PRELIMINARY

ACE-CT-013-40

University of New Hampshire

SEPICA:
Solar Energetic Particle Charge Analyzer

Instrument Functional Requirements Document

for

The Advanced Composition Explorer Mission

California Institute of Technology
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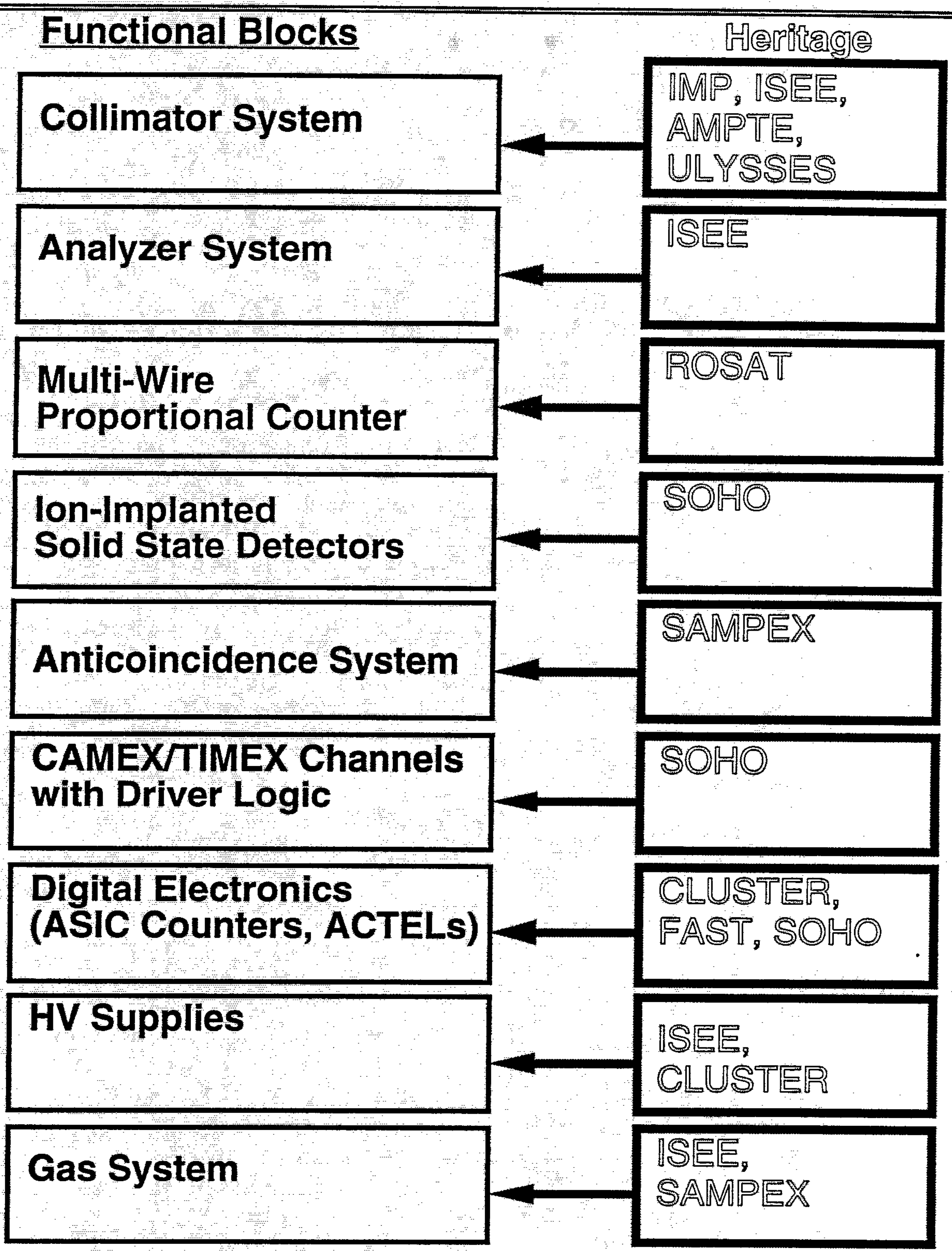
1. BACKGROUND

The SEPICA instrument is the prime sensor on ACE for the determination of the charge state distribution of energetic particle distributions. The SEPICA science requirements are contained in the ACE Science Requirements Document (GSFC-410-ACE-004). The instrument design and its design parameters as discussed below are consistent with the SRD and represent the concept and design goals for SEPICA.

The SEPICA instrument is based on the design of the ULEZEQ sensor flown on the ISEE spacecraft (Hovestadt et al., 1978). The SEPICA instrument however is a greatly improved version over its predecessor. The basic elements of SEPICA, including the electrostatic deflection system, the solid state detectors, the proportional counters, and their gas-pressure regulation system, have all operated reliably in previous space applications. An overview of the specific functional elements of SEPICA from other spacecraft programs is given in Fig. 1.0-1.

During Phase B, the design of the SEPICA instrument was further specified. In particular, it was shown that a multiwire frame proportional counter could be used to determine the charge state of the ions, and would not be the limiting factor for the charge resolution of the instrument. Highly integrated amplifiers(CAMEX) were studied for possible use in SEPICA. These amplifiers, based on a long history at MPE and CERN, have now been specifically modified and qualified for an application similar to SEPICA's in the SOHO CELIAS experiment. Because of the inherently flexible design the dynamic range can be easily adapted to the SEPICA requirements.

During Phase B, it was decided that three instruments will be serviced by one data processing unit (DPU) which would also serve as the command interface to the spacecraft command and Data Handling (C & DH) system. This multi-purpose DPU will be provided under contract to the University of New Hampshire by the Technical University at Braunschweig (Germany). Because the DPU services the needs of the SWICS and SWIMS instruments as well as those of SEPICA, it has become known as the S3DPU.



Functional Blocks	Heritage
Collimator System	IMP, ISEE, AMPTE, ULYSSES
Analyzer System	ISEE
Multi-Wire Proportional Counter	ROSAT
Ion-Implanted Solid State Detectors	SOHO
Anticoincidence System	SAMPEX
CAMEX/TIMEX Channels with Driver Logic	SOHO
Digital Electronics (ASIC Counters, ACTELs)	CLUSTER, FAST, SOHO
HV Supplies	ISEE, CLUSTER
Gas System	ISEE, SAMPEX

Figure 1.0-1 SEPICA Functional Blocks Heritage

2. PURPOSE & SCOPE

The purpose of this Instrument Functional Requirements Document is to describe which mission science objectives are relevant to the SEPICA instrument design, translate those science objectives into specific performance objectives for the instrument, and then describe the basic instrument architecture, partitioning the assembly and sub-assembly requirements in a way that the overall performance objectives can be met. This includes describing the performance criteria of the sensor assembly, as well as specifying the necessary support assemblies such as the power, data processing, thermal, etc., and identifying the constraints on resources such as mass, power, size, etc. Environmental constraints on the design are also identified.

Change in one of these external or implied constraints constitutes a change to the design requirements.

The IFRD is not meant to give detailed design specifications for all sub-assemblies of SEPICA. Those will be delineated as part of the detailed design process during phase C/D and documented in the Instrument Design and Data Package (ACE-CT-013-42). The IFRD identifies instrument components and assemblies at the block diagram level. Each instrument assembly is based on the design architecture selected during Phase B. Those specifications which are driven by external requirements such as spacecraft interfaces, environmental test specifications, etc. are noted. Signature of the IFRD by the Co-Investigator responsible for instrument design constitutes recognition of performance goals consistent with the mission requirements, and defines the scope of build for the instrument. The IFRD is the metric by which instrument design and performance will be measured throughout phase C/D. As described in the Caltech Configuration Management Plan (ACE-CT-100-031), the SEPICA IFRD will be under configuration management of the Caltech PMO. Changes to the IFRD, when required and approved, will be considered a change of scope on the instrument design. Consequently, the basis for evaluation of CRs will include consideration of the impact on mission science requirements as well as the potential cost and schedule implications.

Because SEPICA depends on the S3DPU for on board processing of sensor data and since the S3DPU acts as the data and command interface to the Spacecraft C&DH component, Appendix A of this document specifies the performance requirements on the S3DPU for SEPICA support. Moreover, since UNH is responsible for the S3DPU contract, Appendix B of this IFRD specifies the overall performance requirements for the S3DPU in its support of the three separate science instruments that it serves. An Interface Control Document that specifies all necessary electronic, and software interfaces to the DPU from SEPICA, SWICS, and SWIMS will be produced by UNH and put under the configuration management responsibility of UNH. A separate IDDP for the S3DPU describing its detailed design specifications and configuration will also be produced jointly by UNH and TUB, and be under the configuration control of UNH.

3. APPLICABLE DOCUMENTS

The following documents impact the design requirements for SEPICA or the S3DPU directly:

1) **ACE Mission Science Requirements Document (GSFC-410-ACE-004)**
Specifies instrument measurement requirements.

2) **Spacecraft Environmental Specification (JHU/APL 7345-9007)**
Specifies environmentas to which SEPICA and the S3DPU will be subjected.

3) **Environmental Design and Test Requirements for the ACE Payload (ACE-CT-100-22)**
Specifies requirements and procedures for meeting the Env. Spec.

4) **Payload Verification Matrix (ACE-CT-100-024)**
Specifies instrument verifications (analysis and/or testing) parameters required.

5) **Instrument Assurance Implementation Plan (ACE-CT-013-25)**
Describes the practices used at UNH to produce an instrument that meets the reliability and lifetime requirements commensurate with the ACE mission requirements.

6) **General Instrument Interface Specification (ACE-APL-7345-9005)**
Specifies general interface requirements for accommodation on the spacecraft.

7) **Specific Instrument Interface Specification for SEPICA (ACE-APL-7345-9013)**
Constitutes the Interface Control Document between SEPICA and the spacecraft.

8) **Payload Configuration Management Plan (ACE-CT-100-031)**
Describes the Caltech PMO CM procedures which must be consisted with those stated in the SEPICA IAIP>

9) **Instrument Design and Data Package (ACE-CT-013-42)**
Contains details of the design execution which meets the requirements described herein. Included are detailed design specifications for SEPICA and S3DPU components, assemblies and subassemblies. Also included are GSE design details. In general, the IDDP includes drawings, parts, and materials, test reports, analyses and instrument log books.

10) **Interface Control Document for the S3DPU**
(This is a place holder for whatever documents control the scope and interface to the S3DPU).

11) **Specific Instrument Interface Specification (ACE-APL-7345-9019)**
Specifies general interface requirements for accommodation on the spacecraft.

4. FUNCTIONAL / PERFORMANCE REQUIREMENTS & CONSTRAINTS

The science requirements delineated in the ACE Science Requirements Document (GSFC-410-ACE-004), drive the basic performance requirements for the SEPICA instrument. Mission science goals include *characterization of the ion distributions accelerated in solar flares as well as in interplanetary space during ESP (energetic storm particle) and CIR (co-rotating interaction region) events with regar to their elemental and ionic charge composition.*

4.1. Instrument Performance Requirements

Specific characteristics and measurement requirements for SEPICA are:

1) Measure the ionic charge state, Q, the kinetic energy, E, and the nuclear charge, Z, of energetic ions;

2) Measure these properties for elements H through Fe(refer to Table 6.3-1);

3) Uniquely identify charge states by designing an instrument with charge state resolution $\Delta Q/Q \leq 0.1$ up to >1 MeV/charge;

4) SEPICA will provide elemental resolution over a wide energy range (refer to Table 6.3-1)

5 For low mass numbers, SEPICA should also separate isotopes, for example, ^{3}He and ^{4}He, to allow the study of ^{3}He-rich solar events; [A goal, not a requirement]

6) During solar quiet times, SEPICA should also be able to directly measure the charge states of anomalous cosmic ray nuclei, including He, N, O, and Ne, which are presumed to be singly-charged; [A goal, not a requirement] and

7) Finally, in order to study small solar events with sufficient statistical accuracy a geometrical factor of ≈ 0.4 cm^{2}sr is necessary. [Minimum = 0.2cm^{2}sr]

These measurement requirements and objectives call for significant improvements in SEPICA over the ULEZEQ sensors in two specific parameters:

1) Increase of the geometrical factor by at least a factor of 20 (over the 0.02 cm^{2}sr accomplished with ULEZEQ) to improve significantly the measurement statistics;

2) Improvement in the charge resolution to $\Delta Q/Q \approx 0.1$ for an energy range up to at least 1 MeV/charge (over the $\Delta Q/Q \approx 0.3$ accomplished with ULEZEQ). (This allows resolution of individual charge states for elements with atomic masses up to oxygen.)

4.2. Ground Support Equipment Functional Requirements

The SEPICA GSE must serve several functions. The main function will be stimulus and control of SEPICA via a component of the GSE developed by the Technical University at Braunschweig. This component will be delivered early in SEPICA's development phase in the form of a breadboard or "Rumpf" DPU simulator. The capablities of this simulator will be limited in latch-up and emergency control circuitry, and a lessor version of software but otherwise identical in function to the flight DPU. It must support the instrument operation and test, interface to the S/C simulator (the design of which is provided by APL but will also be incorporated into the simulator), support the instrument for its environmental test and calibration phase, and last of all, provide ancillary support at S/C level integration.

The GSE will support the full calibration and functional tests of the SEPICA instrument. It will have the capability to send commands and receive, analyze, and display the output data stream. It will be able to stimulate electronically all amplifier inputs in predetermined combinations by pulsing the preamplifiers at various specified levels. The use of precisely controlled and stepped test pulses will allow accurate measurements of all amplifier/ADC response functions, discriminator thresholds, and noise characteristics, and thus provide complete functional checks of the instrument logic. The GSE will be implemented as a 486 PC based workstation with a combination of custom designed and commercially procured interfaces. The design and configuration of the supporting GSE workstation will be the responsibility of UNH.

Figure 4.2-1 is a block diagram of the GSE illustrating its functional subcomponents and its interfaces. Details regarding the interfaces between the instrument and the GSE are described in Appendix B, section B6.

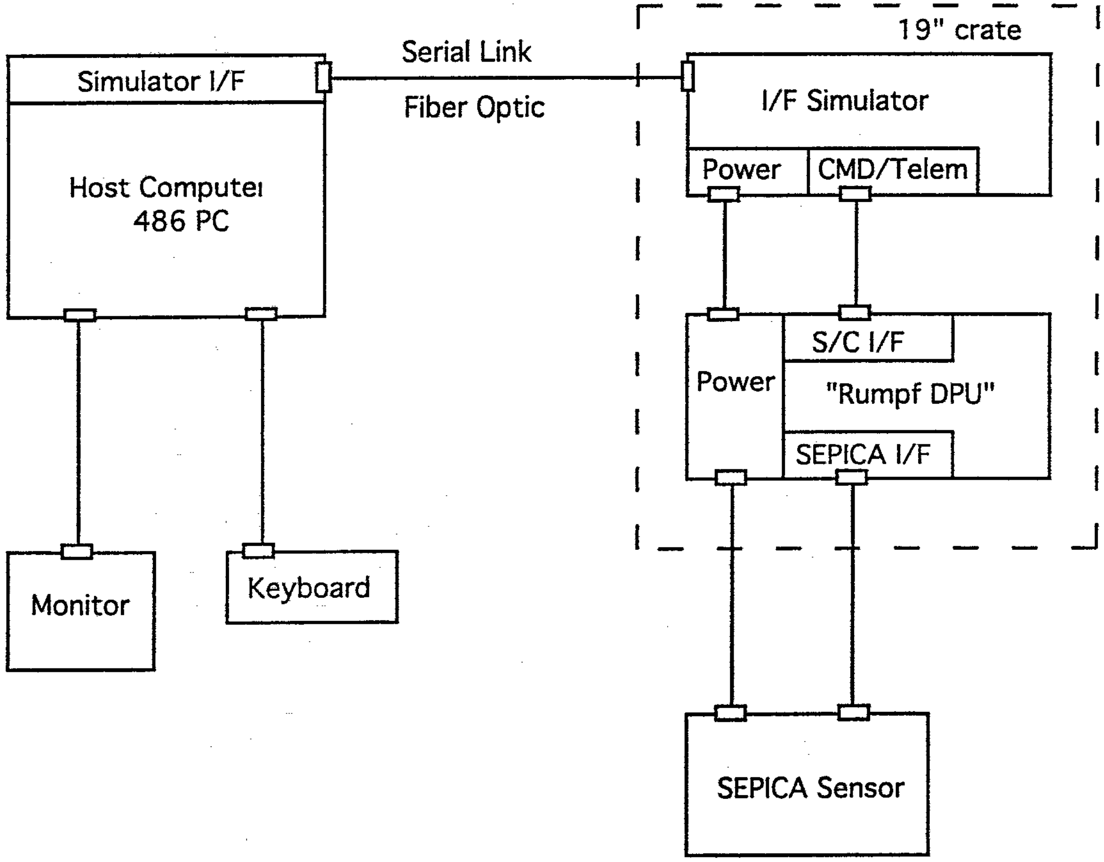


Figure 4.2-1 SEPICA GSE Block Diagram

4.3. Resource Constraints

Based on an architecture and design concept described below, a careful study of the SEPICA instrument resource requirements for mass, power, and volume and data have been completed in Phase B. Likewise, development of a spacecraft bus design has matured to the level that overall allocations of mass and power and data can be made to each instrument commensurate with their anticipated needs at this time. This allocation currently shows a reserve in both mass and power which must be carefully managed during phase C/D. The following table (Table 4.3-1) allots resources of mass, power, and data to SEPICA and the implementation of this instrument must not only be specified by its performance requirements listed above, but constrained to be within these baselined resource allocations.

Table 4.3-1 Resource Constraints

Resource	Phase B Estimate	Allocation
mass	19.5 kg	22.5 Kgrms
power*	6.8W nominal, 8.2W peak	7.8 W/9.4 W
average data rate*	608 bps	608 bps

* Includes power for internal thermal control

** Peak data rate of SEPICA must be coordinated with the data requirements of the SWICS and SWIMS instruments such that the total rate available to the S3DPU (1624 bps) is never exceeded.

4.4. Operational Constraints

As discussed in the introduction, certain externally imposed requirements dictate the *conditions under which the instrument must perform.* Table 4.4-1 lists the known "operational constraints," references the source of the requirement, and notes which of the instrument subsystems or assemblies are impacted by these constraints.

Table 4.4-1 Operational Constraints

Constraint	Source	Impact
Instrument angle with respect to sun restricted to 20 degrees max.	Impact of sun (UV) on PC window	Thermal control and operational temperature limits--principal impact on entrance aperture assembly.
Temperature	Detector temperature must be controlled to stay within certain parameters	SEPICA is isolated from S/C and is responsible for its own thermal control
Lack of contact for up to 48 hrs.	DSN scheduling constraint for ACE	requires certain functions be autonomous
Contamination	Sensitivity of solid state detectors	ground handling and integration (requires purge)
Corona discharge and/or contamination		Outgas instrument before 30kV P.S. brought to nominal voltage HV operation limited to TBD(except during TV) SSD bias and HV operation prohibited during vacuum pump-down

5. INTERFACE FUNCTIONAL REQUIREMENTS

Functional interface requirements on interfaces between the instrument and the spacecraft, S3DPU, and GSE are briefly described below. Details of the S/C interface design are specified in the SEPICA SIIS (ACE-APL-7345-9013). Details of the interface between the SEPICA instrument and the S3DPU will be documented in the S3DPU Interface Control Document. Functional interface requirements between the S3DPU and the spacecraft are described in the S3DPU SIIS (ACE-APL-7345-9019). Those dealing with the instrument GSE will be described in the SEPICA IDDP (ACE-CT-013-42). The following subsections specify only the functionality of the interfaces that are required or constrained by those elements discussed in section 4.

5.1. Instrument / Spacecraft

A single cable interfaces the SEPICA instrument to the spacecraft. This cable carries two redundant 28V primary power lines as well as a redundant set of heater power, pyro power, and analog temperature readouts.

5.2. Instrument / DPU

The second cable interfaces the instrument to the S3DPU. This cable will carry the science and housekeeping data as well as commands used for instrument configuration.

5.3. Instrument / GSE

If the GSE is to be connected to the SEPICA instrument or the S3DPU after they have been integrated on to the spacecraft, the GSE interface shall be of a design which isolate GSE power ground from spacecraft star ground.

6. SEPICA INSTRUMENT DESCRIPTION & REQUIREMENTS

6.1. Principles of Operation

The sensor employs electrostatic deflection of incoming ions in a collimator-analyzer assembly, and then measures their impact position in the detector plane. dE/dx - E are determined using a proportional counter / solid state detector combination. Potential background from penetrating radiation is suppressed by the use of an anti-coincidence detector.

Figure 6.1-1 shows the basic measuring principle. To simultaneously determine the energy E, nuclear charge Z and ionic charge Q of the incoming particles several methods are combined:

- Energetic particles entering the multi-slit collimator, which focuses the particles on a line in the detector plane, will be electrostatically deflected between a set of electrode plates which are supplied with a high voltage up to 30 kV (to be set by telecommand).
- The deflection, which is inversely proportional to energy per charge, E/Q, is determined in a multi-wire thin-window proportional counter.
- The thin-window proportional counter is also used to measure the specific energy loss dE/dx, which depends on the energy E and the nuclear charge Z of the particle.
- Finally, the residual energy of the particle, E_{Res}, is directly determined in the solid-state detector.
- An anti-coincidence system, which consists of a CsI scintillator and silicon photodiodes, is used to suppress background signals from penetrating high energy particles. This is of particular importance for the study of low fluxes in weak solar events and during quiet times.

Using the relations

$$dE/dx \sim Z^2(E/M)^\alpha$$

$$Q = (Q/E)*E, \quad \text{and}$$

$$M \sim 2*Z$$

the ionic charge, Q, the initial energy, E, and the atomic number, Z, as well as the atomic mass number M (for low mass ions, e.g., He) can be separately derived for individual particles. The coefficient α is close to 1/2 for energies greater than $\approx$ 5 MeV/Nucleon. At lower energies the energy loss is reduced due to incomplete ionization of the particles. The correct relation can be taken from tables (e.g. Ziegler, 1980) and will be calibrated with an ion accelerator for the flight instrument.

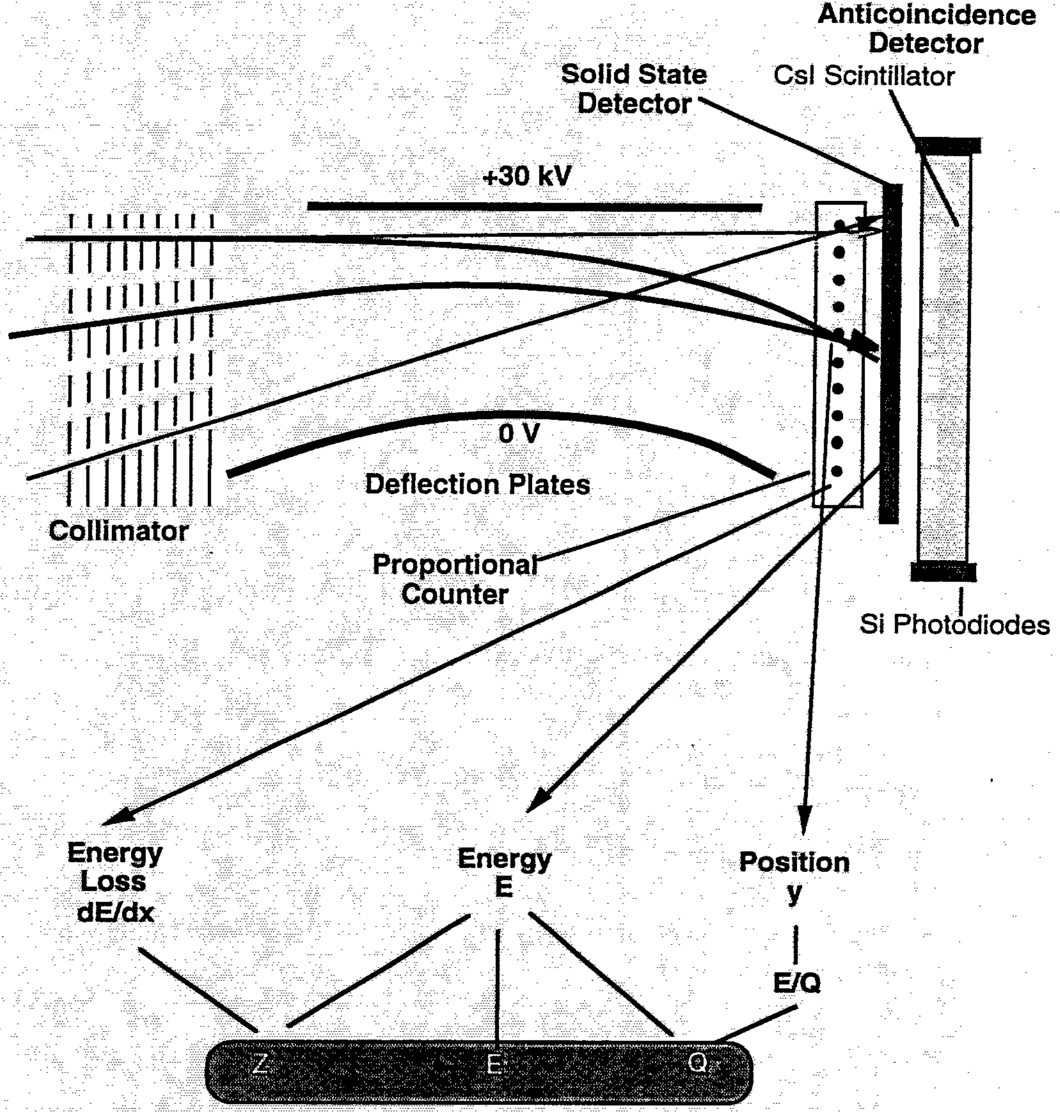


Figure 6.1-1 SEPICA Principles Of Operation

6.2. Design Philosophy

SEPICA will be designed as an improved version of the ULEZEQ sensors on ISEE-1 and ISEE-3. Improvements will be made in both sensitivity and charge resolution. However, the same basic techniques will be used again, but refined, and some subsystems will be replaced by newer developments. For example, the position measurement is now performed in the proportional counter with a technique used on the German X-ray satellite ROSAT and highly integrated circuits will be utilized to reduce the volume and weight of the electronics. However, no new technologies will be developed for this instrument.

6.3. Requirements Partitioning

In this section we describe an architecture which allows the top level instrument performance requirements to be met. Figure 6.3-1, the SEPICA block diagram, illustrates the principle functional components of the instrument and shows how they are interrelated.

Table 6.3.1 lists the controlling design Parameters and constraints for the SEPICA instrument. Onboard data processing requirements of SEPICA on the S3DPU are discussed in Appendix A. Appendix B lists other requirements on the S3DPU.

Table 6.3.2 identifies the required components and assemblies/subassemblies which constitute the SEPICA flight instrument subsystem. Required constraints in parameters associated with the listed components, assemblies or subassemblies are also given.

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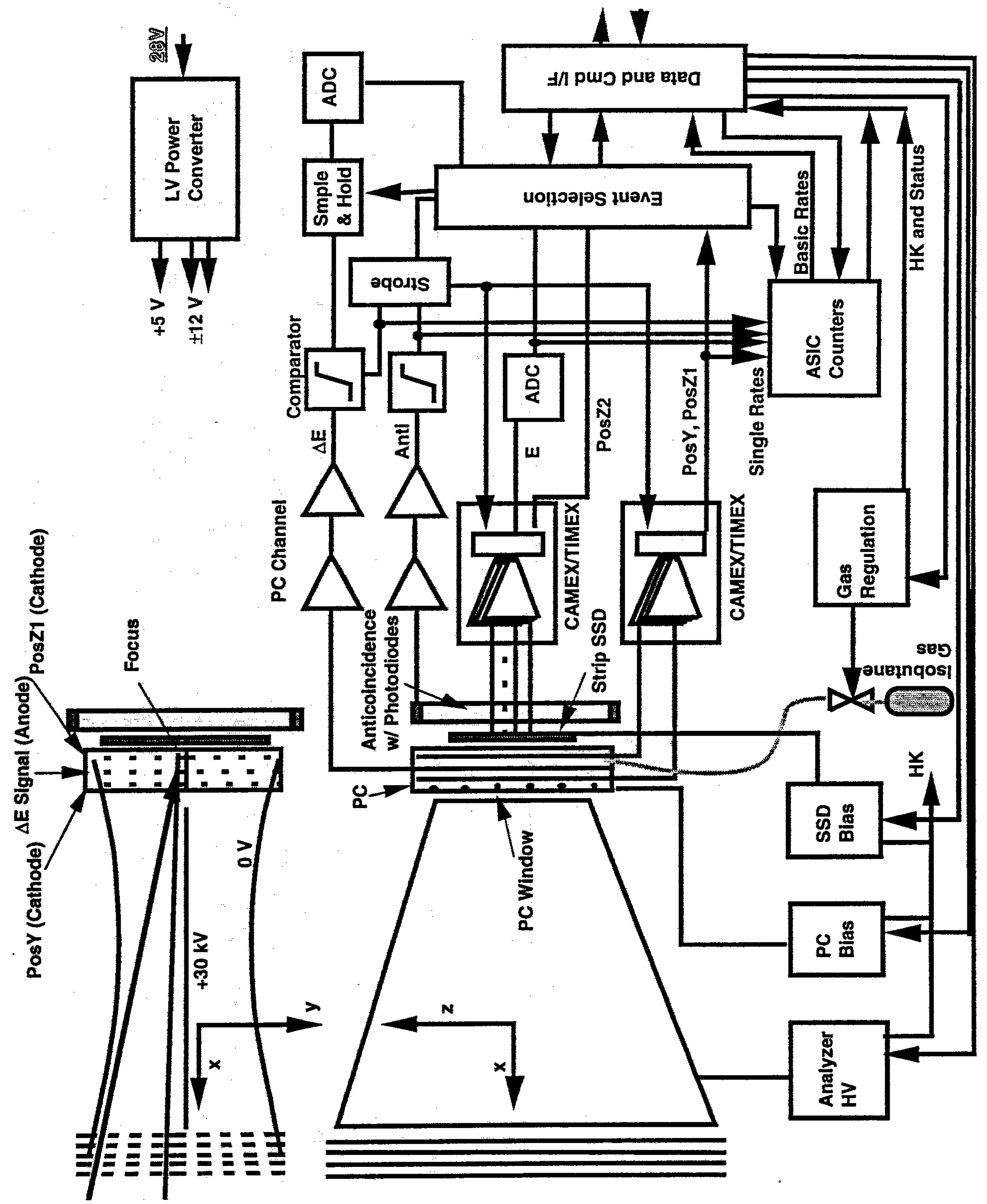

Figure 6.3-1 SEPICA Functional And Electrical Block Diagram

Table 6.3-1 SEPICA Instrument Controlled Design Parameters

	REQUIREMENT	GOAL
Field of View		80 x 15 deg.
Geometric Factor (low resolution)	≥ 0.2 cmsqsr	0.36 cmsqsr
Geometric Factor (high resolution)	≥ 0.03 cmsqsr	0.06 cmsqsr
Particle Species Measured (Nuclear Charge Z)	$2 \le Z \le 28$	$1 \le Z \le 28$
Energy Range For Charge State Resolution	$0.3\text{-}2.0\ \frac{\text{MeV}}{\text{Q}}$	(Z= 6) $0.3\text{-}2\ \frac{\text{MeV}}{\text{Q}}$ (Z=26) $0.1\text{-}2\ \frac{\text{MeV}}{\text{Q}}$
Charge Resolution (dQ/Q) $\left(\le 1\frac{\text{MeV}}{\text{Q}}\right)$	15% (high res.) 50% (low res.)	10% (high res.) 30% (low res.)
Charge Resolution (dQ/Q) $\left(\le 2\frac{\text{MeV}}{\text{Q}}\right)$	30% (high res.) 100% (low res.)	20% (high res.) 60% (low res.)
Element Resolution Energy Range	$0.3 - 8\ \frac{\text{MeV}}{\text{Nucleon}}$	(Z=6) $0.2\text{-}17\ \frac{\text{MeV}}{\text{Nucleon}}$ (Z=26) $0.1\text{-}32\ \frac{\text{MeV}}{\text{Nucleon}}$
Event Rate Range, R	1/hr ≤ R ≤ 10^ 3/sec	1/hr ≤ R ≤ 5*10^3/sec

Table 6.3.1 SEPICA Instrument Controlled Design Parameters (continued)

	REQUIREMENT	GOAL
Temperature Range, T (deg C)		
- Preferred Operating	$-5 \le T \le +15C$	
- Allowable Operating	$-10 \le T \le +30C$	
- Qualification	$-20 \le T \le +50C$	
- Survival	$TBD \le T \le +60C$	
Design Lifetime (In Space Operating with total radiation dose ≤10K Rads)	≥ 2 Years	11 Years
Mass (Including intra-instrument cabling, but not DPU harness)	≤ 22.5 kgm	≤ 21.5 kgms
Power, (watts):		
- Nominal	≤ 7.8 Watts	≤ 7.5 Watts
- Peak	≤ 9.4 Watts	≤ 9.0 Watts

Table 6.3.2 SEPICA Components And Assemblies/Subassemblies

FUNCTIONAL ELEMENT	DESIGN GOAL
• Electrostatic Deflection	
- Qualification Voltage	~ 32,000 volts
- Normal Operating Voltage @ ~ 3 uAmps	≤ 30,000 volts
• Collimator	
- Entrance Size (incl. closed cover)	~ 547 x 371 mm
- Transparency	> 25 %
• Isobutane (C4H10) Gas Components Assemblies and Subassemblies	
- Size, Each of Two Tanks	< 360mm high x 108mm dia.
- Capacity, Each of Two Tanks	< 2.4 liters
- Tank Qualification Pressure	3000 psig
- Tank Operating Pressure	45.7 psia (flight),31.0 psig (ground)
• Proportional Counter	
- Entrance Window Thickness	650 nanometers
- Operating Pressure (in 0.36 liter volume)	35-45 mbar
- Flow Rate	0.75 cc/minute
- Bias Supply Qualification Voltage @ 1 mAmp	2,400 volts
- Nominal Bias Supply Voltage	1,500 volts
- Minimum Penetration Energy	100 kev/nucleon (for Oxygen)
- Position Resolution	< 0.3 mm
• Ion-Implanted Solid State Detectors	
- Thickness	500 um
- Bias Voltage @ 100 uAmps	≤ 150 volts
- Voltage Turn-on Rate	< 30 volts / second
- Nmber of Pixels < 1Mev/q	8
- Number of Pixels > 1 Mev/q	8
- Noise	< 10 keV
• Anticoincidence Detector	
- Number of Scintillator/Detector Units	3
- Size, Each of 3 CsI Scintillator Crystals	100 x 60 x 10 mm
- Scintillator Quantum Yield	1.76 femto-coulombs/MeV
- Scintillator Noise Level	< 150 keV
- Number of 10 x 20 mm PIN Photodetectors	16
- Photodetector Bias Voltage @ 100 uAmps	≤ 150 volts

Table 6.3.2 SEPICA Components And Assemblies/Subassemblies (continued)

FUNCTIONAL ELEMENT	DESIGN GOAL
• Low Voltage Power Supply (LVPS)	
- Number of Voltages Generated	Three: +/-12vdc, +5vdc
- Overall LVPS Conversion Efficiency	> 70 %
- LVPS Noise	< 50 mvolts
• Analog and Digital Electronics Consisting of Charge Amplifiers, Comparators, ADCs, ASIC Counters, Event Selection Logic, plus Data and Command Interfaces:	
- Total Number of CAMEX/TIMEX Chip Sets Used	Twelve (12)
- Data Acquisition Time, Pulse Height Analysis	600 nanoseconds
- Data Generated per Valid Raw Event Selected 705 bits (SEPICA Eng'r'g Mode)	99 bits to 126 bits (Science Mode)

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APPENDIX A

SUPPORT FOR SEPICA TO BE PROVIDED BY THE S3DPU

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A1 SUPPORT OF SEPICA BY THE S3DPU

The SEPICA instrument will be served by a common Data Processing Unit (DPU) together with the SWICS and SWIMS experiments. In the following sections the requirements for the DPU from the side of SEPICA are compiled.

The following tasks have to be performed by the DPU for SEPICA:

- Control sensor status routinely;
- Monitor housekeeping values;
- Receive, decode and execute memory load commands;
- Perform in-flight calibration cycle of sensor on telemetry request (a cycle of different In-flight Calibration commands, various settings of the stimulation DACs for the sensor elements should be stored in the DPU);
- Read out SEPICA Rate Counters every sector and accumulate the rates into DPU memory;
- Read raw pulse height analysis (PHA) events from SEPICA buffer memory and feed into the telemetry stream;
- Calculate the azimuthal sectoring from the S/C sun sensor and timing information and add the sector information to the Rate and PHA data;
- Format and transfer the experiment data block into the S/C telemetry. In addition to these regular formatting and control tasks the DPU is supposed to carry out some higher functions for SEPICA;
- Derive calculated parameters for each event and apply necessary corrections to events according to algorithms given below;
- Feed samples of PHA events into the telemetry buffer according to a predefined priority scheme for different particle species and energies;
- Classify events into Matrix Rates using look-up tables.

Figure A1-1 shows the traces of various elements in a ΔE versus E representation. From these traces, which have been derived by simulations and which will be refined by calibrations, the algorithms for the DPU will be derived. The boxes in the figure indicate regimes with different priority for the acceptance of events, if the total rates exceed the capability of the telemetry for pulse height events.

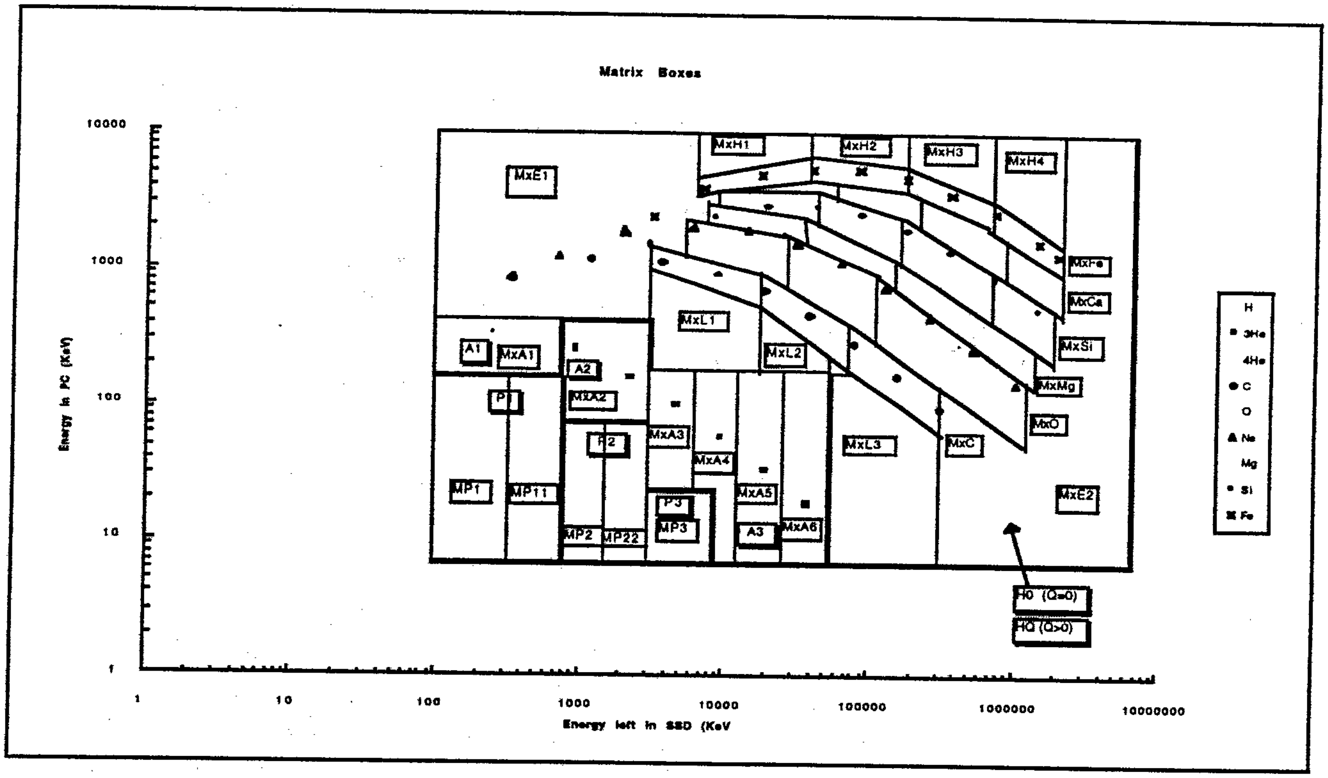

Figure A1-1 Boxes For The Basic Rates And Priorities In A ΔE Vs. E Diagram

A1.1 Control Software

The S3DPU must be the interface between the SEPICA instrument and the C & DH component of the S/C. Functionally, control of the SEPICA instrument by the S3DPU requires that the S3DPU to do the following:

- o receive, decode and execute memory load commands for SEPICA;
- o send memory information to registers in SEPICA on command;
- o perform in-flight calibration cycles in SEPICA on command, which stimulate various detector channels in SEPICA according to a predefined sequence which resides in the DPU memory

A1.2 Data Processing Requirements for the S3DPU

The data from SEPICA into the DPU consist of the following types:

1) Raw Event Data contain the energy loss, energy and position information from the proportional counters and SSDs. Depending on the number of adjacent wire strips which will be taken into account for the position determination each event will 99 - 126 bits of information. For diagnostic purposes an engineering mode is required in which the information of all strips, i.e. 705 bits per event are to be transmitted.

2) Rate Data summarize the number of individual triggers in the individual detector elements and for some key coincidence conditions in order to monitor the detector performance and to normalize the event rate. The detector monitor rates are compiled in Table A1.3-4. These rates are accumulated in the SEPICA digital electronics. In addition, separate rates for protons and all heavier particles will be generated in the sensor electronics. All other detailed rate information is to be generated in the DPU.

3) Housekeeping Data monitors the instrument's status and health. This information is also to be used to monitor critical parameters of SEPICA, such as **Deflection HV** and **PC HV.** Irregularities in these parameters require immediate action by the DPU

A1.3 SEPICA Data Stream through the S3DPU

A1.3.1 Pulse Height Event Data

The Raw Event Data Input from SEPICA into the DPU is organized as follows:

1) ΔE	**10 Bit**	Pulse height of PC counter signal
2) n times		(position in deflection direction)
PosYP	**10 Bit**	Pulse heights of individual strips
PosYC	**5 Bit**	Strip no.
n = 3-4 for scientific data, n = 32 for a special engineering format		
3) m times		(position in fan direction)
PosZ1P	**8 Bit**	
PosZ1C	**4 Bit**	
m = 2-3 for scientific data, m = 16 for a special engineering format		
4) **E**	**10 Bit**	Pulse height of SSD signal
5)		(position in fan direction)
PosZ2	**4 Bit**	Strip no. of signal
6) **S**	**3 Bit**	Sensor system code
7) **Prio**	**3 Bit**	Priority code (3 E for H and He, 1 Z>2 Q=0, 1 Z>2 rest)

Thus the raw data stream from SEPICA into the S3DPU contains:

99 - 126 Bit per event **n = 3-4, m = 2-3**
for the scientific modes

and up to

705 Bit per event **n = 32, m = 16**
for an engineering diagnostic mode

No compression of these data is required in the engineering format. This format should allow a dump of the raw data.

In the scientific modes the Live Pulse Height Events should be compressed in the following way as
Output data into Telemetry:

1) ΔE	**10 Bit**	Pulse height of PC counter signal
2) **Y**	**10 Bit**	Computed position in deflection direction
3) **PosZ1**	**4 Bit**	Computed position in fan direction
4) **E**	**10 Bit**	Pulse height of SSD signal
5) **PosZ2**	**4 Bit**	Strip no. of signal, pos. in fan dir.
6) **S**	**3 Bit**	Sensor system code
7) **Prio**	**3 Bit**	Priority code (H0/HQ Bit set by S3DPU)
to be added by the S3DPU:		
8) **Azi**	**3 Bit**	Direction from S/C spin clock
Sum	**47 Bit per event**	
+ spare	**1 Bit**	
	48 Bit per event	(3 Words per event)

The following Algorithms will have to be applied to the **Raw Pulse Height Events** in order to transform them into **Live Pulse Height Events**

1) Y:	Deflection direction

$$\mathbf{Y = \Sigma_i(PosYP_i*PosYC_i)/\Sigma_i(PosYP_i)}$$

2) PosZ1:	Fan direction from proportional counter

$$\mathbf{PosZ1 = \Sigma_i(PosZ1P_i*PosZ1C_i)/\Sigma_i(PosZ1P_i)}$$

b) Priority Code

The priority code will be set using comparators in ΔE and E in the SEPICA sensor.

The areas of the priority codes will represent rectangular boxes in a ΔE vs. E diagram. The complete valid event range is defined by a lowest DE and E threshold in the SEPICA sensor.

This priority code will be transmitted with each event to the S3DPU. It will be used to reduce the data flow from SEPICA to the S3DPU in case one of the proton count rates exceeds a rate of ***TBD*** counts/sec. Then the flow of H and He will be reduced, using either an artificial dead time or a polling scheme. In the latter case the events from the different priority classes will be transmitted according to a TBS distribution.

Table A1.3-1 Priority Codes For The Data Transmission To The S3DPU

Code	Particles	Transmission
P1, 2, 3	Protons for 3 energy ranges	3
A1, 2, 3	Helium for 3 energy ranges, both ^{3}He and ^{4}He	6
H	heavy ions $Z > 2$	23

The number under transmission gives the number of polls for each category in case the rate exceeds the available bandwidth between SEPICA and S3DPU. The 3 energy ranges of H and He have equal weight.

The distinction between P, A and H will be made in SEPICA. A further subdivision between H0 ($Q = 0$) and HQ ($Q \geq 1$) has to be made in the S3DPU. The S3DPU then uses the code for the allocation of telemetry space for the Live Pulse Height events.

Table A1.3-2 Priority Codes For The Telemetry

Code	Particles	Transmission
P1, 2, 3	Protons for 3 energy ranges	3
A1, 2, 3	Helium for 3 energy ranges, both ^{3}He and ^{4}He	6
H0	heavy ions $Z > 2$, $Q = 0$	5
HQ	heavy ions $Z > 2$, $Q \geq 1$	18

The number under transmission gives the number of polls for each category in case the rate exceeds the available telemetry. The 3 energy ranges of H and He have equal weight.

A1.3.2 Matrix Rates

a) Live Pulse Height Events

To compute Matrix Rates from the Raw Pulse Height Events first the step to the Live Pulse Height Events has to be made.

b) Corrections for incoming direction

Then corrections for the incident direction of the ions (in fan direction) have to be made. Both, PosZ1 from the PC and PosZ2 from the SSD, are evaluated for 4 Bits. The mapping of the 2 position codes are to be such that

$$\mathbf{PosZ1 = PosZ2}$$

means

Normal incidence of the ion

Thus the absolute value:

$$\mathbf{j = |PosZ1 - PosZ2|}$$

is a unique value of the incoming angle θ. Two corrections are based on this information:

i) correction for the path length in the PC in the DE signal:

$$E' = E * \cos\theta$$

The corrected value $\Delta E'$ is to be used for further computations.

ii) correction for the deflection at oblique angles:

$$Y' = Y * \cos^2\theta$$

The corrected value Y' is to be used for further computations.

To simplify the task of the S3DPU, a look-up table can be used. Up to 16 values of cos θ will be stored for $0 < \theta < 40°$. For ii), a second table with $\cos^2\theta$ is stored.

c) Matrix Rates

The events will be accumulated into memory according to a Matrix Rate scheme. The Matrix Rates will be defined in the ΔE vs E matrix as diamond shaped boxes. For each box, the corner points are defined with ΔE and E values.

In addition, the events will be sorted according their charge state Q^*

$$Q^* = C1*Y'*E$$

where Q^* is a quantity derived from the measured energy E which represents the original particle energy reduced by the energy loss in the proportional counter and various dead layers in the sensor, which is energy and element dependent. Therefore, the limits for the charge ranges need to be defined individually for each element and energy range. A strawman compilation of Matrix Rates with the necessary box limits is given in Table A1.3-3.

Table A1.3-3 Matrix Boxes

Matrix Code	Particles	E	Azi	Q	No. of Boxes	No. of E	LUT values ΔE	LUT values Q
Priority P1, P2, P3:	(Priorities as set up by SEPICA)							
MxP01..3	H(Q=0)	3	-	1	3	0	0	3
Priority A1, A2, A3:								
MxA1, 6	He+, 2+	6	8	2	12	7	14	6
MxHe01..3	He(Q=0)	3	-	1	3	0	0	3
Priority HQ:								
MxC1..3	C	3	-	2	6	4	8	3
MxO1..3	O, Ne	3	-	2	6	4	8	3
MxMg1..3	Mg etc	3	-	2	6	4	8	3
MxS1..3	Si, S	4	-	3	12	5	8	8
MxCa1..3	Ca etc.	4	-	3	12	5	8	8
MxFe1..3	Fe	4	-	3	12	5	8	8
MxH1..3	heavy	4	-	1	4	5	4	0
MxL1..3	<C	3	-	2	6	5	4	3
MxE1, 2	rest	2	-	1	2	1	0	0
Priority H0:								
MxCNO0	CNO	2	-	1	2	1	0	2
MxHev0	Z>8	2	-	1	2	1	0	2

86 Mx Rates + spares = 128

Including sectors for MxA to be stored

170 Mx rates + spares = 256

It is planned to make all Mx Rates contiguous in ΔE vs. E. The rates MxL, MxH and MxE occupy the remaining space not used by the other rates. Therefore, the outer boundaries of these rates will not be defined. The contiguous coverage allows a cross check with the Basic rates on the ground.

A1.3.3 Rate Data

Count rates will be accumulated by SEPICA in 24 x 24 Bit ASIC counter chips. The counters are to be read out at the end of each azimuthal sector. The readout protocol is described the in the ASIC counter description. The S3DPU has to store the counter readings in its memory and either accumulate them over the specified accumulation time for each sector individually or integrate over the complete spin depending on the rate. There will be:

Monitor Rates which contain the counts of individual sensor elements
Basic Rates which contain absolute count rate information for events

The Monitor Rates are compiled in Table A1.3-4.

Table A1.3-4 Monitor Rates

Rate	No.	Sectors	Bits/read	Bits/write	Time
PC	6	8	16	12	120
Anti	3	1	16	12	120
PC*Anti	6	1	16	12	120

The Basic rates are derived from the Priority scheme as discussed above. Each Priority Class makes at least 1 Basic Rate. The Proton rates are subdivided further.

Table A1.3-5 Basic Rates

Rate	Energy	lo/hi	Sectors	Bits/read	Bits/write	Time
P1..5	5	2	8	16	12	60
A1..3	3	2	8	16	12	60
H0	1	2	8	16	12	60
HQ	1	2	8	16	12	60

lo/hi: refers to the low resp. high resolution sections of SEPICA. SEPICA has 4 low resolution and 2 high resolution sections. There will be combined rates for all low and all high resolution sections.

A1.3.4 Housekeeping and Status Information

In addition housekeeping and status information has to be read and formatted.
This information is also to be used to monitor critical parameters of SEPICA:

Deflection HV

PC HV

If n (***TBD***) glitches are detected, the voltage needs to be reduced by m (***TBD***) steps and a Flag should be sent into the telemetry.

APPENDIX B

FUNCTIONAL REQUIREMENTS ON THE
SWICS/SWIMS/SEPICA (S3)
DATA PROCESSING UNIT (DPU)

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B1 INHERITANCE:

The ACE S3DPU which provides onboard data processing capabilities for the SWICS, SWIMS and SEPICA instruments has its heritage in the ULYSSES SWICS, GEOTAIL EPIC, and SOHO CELIAS data processing units (DPUs).

B2 TASKS:

Tasks performed by the S3DPU for the SEPICA instrument are described in APPENDIX A. For the SWICS and SWIMS instruments, the tasks to be performed are as follows:

B2.1 Path Length Correction

Path length correction for the time-of-flight according to the impact positions (SWIMS).

B2.2 Classify (E) - T events

- a two-dimensional M versus M/Q matrix for SWICS
- a one-dimensional M vector (SWIMS) and count them separately
- with low res. in matrix space and high res. in time (Matrix Rates)
- with high res. in matrix space and low res. in time (Matrix Elements)

B2.3 Prioritize

Classify (E), T-events acc. to a priority scheme and to insert priority events into the pulse height analysis (PHA) section of the Experiment Data Block (EDB).

B2.4 Control Stepping Voltage

Control stepping of the deflection voltage acc. to an adaptive scheme (SWICS & SWIMS).

B2.5 Control Sensor

Control the sensor status and the reconfigurable DPU parts routinely or triggered by telecommand.

B2.6 Initialize DPU

Initialize DPU after a latch-up induced power-down period.

B2.7 Housekeeping

Monitor the housekeeping (HK) values.

B2.8 Data Formatting

Format and transfer the Experiment Data Block.

B2.9 Memory Loads

Receive, decode, and execute memory load commands.

B3 DPU ARCHITECTURE

B3.1 Redundancy Concept

The S3DPU uses a massive redundancy concept to withstand the environmental conditions for VLSI-electronics in space for the ACE mission. A block diagram of the DPU is shown in FIgure B3-1.

Table B3.1-1 illustrates the protections that will be used:

Table B3.1-1 Redundancy Approach

Board	Protection	add. H/W
CPU	- double redundancy against total failure, switched by H/C or by S/C command Line - SECDED for 128 KB RAM, 128 KB ROM by Hamming Code	- 2nd CPU system, H/C - 64 KB RAM, 64 KB ROM HST 630 (SOS)
Classification	- 3 identical Classification boards, S/W configurable for each sensor, cross switch CPU controlled - parity check for classification tables, 384 MB	- programmable classif. control, cross switch - parity checker
CMD/Telm. I/F	- double redundancy against total failure, switched by CPU - RAD-hard FIFOs, Marconi, SOS	- 2nd I/F system

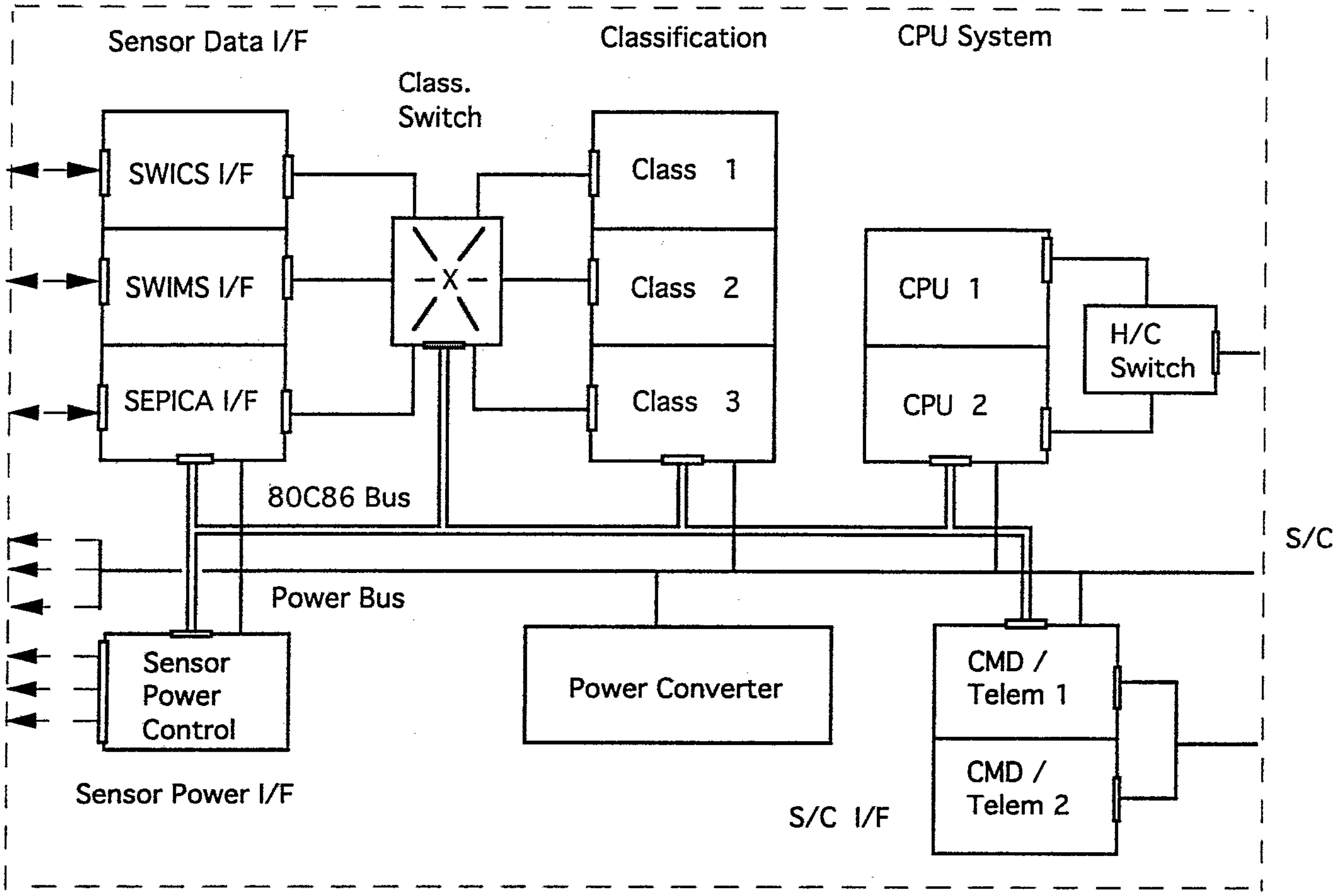


Figure B3-1 Block Diagram

B4. INTERFACES

The S3DPU shall provide the necessary command and data interfaces between the ACE Spacecraft command and data handling (C & DH) unit and the SWICS, SWIMS & SEPICA instruments. On the spacecraft side, the interfaces shall be in accordance with the S3DPU SIIS (ACE-APL-7345-9019). On the instrument side, the S3DPU interfaces shall be in accordance with TUB drawing number S3DPU-ICD-001.

B5. SPACECRAFT RESOURCES

The S3DPU shall be designed to stay within the spacecraft allocated constraints listed in Table B6-1.

Table B5-1 S3DPU Constraints

Resource	Estimate	Allocation
Mass:	4.0 kg box, 1.8 kg cables	6.7 kg*
Power:	3.8 nominal, 4.0 peak	4.2 nominal, 4.5 peak
Data Rate	1624 bps	1624 bps

* allocation includes cabling

B6. ELECTRICAL GROUND SUPPORT EQUIPMENT (EGSE)

EGSE for the S3DPU will consist of several units. Table B6-1 and B6-2 list the intended usage and GSE prime functions. Functional elements and configuration for bench checkout, S/C tests and flight operations are shown in Figure B6-1.

Table B6-1 GSE Usage

* hardware and software development of the DPU
* bench tests during instrument integration
* sensor calibration tests, instrument qualification test
* integrated system tests
* data quicklook during mission

Table B6-2 GSE Prime Functions

- **Spacecraft Interface Simulation**
  - instrument power supply
  - instrument telecommand
  - instrument digital science and digital HK data aquisiton
  - instrument analog HK data aquisition
  - S/C service signals(e.g. spin information, time information, inter-eperiment data exchange)

- **Instrument Control/Monitoring**
  - display of HK and science data(configurable:textual, plot, etc.)
  - instrument data monitoring(e.g. limit checks for HK values)
  - recording of telemetry data(mass storage)
  - instrument commanding(command data base)
  - automatic test sequences
  - optional: customized data evaluation display (e.g. for calibration, quicklook)

B6.1 S/C Simulator Subsystems

The S/C simulator utilizes a VME card cage system allowing versatility for changing configurations as application needs arise. Some of the elements of the simulator include:

* An 80386 microprocessor system which provides central control of S/C simulator subsystems and handles commands received via Ethernet I/F and also buffers telemetry data received from the experiment hardware.

* The digital TLM data acquisition control system generates TLM signals in the form of shift clock, word gate, frame pulse, etc., via programmable pulse timing(typ. dt=50ns).

* Telecommand control generates telecommnad signals also via programmable word timing(typ dt=50ns).

* The S/C service signal simulates all S/C service signals such as: spin clock at a programmable frequency; sun pulse at a programmable position; and on-board programmable clock.

* Analog data acquisition control monitors experiment analog HK signals and controls S/C thermistors attached to the experiment hardware.

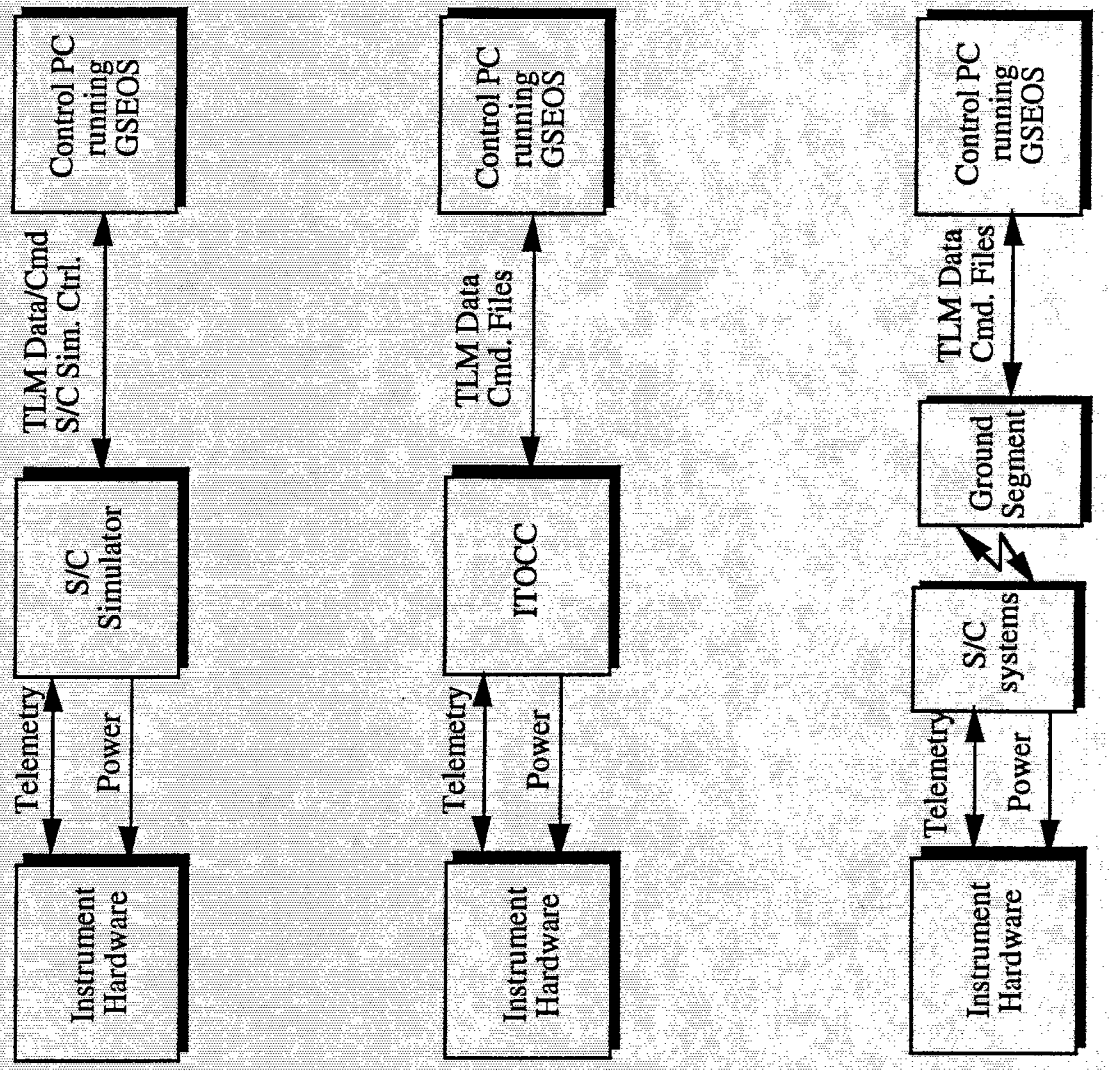
* Power supply control/monitoring provides experiment power with voltage and current monitoring.

* Driver/receiver control implements S/C electrical interfaces through the S/C redundancy concept to allow adequate control of all signals individually.

* Hard disk allows data buffering required by TCP/IP for storage of S/C simulator operating system and storage of S/C simulator configuration.

* Optional floppy disk allows S/W updates, system backup, and data exchange.

* Ethernet interface, which is a standard interface for GSE systems, provides the overall connection to the Control PC.



- **Bench Test**
  - for instrument development
  -S/C Simulator emulates S/C C&DH, and power supply
  - Control of PC for S/C simulator control, telemetry data handling (display, recording, etc.), and real time commanding

- **Spacecraft Integration**
  - for instrument integration into S/C
  - ITOCC emulates S/C systems
  - Control PC for telemetry data handling (display, recording,etc.), real time commanding and command file generation

- **Flight Operations**
  - for flight phase
  -Ground Segment delivers TLM data, command staus, S/C status
  - Command PC for telemetry data handling (display, recording,etc.), real time commanding and command file generation

Figures B6-1 EGSE Use for Different Program Phases