 0 | | | | | | | TP26 | DAE | J14 |

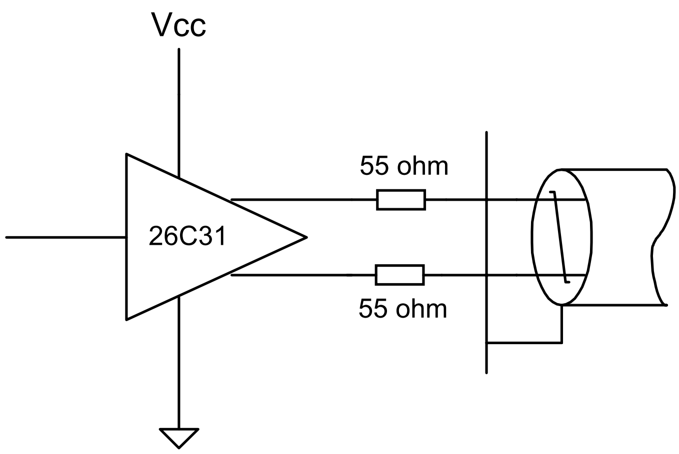
| **Unit: DFEE** | | **Function: Test** | | **Checked by:** | | | | | | | | | | **Issue** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Connector Identification: J03** | | | | | **Connector type: ESA/SCC-3401-002-01B-DEMA-9P-NMB-FO** | | | | | | | | | | | |
| Pin Number | Signal Type | Signal Name | Signal Description | Electrical Type | Current (mA) | Source Impedance (Kohm) | Load Impedanc (Kohm) | Frequency (Hz) | Voltage (V) | Load Capacity to GND (pF) | Source Capacity to GND (pF) | Rise Time (uS) | Pulse Width (uS) | Sensitivity | Specific Harness Requirements | To Unit |
| 1 | | TSTO+ | Test Out | DIG | | | | | | | | | | | | NA |
| 2 | | TSTO- | Test Out RTN | DIG | | | | | | | | | | | | NA |
| 3 | | TSTI+ | Test In | DIG | | | | | | | | | | | | NA |
| 4 | | TSTI- | Test In RTN | DIG | | | | | | | | | | | | NA |
| 5 | | | | | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | | | | | |

| **Unit: DAE** | | **Function: Control Signal** | | **Checked by:** | | | | | | | | | | | **Issue** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Connector Identification: J15** | | | | **Connector type: Hermetic Ceramaseal** | | | | | | | | | | | | | | |
| Pin Number | Signal Type | Signal Name | Signal Description | Electrical Type | Current (mA) | Source Impedance (Kohm) | Load Impedanc (Kohm) | Frequency (Hz) | Voltage (V) | Load Capacity to GND (pF) | Source Capacity to GND (pF) | Rise Time (uS) | Pulse Width (uS) | Sensitivity | Specific Harness Requirements | To Unit | Connector | Pin Number |
| 1 | | CALON | Calibration On/Off | DIG | | | | | | | | | | | TP26 | DFEE | J02 | 1 |
| 2 | | CALON | Calibration On/Off | DIG | | | | | | | | | | | TP26 | DFEE | J02 | 2 |
| 3 | | D_GND | Shield(Not connected at J 15) | DC | | | | | | | | | | | | | | |
| 4 | | NC | | | | | | | | | | | | | | | | |
| 5 | | ANO_CON0 | Anode Control 0 | DIG | | | | | | | | | | | TP26 | DAE | J15 | 5 |
| 6 | | ANO_CON0 | Anode Control 0 | DIG | | | | | | | | | | | TP26 | DAE | J15 | 6 |
| 7 | | ANO_CON1 | Anode Control 1 | DIG | | | | | | | | | | | TP26 | DAE | J15 | 7 |
| 8 | | ANO_CON1 | Anode Control 1 | DIG | | | | | | | | | | | TP26 | DAE | J15 | 8 |
| 9 | | ANO_CON2 | Anode Control 2 | DIG | | | | | | | | | | | TP26 | DAE | J15 | 9 |
| 10 | | ANO_CON2 | Anode Control 2 | DIG | | | | | | | | | | | TP26 | DAE | J15 | 10 |
| 11 | | ANO_CON3 | Anode Control 3 | DIG | | | | | | | | | | | TP26 | DAE | J15 | 11 |
| 12 | | ANO_CON3 | Anode Control 3 | DIG | | | | | | | | | | | TP26 | DAE | J15 | 12 |
| 13 | | CALV | Calibration Level | DC | | | | | | | | | | | TP26 | DAE | J15 | 13 |
| 14 | | D_GND | Shield(Not connected at J 15) | DC | | | | | | | | | | | | | | |
| 15 | | NC | | | | | | | | | | | | | | | | |
| 16 | | NC | | | | | | | | | | | | | | | | |
| 17 | | NC | | | | | | | | | | | | | | | | |
| 18 | | NC | | | | | | | | | | | | | | | | |
| 19 | | NC | | | | | | | | | | | | | | | | |
| 20 | | NC | | | | | | | | | | | | | | | | |
| 21 | | NC | | | | | | | | | | | | | | | | |
| 22 | | NC | | | | | | | | | | | | | | | | |
| 23 | | NC | | | | | | | | | | | | | | | | |
| 24 | | NC | | | | | | | | | | | | | | | | |
| 25 | | CALV | Calibration Level | DC | | | | | | | | | | | TP26 | DAE | J15 | 25 |

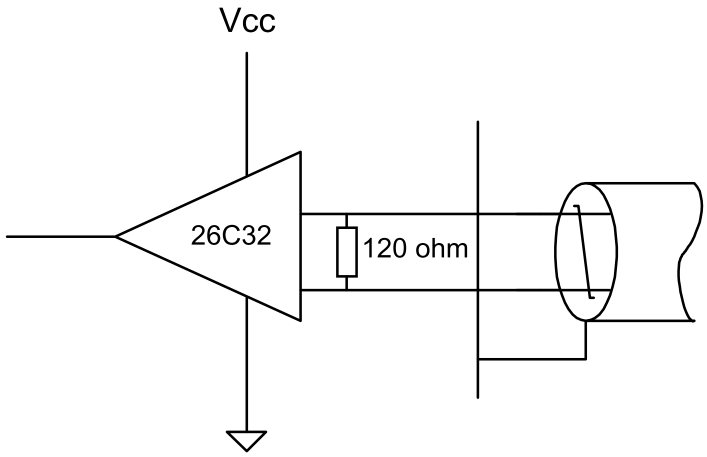
**Annex 4. Interface Circuits.**



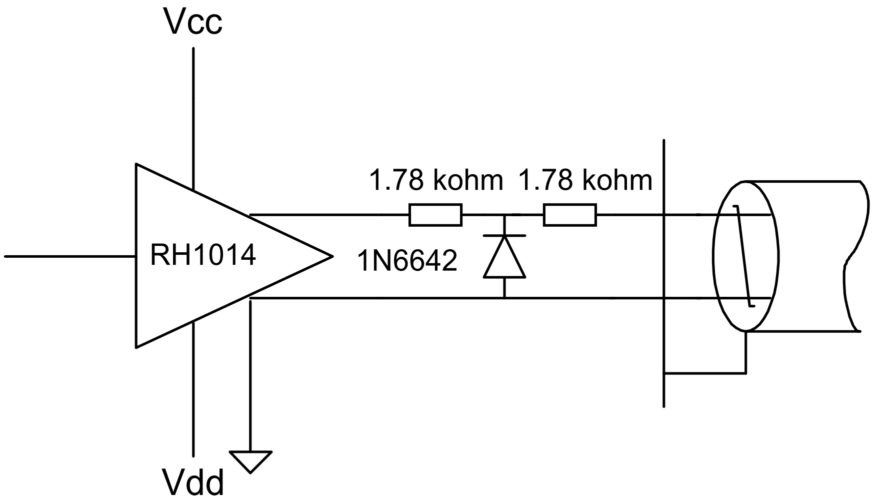

**Interface Circuit 1**
**High Speed Interface Circuit for ENABLE, CLOCK, 4 MHz, 1 Hz, 1/8 Hz, and TEST Signal**



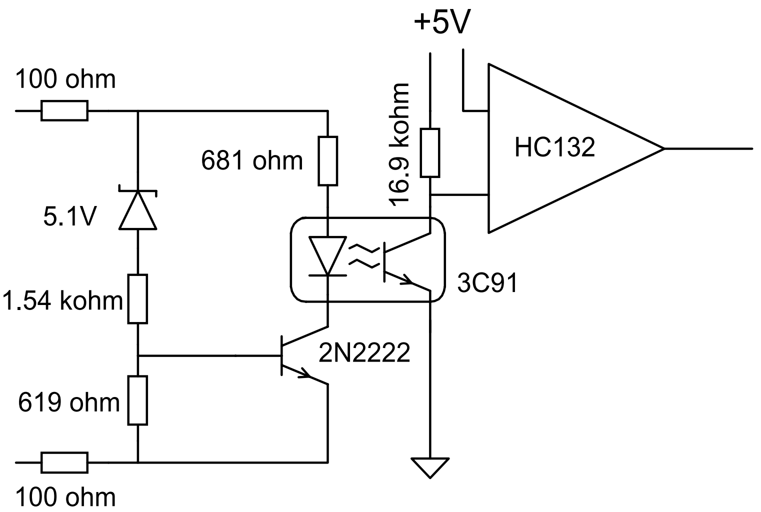

**Interface Circuit 2**
**Interface Circuit for HS-DATA, LS-TRANSMIT, and TEST Signal**



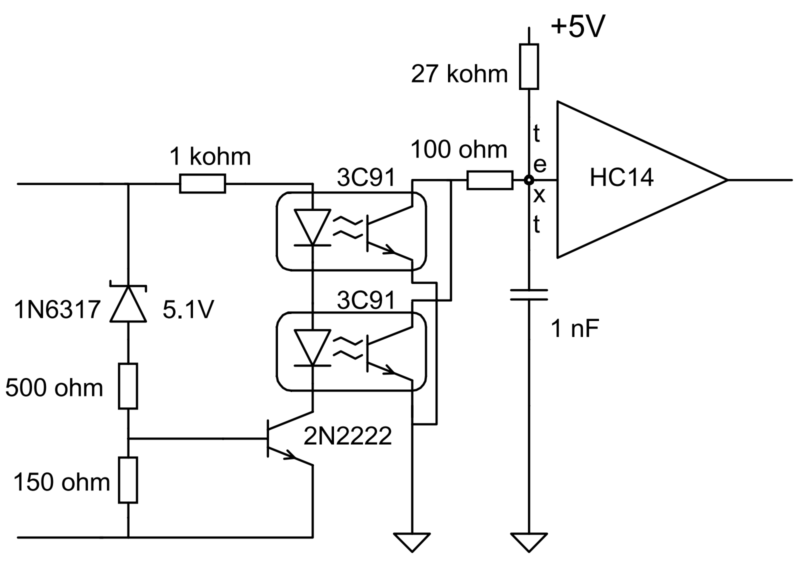

**Interface Circuit 3**
**Low Speed Interface Circuit for RECEIVE, CLOCK, and REQUEST Signal**



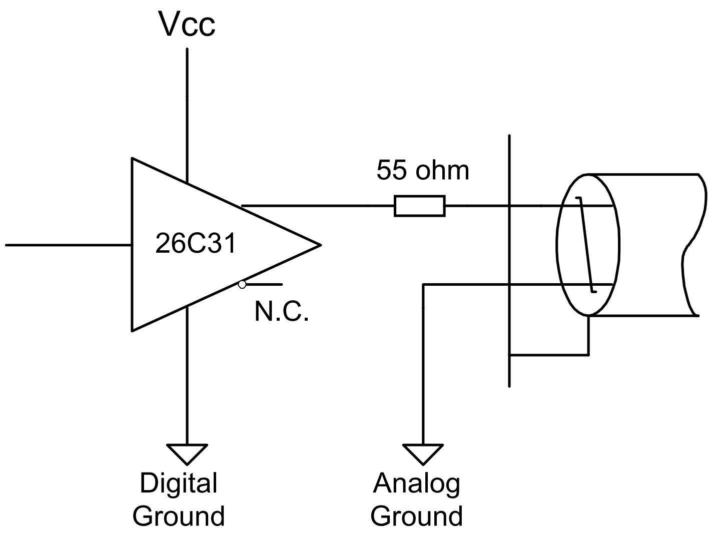

**Interface Circuit 4**
**Interface Circuit for all ANALOG Signals**




## Interface Circuit 5
## HV OFF Command Interface from DPE




## Interface Circuit 6
## HV OFF Command Interface from RTU




**Interface Circuit 7**
**Interface Circuit for FIFO-FLAG**