ENERGETIC PARTICLES AND ION COMPOSITION EXPERIMENT (EPIC)
SOFTWARE REQUIREMENTS and
DATA DEFINITION DOCUMENT
FOR THE
ISTP GEOTAIL SPACECRAFT

REVISION d

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INTRODUCTION

The EPIC instrument is comprised of two separate science subsystems known as ICS and STICS. These subsystems, each made up of a sensor and an analog electronics pre-processing unit (AE), will receive commands from and send data to a common data processing unit, or DPU. All instrument software resides in the DPU.

The purpose of this document is to provide the requirements for the DPU processing software. It also contains the basis for the classification unit memory maps also generated and stored in the DPU hardware.

In all cases, the DPU software must support the design and operational guidelines contained in the GEOTAIL spacecraft documentation (GTL documents). Any differences between the requirements stated in this document and the GTL documents should be highlighted and eventually resolved.

The DPU software will primarily reside in PROM memory in the DPU hardware. Upon initial delivery to APL, configuration control will applied to the DPU software and hardware. Because of the ability to change or add code during the development phase, some items in this document, such as the macro contents, are not determined at this time. These items will be added to the software as they become available.

GENERAL BACKGROUND

The DPU will be responsible for all interfaces between the spacecraft and STICS and ICS subsystems. It will handle all command processing, telemetry formatting, analog interfaces, power switching, alarm monitoring, and mechanical device control for the instrument. Through the use of the spacecraft-provided timing and spin signals, the DPU will periodically collect science data from the subsystems via serial command and data lines. This data will be processed on board the instrument, sorted by category and type of event, and compressed into the available telemetry stream.

All instruments on the GEOTAIL spacecraft are responsible for their own power switching and management. Because the spacecraft has no direct control over these functions (but rather must implement them via instrument hardware), the instrument command interface must insure that priority power commands are executed properly even if the microprocessor-based controller stops. This is primarily accomplished via a small, permanently powered section of circuitry called the Peripheral Interface Module, or PIM hardware. In some cases, this hardware provides a delayed backup to critical software functions (see UVC description).

In addition to the normal telemetry interface, the EPIC instrument DPU must also support the spacecraft RAM-check mode. In this mode, the normal science telemetry is replaced by RAM content data. The DPU will support this function in both the telemetry and command interface.

STICS Subsystem.

The STICS sensor measures the 3-dimensional distribution functions of suprathermal ions in the energy range ~ 10 to 230 keV/e. The sensor determines the mass, charge state, and mass per charge of ions, their arrival directions both in and out of the ecliptic plane, and their energy spectra. STICS will be used to study the source regions and acceleration processes of suprathermal ions in the near and distant geomagnetic tail.

Physically, STICS is made up of two units: the STICS sensor and the analog electronics box. The sensor contains the deflection system, time-of-flight (TOF) telescopes, high voltage (HV) power supplies, and the detector preamplifiers. The remainder of the analog electronics, including shaping amplifiers, discriminators, time-of-flight circuits, analog-to-digital converters (ADC), and valid-event logic circuits are located in the separate analog electronics box. Outputs from the analog electronics box are sent to the data processing unit where they are processed for submission to the spacecraft. A block diagram of the STICS sensor electronics is given at the end of this section.

ICS Subsystem.

The ICS instrument has two detector heads. Each measures incident ion time-of-flight between a front foil and a back solid state detector (SSD). Thus for each ion that reaches the back SSD with sufficient energy there will be a measured E signal. Ions penetrating the front foil will (usually) produce a signal in the front microchannel plate (MCP1), and those that impact the rear SSD will (usually) produce also a signal in the back microchannel plate (MCP2). The combination of correlated MCP1 (start) and MCP2 (stop) signals gives the ion time-of-flight (TOF), and knowledge of TOF and E determines the ion species.

Data Processing Unit.

The data processing unit (DPU) provides an interface between the analog electronics (AE) and the spacecraft and performs on-board data processing using the time-of-flight and energy pulse height data obtained from the analog electronics. The other principal functions of the DPU are to:

> Execute the fast classification of ions analyzed in STICS according to the ion mass and mass per charge;
>
> Collect and store count rate and pulse-height data, determine event priority and execute appropriate event sequencing;
>
> Compress the contents of each counting rate register into an 8-bit floating point representation and format all data and transfer this information to the spacecraft;
>
> Perform all necessary control functions for the experiment, accept and execute commands, monitor the experiment status, and execute the internal calibration sequence upon command.

Analog Electronics.

The primary function of the analog electronics (AE) is to measure the time-of-flight (τ) and the energy (E) of ions triggering the TOF *vs.* E system. In addition, coincidence conditions are established and a number of rates are counted.

The output signals from the timing discriminators for the universal start and universal stop are used as inputs to the Time-to-Amplitude Converter (TAC) which produces

(a) An analog TOF pulse height signal whose amplitude is proportional to the time interval between the triggering of the start and stop discriminators;

and

(b) A TOF strobe or logic pulse indicating a candidate for time-of-flight analysis, i.e., the stop signal follows the start signal within the time analysis window and the Multiple Front Seda Rate (MFSR) = 0 and the Multiple Double Coincidence Rate (MDCR) = 0 for this event. This pulse is used to establish some of the logic conditions for the pulse height data and for certain counting rates, e.g., the Multiple Position - Front (MPF) and the Multiple Position - Rear (MPR) rates. (These rates are discussed in the STICS Engineering Rate Definitions section.)

At this point the AE checks the MCP IDs of the start and stop signals and the PHA trigger conditions (see Definition of the STICS and ICS Event Word sections) to verify that the event meets additional "valid event" logic conditions for pulse height analysis and for incrementing certain rates (e.g., the DCR and TCR). If all logic conditions are met, the event is considered a "valid" pulse height event. The analog TOF pulse height signal is then sent to the "Time" Amplitude-to-Digital Converter (T-ADC) and the analog SSD energy pulse height signal (if any) is sent to the "Energy" Amplitude-to-Digital Converter (E-ADC). An Event Word (see Definition of the STICS and ICS Event Word sections) is composed by the analog electronics and sent to the data processing unit.

STICS Sensor.

The STICS sensor determines particle composition using a combination of electrostatic deflection and a time-of-flight and energy measurement:

- Particles enter the quadrispherical *electrostatic deflection system* through a simple aperture. The deflection system acts as an energy-per-charge filter, allowing only ions in a given energy-per-charge interval to enter the time-of-flight system. A pair of high voltage power supplies step the voltage on the deflection plates once per spin. The voltage steps are logarithmically spaced to take the system from a minimum of ~0 volts to the maximum deflection voltage of ~20 kV.

- Particles with the appropriate energy per charge enter the *time-of-flight system* where the speed of each ion is determined by measuring the travel time τ of the particle between the start and stop detectors separated by a known distance.

  The time-of-flight system contains three time-of-flight (TOF) telescopes. Each telescope has a "front" or "start" detector consisting of a thin (2 - 4 $\mu g/cm^2$) carbon foil and an associated secondary electron detector assembly (the front SEDA) and a "rear" or "stop" detector consisting of a solid state detector (SSD) and an associated secondary electron detector assembly (the rear SEDA). (In the context of this document, the term "front" is synonymous with "start", and the term "rear" is synonymous with "stop". When applied to a particular subassembly, the terms "front" and "rear" may not necessarily correspond to the actual mechanical configuration.) The front SEDA measures the secondary electron emission due to an incident ion passing through the carbon foil located at the front of the TOF telescope, thereby generating the start signal for the time-of-flight analysis. The front SEDA consists of a front (start) microchannel plate (MCP), two discrete front anodes, and a system of acceleration gaps and deflection surfaces for accelerating and deflecting the electrons emitted from the foil onto the front MCP. The rear SEDA measures the secondary electron emission due to the ion subsequently striking the surface of the solid state detector located at the rear of the TOF telescope, thereby generating the stop signal for the time-of-flight analysis. The rear SEDA consists of a rear (stop) MCP, a rear anode, and a system of acceleration gaps and deflection surfaces for guiding the electrons emitted from the solid state detector onto the rear MCP.

  The three TOF telescopes are stacked vertically in the STICS sensor and are designated the "SOUTH", "EQUATORIAL", and "NORTH" telescopes relative to the sensor mounting feet (south).

- The particle identification is completed by measuring the residual energy of the ions in one of the *solid state detectors* located at the rear of the TOF system.

From simultaneous measurements of the time-of-flight (τ), the residual energy (E_{meas}), and a knowledge of the energy per charge (E/Q) from the deflection system, we can determine the mass (M), ionic charge state (Q), and the incident energy (E) of each ion as follows:

$$M = 2\,(\tau / d)^2\,(E_{meas}/\alpha)$$

$$M/Q = 2(\tau/d)^2\,(E'/Q)$$

$$Q = (E_{meas}/\alpha)\;/\;(E'/Q)$$

$$E = Q \bullet (E/Q)$$

where d is the flight path (~10 cm), E'/Q takes into account the small energy loss of ions passing through the thin carbon foil of the start detector, and α takes into account the pulse height defect in the solid state detectors. In addition to measurements of the mass, charge, and energy of each ion, the six discrete start anodes (two per each start microchannel plate) provide information on the polar entrance angle (six equal polar sectors covering +80° to –80°) of the incident particle, and the spinning of the spacecraft allows information on the equatorial angle (sixteen equal azimuthal sectors, determined from the spacecraft spin/sector clock).

ICS Sensor.

The ICS sensor determines particle composition using a combination of time-of-flight and energy measurement:

- Particles enter into either of the ICS heads via a conical sunshade mechanism and pass through a sweeping magnet assembly which deflects electrons with energies below 100 keV. The particles then pass into the time-of-flight system where the speed of each ion is determined by measuring the travel time τ of the particle between the start and stop detectors which are separated by a known distance.

  There are two separate ICS measurement heads, designated "North" and "South". Each telescope has a "front" or "start" detector consisting of a thin front parylene/aluminum foil and an associated secondary electron detector assembly (the front SEDA) and a "rear" or "stop" detector consisting of a solid state detector (SSD) and an associated secondary electron detector assembly (the rear SEDA). The front SEDA measures the secondary electron emission due to an incident ion passing through the front foil located at the front of the TOF telescope, thereby generating the start signal for the time-of-flight analysis. The front SEDA consists of a front (start) microchannel plate (MCP), a front anode, and a system of acceleration grids and deflection surfaces for accelerating and deflecting the electrons emitted from the foil onto the front MCP. The rear SEDA measures the secondary electron emission due to the ion subsequently striking the surface of the solid state detector located at the rear of the TOF telescope, thereby generating the stop signal for the time-of-flight analysis. The rear SEDA consists of a rear (stop) MCP, a rear anode, and a system of acceleration grids and deflection surfaces for guiding the electrons emitted from the solid state detector onto the rear MCP.

- The particle identification is completed by measuring the residual energy of the ions in one of the *solid state detector* located at the rear of the TOF system.

From simultaneous measurements of the time-of-flight (τ), and the residual energy (E_{meas}), we can determine the mass (M):

$$M = 2\,(\tau / d)^2\,(E_{meas}/\alpha)$$

where d is the flight path (~6.4 cm), and α takes into account the pulse height defect in the solid state detectors. In addition to measurements of the mass and energy of each ion, the two head IDs provide information on the polar entrance angle (two equal polar sectors covering 52° to 82° and 98° to 128° relative to the spin axis) of the incident particle, and the spinning of the spacecraft allows information on the equatorial angle (sixteen equal azimuthal sectors, determined from the spacecraft spin/sector clock).

EPIC TELEMETRY FORMAT

The EPIC experiment has a telemetry allocation of 2560 bits per second in the spacecraft Record Mode Interface and 6 bytes every 0.5 second on the spacecraft Real-Time Mode Interface.

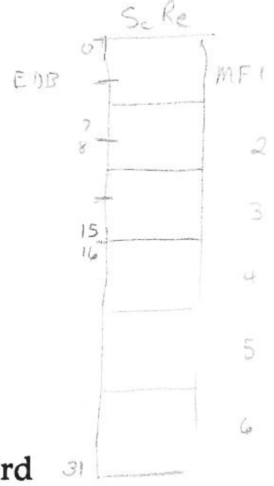
The EPIC instrument is allocated 2560 bits per second on the 16 Kbit per second Record Mode interface. It also has 6 bytes every 0.5 seconds on the Real Time Mode interface for status data. The real time interface is used to transmit experiment status and housekeeping information to the ground for use during real time monitoring of the experiment by spacecraft ground controllers. In the record mode interface, the science data as well as housekeeping and status information are transmitted.

The instrument shall primarily use the real time interface to communicate status and housekeeping information; this data will be monitored in real time on the ground for up to 8 hours per day. The record mode interface shall be used primarily to send the EPIC science data down, although the housekeeping and status information are also included. In the case of a failure on either the real time or record mode interface, the instrument will be able to send data to the ground via the contingency format mode.

Concentrating solely on the Record Mode interface for now, we have the following telemetry parameters:

There are:
* Nominal 3 seconds per spin
* Nominal 20 spins per minute
* 16 S/C minor frames per second
* 20 EPIC bytes per S/C minor frame
* 8 bits per byte
* 32 spins per EPIC Science Record
* Projected maximum spin variation < ± 1 rpm

therefore:
* Nominal EPIC Science Record = 96 seconds
* 2560 bits per second EPIC data (16 x 20 x 8)
* 320 bytes per second EPIC data (16 x 20)
* Nominal 960 EPIC science bytes per spin
* Nominal 30720 EPIC science bytes per Science Record



1 mf = 1/16 sec = 62.5 msec

1536 mf / ScRc

256 minor frames $\overset{?}{=}$ 1 Major Frame

if true

6 Major Frames / Science Record

Each spacecraft record mode interface minor frame contains 128 bytes of information. The format is:

Word #	Data Description
W0-W2	Frame sync. words
W3	Frame counter
W4	Time counter
W5	ANG/SBR/WAT
W6-W7	Command Answer
W8-W10	Common Status (our real time status goes here)
W11	Spacecraft Analog Housekeeping
W12-W15	AOCS/DCS Data and Status (Navigation)
W16-W23	EFD Instrument Science
W24-W31	MGF Instrument Science
W32-W47	LEP Instrument Science
W48-W60	HEP Instrument Science
W61-W71	PWI Instrument Science
W72-W107	CPI Instrument Science
W108-W127	EPIC Instrument Science

SCIENCE DATA BUFFERING

The EPIC science data is primarily spin-based. Spin synchronization is accomplished by using the sun pulse and spin clock information provided by the spacecraft over dedicated hardware lines. The instrument must be able to adjust to a variable spin rate while constrained by the constant spacecraft telemetry interface rate.

Because of the spin *vs.* telemetry synchronization problem, it is necessary to do some sort of telemetry buffering within the instrument. One of the important design choices that we must make is to select the size of the telemetry buffer in the DPU. This selection is, as always, a tradeoff between hardware complexity, software sophistication, ground processing needs, science requirements, etc.

The data collected and formatted by the DPU during one complete spin will be known as an Experiment Data Block, or *EDB*. Occasionally, the science telemetry is collected faster than it can be sent. Under these conditions, the instrument will not transmit all the data it has collected. The data will be thus dropped one whole spin at a time; the instrument should never send a partial EDB data set.

The EDB consists of the DPU common area 1, ICS telemetry, DPU common area 2, and STICS telemetry. See Appendix E EPIC EDB-based Telemetry Format for details. The DPU common area 1 has 16 bytes and begins with a 2-byte identifier or "EDB sync pattern" which has a fixed value. It is followed by the EDB Counter, Spin Counter, Measured Spin Counter, digital status, and housekeeping data. The ICS telemetry then follows using ?? bytes with PHA data appearing at the start of the odd EDBs and the rest consisting of formatted rate data. The DPU common area 2 is still TBD at this time

, STICS, and DPU *Housekeeping* data immediately follow the EDB sync pattern. The sync pattern and the housekeeping data constitute the **DPU/Common** section of the EDB. This segment is followed by the **ICS** and **STICS** science sections. To the extent possible, the ICS and STICS science sections of the EDB will be separate and self-contained. The format (data sequence) of the EDB, both among and within the separate subsystem sections, will be determined by **TUB**.

A collection of EDBs that represent a complete science cycle shall be known as an *EPIC Science Record*. The EPIC instrument Science Record will contain 32 consecutive EDBs, meaning that every 32 spins (nominally), the telemetry begins a new data cycle. If data must be dropped during this time, the Science Record shall still contain the data collected during 32 spin cycles, but the 32 spins may not be completely contiguous. (See spin variation section).

In the ICS subsystem, a number of channels are accumulated over different time periods varying between 1 spin and 32 EDBs. As a result, much of the ICS science telemetry data becomes available only at a few EDB boundaries (with the majority at EDB number 16 and 32). It will be necessary, therefore, to buffer this data in DPU RAM, and read it out over the next collection period.

The STICS subsystem, however, is entirely spin-based, except diagnostic rates. Even though the DPPS deflection voltage stepping selects different mass/charge ratios each EDB, the data collected within a spin is a complete data block. The EPIC Science Record block only represents a convenient framework in which to step the DPPS voltage pattern. This format requires that the RAM telemetry buffer be only one spin's-worth of STICS data long.

TELEMETRY DISTRIBUTION

The EPIC telemetry allocation was divided up at a meeting on June 11, 1987 at APL and later revised on September 7 & 8, 1989. The agreement between APL, UMD, and TUB for the following normal mode allocations within EPIC is:

Subsystem	Bits per Sec	Bits per EDB	Bytes per EDB
ICS	952.50	2857.50	357.19
STICS	1544.00	4632.00	579.00
DPU/Common	63.50	190.50	23.81
Total	2560.00	7680.00	960.00

These allocations may be slightly modified in the future, after detailed software design is underway. Also at the September, 1989 meeting, it was decided that the instrument health and status information would be split between two lists; data that is sent down every EDB, and data sent down every Science Record (subcommutated data). Details of the information is in the sections on Common EPIC Status and Housekeeping, and EPIC Subcom Housekeeping/Status Data.

The major portion of the EPIC telemetry may be allocated to a single sensor (ICS or STICS) by command. These modes are useful during ground testing and calibration, for special science objectives during the mission, or in the event one sensor fails. In these modes, the format of the DPU/Common section of the EDB remains unchanged, thereby allowing continuous monitoring of both sensors.

Common Science Definitions and Requirements

There are two types of science information provided to the DPU directly by the sensor subsystems. One is the Pulse Height Analysis (PHA) Event data which consists of energy, time-of-flight (TOF), and telescope head information for a limited number of "valid" events. The other is the Engineering Rates data which consists of the counts of the various sub-events (stops, starts, energies, etc.) taken over a defined time period.

A third type of science information, the Science Rates, is derrived from the PHA Event data. The DPU categorizes the PHA Event data and "binns" them into counters which are read periodically to yield Science Rates. These rates correspond to particle species, energy range, time-of-flight, and/or charge state.

These three types of science data are then formatted (compressed) and inserted into the telemetry stream.

Rate Compression Codes

Rates are accumulated by sector, spin or Science Record (see STICS and ICS Science Definitions and Requirements). These rates are to be compressed to 1 byte to make better use of the telemetry stream.

These rates can be divided into two groups. The potentially large spin-averaged singles counting rates (FSR, RSR, DCR, UFSR, and URSR) are in group 1; all other rates (including all *Science Rates*) are in group 2. Both rate groups (for each sensor) are separately commandable into compression codes "A" or "C" (see BC D_CMPRSS command).

The two compression codes to handle these rates are known as codes"A" and "C" (in the *CCE/CHEM* terminology); where code A is a uniform floating point code (count range 0 to ~ 5×10^5) and code C is a non-uniform floating point code (count range 0 to ~ 8.4×10^6). This allows the high counting rates to be compressed using code C while retaining the resolution of code A for the lower counting rates. The decompressed value v can be obtained from the following equations:

Code A. Four-bit mantissa "m"; four-bit exponent "e":

for $e = 0, v = m$,

for $e \neq 0, v = (16 + m) \times 2^{(e-1)}$.

Code C. Four-,three-bit mantissa "m"; four-, five-bit exponent "e":

a. Four-bit exponent (bit 7 (msb) OR bit 6 = 0)

for $e = 0, v = m$,

for $1 \leq e \leq 11, v = (16 + m) \times 2^{(e-1)}$.

b. Five-bit exponent (bit 7 (msb) AND bit 6 = 1)

for $24 \leq e \leq 31, v = (8 + m) \times 2^{(e-12)}$.

Energy Compression Code

The analog electronics transmits the measured energy to the DPU as a 10-bit binary number (see Definition of the ICS and STICS Event Word sections). After modification by the Energy Slope Correction factor and the Energy Offset, the DPU compresses the energy pulse height channel address from 10 bits to 9 bits. In this scheme, the address number is converted to a 2-bit exponent and 7-bit mantissa representation. The original value "v" can be calculated from the exponent "e" and the mantissa "m" by the following formulas:

for $e = 0$, $v = m$,
for $e > 0$, $v = (128 + m) \times 2^{(e-1)}$

Commandable PHA Trigger Conditions (Valid Event Modes)

In order to optimize the maximum rate of event words sent to the DPU, only a limited number of states (i.e., bits) have been allocated for specifying the SSD ID and MCP ID. This places certain constrains on the analog electronics in selecting "valid" event words (e.g., only particular combinations of start or stop anodes are recognized.) In addition to these identification criteria, pulse-height-analysis (PHA) valid event conditions are imposed on the event word. There are eight trigger conditions, only one of which (selectable by command) is operational at any given time for a given subsystem. These conditions impact the event word and the Double and Triple Coincidence Rates generated by the AE and also all rates calculated by the DPU from event words (i.e., the High Resolution Rates (except FSR), Basic Rates, Sectored Matrix Rates, and Omni Matrix Rates).

Valid Event Definitions	Comments
(0) E	The event must have at least an energy signal: There are no restrictions on the time-of-flight signal.
(1) T_n	The event may be either double (start and stop) or triple (start, stop, and energy) coincident: The event must have a time-of-flight signal, and the start and stop must come from the same telescope "n". There are no restrictions on the energy signal: there can be no energy signal; an energy signal from the same telescope "n"; or an energy signal from any other telescope.
(2) $(T_n \bullet \sim E) + (T_n \bullet E_n)$	The event may be either double (start and stop) or triple (start, stop, and energy) coincident: The event must have a time-of-flight signal, and the start and stop must come from the same telescope "n". If there is an energy signal, it must be associated with telescope "n".
(3) $T_n \bullet E_n$	The event must be triple (start, stop, and energy) coincident: The event must have both a time-of-flight and an energy signal. Start, stop, and energy signals must all be associated with telescope "n".
(4) $E + T$	The event may be single (energy), double (start and stop), or triple (start, stop, and energy) coincident: The event must have either a time-of-flight, or an energy signal, or both. The start, stop, and energy signals are unrestricted (any telescope combination is allowed).

(5) $(E \bullet \sim T) + (T_n \bullet \sim E) + (T_n \bullet E_n)$	The event may be single (energy), double (start and stop), or triple (start, stop, and energy) coincident: The event must have either a time-of-flight, or an energy signal, or both. If there is a time-of-flight signal, the start and stop signals must originate from the same telescope "n". If there is just an energy signal, it can come from any telescope. If there is both an energy and a time-of-flight signal, the start, stop, and energy signals must all be associated with telescope "n".
(6) $C \bullet (E + T)$	The Internal Calibration (IC) strobe restricts analysis of events to a narrow time window (calibrator test pulses present) in order to prevent analysis of any real events. Test events generated by the internal pulser may be single (energy), double (start and stop), or triple (start, stop, and energy) coincident: The pulser event must have either a time-of-flight, or an energy signal, or both. The start, stop, and energy signals are unrestricted (i.e., any telescope combination is allowed).
(7) $(E \bullet \sim T) + (T_n \bullet E_n)$	The event is either energy and no time-of-flight, or triple coincident: The event must have an energy signal, and if there is a start and stop they must both come from the same head as the energy.

The trigger conditions (1), (2), and (3) are possible flight configurations for STICS. The advantage of (1) over (2) is in the case of spurious energy signals. If all signals are required to be from the same telescope, as in option (2), a noisy detector could lock out signals from other telescopes. Option (1) has no restriction on the energy and would be useful, e.g., in the case of a bursting detector. Option (3) -- requiring triple coincidence -- would only be used occasionally.

In the case of an energy signal failure, (1), (2), or (5) could be used.

In the case of a time-of-flight signal failure, either condition (4) or (5) could be used.

Internal Calibrate modes (see STICS Internal Calibration System section) will use condition (6), exclusively.

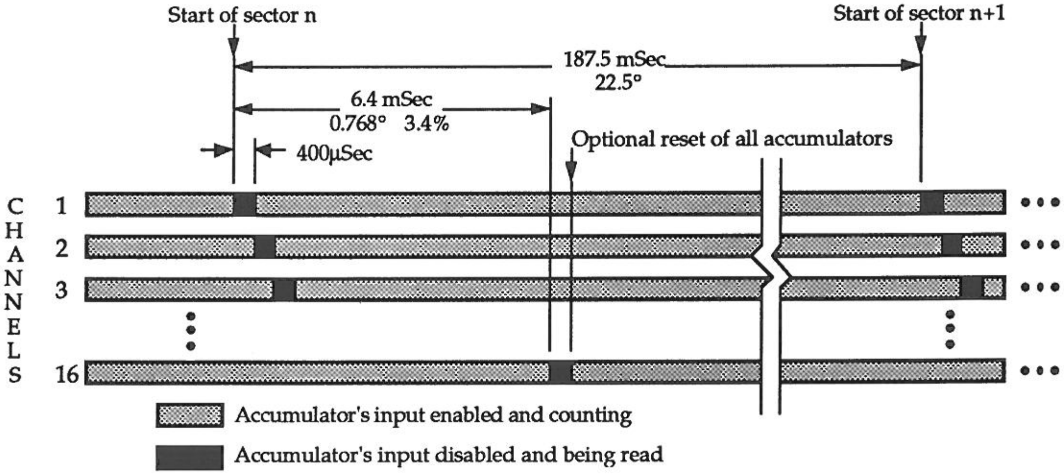
Bench checkout and calibration procedures will test all trigger conditions. Option (4) is the least restrictive with regard to both signal type (single, double, or triple coincidence) and telescope association, and may be useful in checking for cross-talk. Option (5) is unrestrictive regarding coincidence conditions but is restrictive regarding telescope association.

Rate Servicing

Both the STICS and ICS sensors use 24-bit hardware counters to measure the Engineering Rates. These counters, called accumulators, are periodically read out via the serial command and data interface with the analog electronics interface controllers. The number and type of accumulators vary, depending on the sensor and the channel (see the detailed sensor telemetry discussion for more information). This data will be pseudo-log compressed from 24 bits to 10 or 8 bits in the DPU.

The accumulator inputs are only individually disabled during a read, the other channels will continue counting. The two ways of synchronizing accumulator groups are as follows (see the diagram as well):

- Option A Use "reset all accumulators" mode when reading the last accumulator, causes an uneven sampling time between accumulators. This is shown as the option in the following diagram.
- Option B Do not use "reset all accumulators" mode, causes even sample time but there is displacement between sample periods. This is shown as the default in the following diagram.



The desired method for STICS is option A and for ICS is option B,. Note that in both cases an accumulator is always reset to zero after it is read.

Internal Calibration System

The internal calibration (IC) system provides a means of systematically checking the health of the sensor electronics without using external pulser inputs.

Manual Calibration Mode:

In the manual calibration mode, the PHA trigger condition (see Definition of the STICS Event Word section) should be set to C • (E + T), to prevent the analysis of real events. ENERGY (E) and/or TIME-OF-FLIGHT (T) test inputs for calibration are selected and implemented by manual command. The timing pulse is sent to the fast amplifiers of the MCPs, while the energy amplitude pulse is sent to the preamplifiers of the solid state detectors.

Automatic Calibration Mode:

An automatic calibration mode provides, on command, a sequence of timing and amplitude pulses which are fed, respectively, to the constant fraction descriminators of the front and rear MCPs and the preamplifiers of each solid state detector. The preset sequence is useful in the routine monitoring of the sensor electronics, since the outputs are standardized and well documented. The automatic IC sequence is defined in the command macros and will be similar to that used in the *CCE/CHEM*. However, unlike CCE/CHEM, there will be no periodic (i.e., daily, weekly, etc.) DPU initiated automatic internal calibrate mode. The initiation of all internal calibrate sequences will be solely by macro command.

When the sensor is in automatic calibration mode, the trigger logic is automatically set to C • (E + T) in order to prevent analysis of all events other than the test pulses. At the end of the automatic calibration sequence, the DPU returns the sensor to its previous configuration.

The ICS sensor has a radioactive calibration source in addition to the internal calibrate pulsers. This source is used to verify base-line operations and efficiencies. Additionally there are four accumulators that are swapped by command (see BC I_DIGCMD).

STICS Science Definitions and Requirements

Definition of the STICS Pulse Height Analysis Word

(DPU ⇒ S/C)

The **STICS PULSE HEIGHT ANALYSIS (PHA) WORD** contains the STICS pulse height information which has been processed and prioritized by the data processing unit (DPU) and is sent by the DPU to the spacecraft (S/C) telemetry. The format is as follows:

ENERGY	E	=	9 bits
TIME-OF-FLIGHT	T	=	10 bits
EQUATORIAL SECTOR (16 states)	SEC	=	4 bits
IDENTIFICATION PHA RANGE ID (3 states) FRONT (START) MCP ID (10 states)	ID	=	5 bits
SSD ID (4 states)	DET	=	2 bits
REAR (STOP) MCP ID (4 states)	RMCP	=	2 bits
STICS PHA WORD		=	32 bits/event
		=	4 bytes/event

Notes:

1. *ENERGY CONVERSION FACTOR.* The original value of the ENERGY pulse height channel number transmitted by the analog electronics to the DPU is modified by the DPU to include the ENERGY CONVERSION FACTOR, the value of which is supplied in the command alterable parameter list. This correction factor is used to map the chennel value to energy in keV and can also be used to compensate for gain shift in the energy analog-to-digital converter. The default value is "**TBD UMD**".

2. *ENERGY OFFSET CORRECTION.* The original value of the ENERGY pulse height channel number transmitted by the analog electronics to the DPU is modified by the DPU to include the ENERGY OFFSET CORRECTION factor, the value of which is supplied in the command alterable parameter list. This correction factor is used to compensate if there is an offset shift in the energy analog-to-digital converter. The default value is "0".

3. *COMPRESSION OF THE ENERGY PHA.* See the Energy Compression Code section.

TEN-BIT ENERGY (Event Word)		NINE-BIT ENERGY (PHA Word)		
Linear Channel	No. of Channels	Compressed Channel	Linear chn per compressed chn	Resolution
0-255	256	0-255	1	TBD
256-511	128	256-383	2	
512-1023	128	384-511	4	

4. *TOF-OFFSET CORRECTION.* The TIME-OF-FLIGHT pulse height channel number transmitted by the analog electronics to the DPU is modified by the DPU to include the TOF-OFFSET CORRECTION number, the value of which is supplied in the command alterable parameter list. The default value is "0".

5. *TOF CONVERSION FACTOR.* The TIME-OF-FLIGHT pulse height channel number transmitted by the analog electronics to the DPU is modified by the DPU to include the TOF CONVERSION FACTOR, the value of which is supplied in the command alterable parameter list. This correction factor is used to map the channel value to time-of-flight in nsec and can also be used to compensate for gain shift in the time-to-amplitude or the analog-to-digital converter. The default value is "**TBD UMD**".

6. *SECTOR INFORMATION AND NORMALIZATION OF PHA WITH BASIC RATES.* By using the above bit allocation for the pulse height word, we can identify all 6 polar sectors (from the front MCP information contained in "ID") and all 16 equatorial sectors (from the information in "SEC"). The Basic Rates (which are derived from the pulse height) have only 3 x 8 sector information. To normalize the pulse height data with the Basic Rates, the PHA in adjacent sectors must be added together on the ground. For sufficiently low rates, the full 6 x 16 sector PHA angular distribution will be valid.

7. *PHA RANGE ID.* The entire M *vs.* M/Q matrix is divided into four pulse height priorities; three of these priorities at any given time are assigned by command to the three pulse height ranges. The "PHA RANGE ID" identifies in which of these three ranges this pulse height event is classified (see STICS Pulse Height and Priority Range section).

STICS Pulse Height Priority and Range

The mass (M) *vs.* mass-per-charge (M/Q) classification matrix is divided into four pulse height priorities (P0, P1, P2, P3). Each priority is defined by a rectangular section of the M *vs.* M/Q matrix. A given priority section may be nested within another priority section, but each priority is considered mutually exclusive (i.e., priorities do not overlap). The defined priorities may or may not encompass the entire M *vs.* M/Q matrix.

The boundaries of each priority may be set by loading (*via* a parameter command) the mass and mass-per-charge bin limits, or the following default (preset) values may be used:

Priority	Dominant Ions	Mass-per-Charge Limits	Mass Limits
0	CNO (Q = 5 to 7)	TBD	TBD
1	He^+, He^{++}		
2	O^+, N^+, O^{++}		
3	H^+		

Only a subset of the priorities are enabled by command at any given time. A priority is enabled by assigning it to one or more of the three pulse height ranges (R0, R1, R2). One may assign the priorities in any combination, including having the same priority assigned to all three ranges. The default selection is P0 in R0; P1 in R1; and P2 in R2. The DPU determines the range (if any) for each event word transmitted by the analog electronics, increments the appropriate *Basic Rate* (see STICS Science Rate Definitions section), and selects a subset of the event words for inclusion in the telemetry as PHA words (see Definition of the STICS Pulse Height Analysis Word section).

The specific process used by the DPU for selecting the PHA words will be determined by **TUB**. The basic philosophy is as follows:

- Δ During a nominal spin period of 3 seconds, the STICS telemetry definition contains 48 slots for PHA words (each PHA word slot requires 4 bytes of telemetry). At the start of a spin, the first ***n*** PHA words are accepted by the DPU (without regard to range value or sector). If ***n*** ≤ 48, each of these PHA words is transmitted by the DPU to the S/C telemetry. Unused PHA telemetry slots are filled with zeros.
- Δ If ***n*** > 48, an attempt is made to use the 48 available PHA slots to sample all 16 equatorial sectors and all three ranges. Hence, ranges R0, R1, and R2 are each given 16 PHA slots, one for each azimuthal (equatorial) sector. These slot assignments are shown in Table 1 on the following page.
- Δ Additional PHA words overwrite buffered PHA words only if they occur in unoccupied range/sector slots.

Table 1
STICS PHA Event Allocation

Sector	R0	R1	R2	Number of PHA-Words
0	1	1	1	3
1	1	1	1	3
2	1	1	1	3
3	1	1	1	3
4	1	1	1	3
5	1	1	1	3
6	1	1	1	3
7	1	1	1	3
8	1	1	1	3
9	1	1	1	3
10	1	1	1	3
11	1	1	1	3
12	1	1	1	3
13	1	1	1	3
14	1	1	1	3
15	1	1	1	3
			Total	48

STICS Engineering Rate Definitions

The data items read out in the STICS telemetry include 21 *Engineering Rates* which are derived from the analog electronics accumulator rates (see STICS Rate Accumulators in the Analog Electronics section).

FSR: Six Front Seda Rates, one for each front anode, are read out by the analog electronics to the DPU at the beginning of each equatorial sector. The sector-accumulated FSRs are incremented by any pulse from the appropriate front anode. The time resolution for distinguishing different pulses is ~500 ns.

The fully sectored (6 polar x 16 equatorial) FSRs are transmitted by the DPU to the spacecraft telemetry as a multiplexed *High Resolution Rate* (see STICS Science Rate Definitions section). This rate alternates every 8 spins -- or 24 seconds -- with another ion species, typically O^+. Complete time coverage is provided in the telemetry with the partially sectored (i.e., 3 polar sectors, one for each front MCP), spin-averaged FSRs which are read out in the telemetry as part of the *Engineering Rates*. The summation over polar and equatorial sectors necessary for the generation of the spin-averaged FSRs is performed by the DPU. (Note that FSR rates are read out on sector and spin basis.)

UFSR: The Universal FSR uses the same circuitry as the time-of-flight analysis and therefore has a faster (factor of 5) timing resolution than the FSR, but contains no information on which front (start) anode(s) fired. Simultaneous (within the time resolution) firing by multiple front anodes generates a single universal start pulse. The threshold for the UFSR discriminator is slightly higher than those for the FSRs, assuring the availability of polar sector (front anode) information for the pulse height analysis. The UFSR is accumulated on the sector-accumulator, but is summed by the DPU to be read out in the telemetry as a spin-averaged *Engineering Rate.*

RSR: There are three spin-averaged Rear Seda Rates, one for each rear MCP. An RSR is incremented by any pulse from the appropriate rear MCP (time resolution ~500 ns). The RSRs are read out in the telemetry as *Engineering Rates.* (Note that the RSR rates are not read out by sector.)

URSR: The Universal RSR serves the same function as the UFSR, but for the rear MCPs. The rate is accumulated on the sector-accumulator, but is summed by the DPU to be read out in the telemetry as a spin-averaged *Engineering Rate.*

DCR: The Double Coincidence Rate is incremented when a stop time pulse occurs within the time analysis window (10 ns < Δt < 300 ns) of the universal start time pulse. Only "clean" events with a single start and a single stop pulse are counted (also only "clean" events are nominally pulse height analyzed). There are three spin-averaged DCRs, corresponding to each of the three rear MCPs. These rates are read out in the telemetry as *Engineering Rates.*

The DCRs are required to meet the same PHA trigger conditions (see Definition of the STICS Event Word section) as the event word. Under some of these trigger conditions (specifically # 1, 2, 3, and 5), the identification of the front MCP is unique (i.e., the start and stop signals come from the same telescope). The DCRs under these conditions contain some polar sector information.

TCR: The Triple Coincidence Rate is incremented when there is a valid DCR and a coincident SSD. There are three spin-averaged TCRs, corresponding to each of the rear MCPs. These rates are read out in the telemetry as *Engineering Rates.*

The TCRs are required to meet the same PHA trigger conditions (see Definition of the STICS Event Word section) as the event word. Under some of these trigger conditions (specifically # 2, 3, and 5), the identification of the front MCP is unique (i.e., the start, stop, and energy signals come from the same telescope). The TCRs under these conditions contain some polar sector information.

SSD: The Solid State Detector rate is incremented when an energy pulse occurs. There are three spin-averaged SSDs, one for each solid state detector. These rates are read out in the telemetry as *Engineering Rates.*

MFSR: Any subsequent (i.e., non-simultaneous) universal start pulse following the initializing universal start pulse and occurring within the time analysis window of that pulse (10 ns < Δt < 300 ns; where Δt is the time from the leading edge of the initializing start pulse) will increment the spin-averaged Multiple Front Seda Rate (MFSR); i.e., the start signals are separated in time, but may or may not be separated in position. This rate is read out in the telemetry as an *Engineering Rate.*

The universal start pulse counted by the MFSR then becomes the new initializing universal start pulse and the analysis window is extended accordingly. No pulse height analysis is done for events associated with multiple start signals. It is possible that at high rates (> 3 MHz), if the start pulses are spaced appropriately (e.g., evenly spaced every 300 ns), the analysis window would be extended indefinitely and there would never be a valid PHA event. This criteria can be disabled by command.

MDCR: The spin-averaged Multiple Double Coincidence Rate (MDCR) is incremented when there is an (invalid) DCR event which has multiple universal stop pulses from one or more rear MCPs occurring within the time analysis window defined by the initializing universal start pulse. This rate is read out in the telemetry as an *Engineering Rate.*

Events associated with multiple stop pulses are not normally pulse height analyzed. The exception is the when multiple stops are enabled, which is a contingency mode.

MPF: The spin-averaged Multiple Position -- Front (MPF) rate counts the number of events having an universal start and an universal stop signal in which the universal start pulse was generated by simultaneous signals from more than one of the three front MCPs (i.e., within the time resolution, the universal start signal originated from more than one TOF telescope). This rate is read out in the telemetry as an *Engineering Rate.*

The MPF rate logic requires that the event be "clean" in the sense that it must be associated with a single universal start and a single universal stop signal. The MPF is incremented by "1" whether the multiple firings originated from two or three front MCPs.

MPR: The spin-averaged Multiple Position -- Rear (MPR) rate counts the number of "clean" events associated with a single universal start and a single universal stop pulse in which the universal stop pulse is generated by more than one rear MCP. The MPR is incremented by "1" whether the multiple firings originated from two or three rear MCPs. This rate is read out in the telemetry as an *Engineering Rate.*

RATE COMPARISIONS: When comparing different rates, both discriminator and accumulator deadtimes must be taken into account. For example, the MFSR and MPF are designed for comparison with the spin-averaged FSRs, but they are stored on different accumulators with different deadtimes and also have different discriminator timing resolutions.

PRELIMINARY (TBD):
(Table 2, Discriminator timing goes here.)

RATE LOGIC EXAMPLES: The following examples are to clarify the above rate definitions: (This section mainly still TBD.)

(a) Assume that front anode #1 has fired initiating an universal start pulse, followed 150 ns later by front anode #3 firing (thereby extending the analysis window by 150 ns), followed 250 ns later by front anode #5 firing (extending the analysis window by another 250 ns), followed 30 ns later by an universal stop pulse from rear anode #1 accompanied by an energy signal from SSD #1. The following rate increments would result (subject to timing resolution):

FSR(1) = 1
FSR(2) = 0
FSR(3) = 1
FSR(4) = 0
FSR(5) = 1
FSR(6) = 0
UFSR = 3
MFSR = 2
MPF = 0
MPR = 0

FSR1 = 1
FSR2 = 1
FSR3 = 1

RSR1 = 1
RSR2 = 0
RSR3 = 0
URSR = 1
DCR1 = 0
DCR2 = 0
DCR3 = 0
MDCR = 0

SSD1 = 1
SSD2 = 0
SSD3 = 0
TCR1 = 0
TCR2 = 0
TCR3 = 0

(b) Assume there is a simultaneous firing by front anodes #1 and #5, followed by a stop pulse in rear anode #1. The following rate increments would result:

FSR(1) = 1
FSR(5) = 1
UFSR = 1
MFSR = 0
MPF = 1
MPR = 0

FSR1 = 1
FSR3 = 1

RSR1 = 1
URSR = 1
DCR = 0

(c) Assume there is a simultaneous firing by rear anodes #1, #2, and #3. The following rate increments would result:

MPR = 1

RSR1 = 1
RSR2 = 1
RSR3 = 1
URSR = 1

(d) TBD: OTHER SUGGESTED EXAMPLES OR BETTER ONES????

STICS Rate Accumulators in the Analog Electronics

In addition to the event words described in the Definition of the STICS Event Word section, the analog electronics transmits to the DPU various singles and coincidence rates which are used for both diagnostic purposes and scientific analysis.

The STICS AE rates require 24 channels. The eight sector-based channels are read out to the DPU at the beginning of each equatorial sector (with a 3.2 msec or 1.7% deadtime per sector). The sixteen spin-based channels increment rates over the entire spin period and are read out to the DPU during the deflection voltage sweep (see Deflection Voltage Modes section) that occurs in equatorial sector zero (the position of the sun pulse in relation to sector zero is determined by command). The voltage sweep creates an 80-90 msec deadtime, which is utilized by the DPU for servicing the spin-based channels. The DPU services these channels every spin even if the deflection system is in a mode such that there is no voltage sweep (i.e., the voltage step is being held constant). Hence, the deadtime is still required under a constant deflection voltage.

The accumulators can handle rates up to ~15 MHz (actual frequency TBD).

	Sector-based Channels	Spin-based Channels
	6 FSR (Front Seda Rate)	3 RSR (Rear Seda Rate)
	1 UFSR (Universal FSR)	3 DCR (Double Coincidence Rate)
	1 URSR (Universal RSR)	3 TCR (Triple Coincidence Rate)
		3 SSD (Solid State Detector)
		1 MFSR (Multiple FSR)
		1 MDCR (Multiple DCR)
		1 MPF (Multiple Position-Front)
		1 MPR (Multiple Position-Rear)
TOTAL:	8 sector-based rates	16 spin-based rates

Notes:

1. "Seda" stands for "secondary electron detector assembly".

STICS Science Rate Definitions

The event words generated by the analog electronics (AE) are used by the data processing unit (DPU) to calculate the *Science Rates* portion of the STICS data. There are four types of *Science Rates*: the *High Resolution Rates*; the *Sectored Matrix Rates*; the *Omni Matrix Rates*; and the *Basic Rates*. These rates are read out in the telemetry every spin period.

The DPU uses fast look-up table techniques to establish a correspondence between the ENERGY and TIME-OF-FLIGHT pulse height data contained in the event word (see Definition of the STICS Event Word section) and the positions of the mass (M) and mass-per-charge (M/Q) surfaces in the T *vs.* E parameter space. The classification algorithm used to generate the look-up tables is derived from the fundamental relations presented in the General Background section and includes several instrumental parameters, such as the energy-per-charge value of the deflection voltage step, the energy loss in the carbon foil, and the pulse height defect in the solid state detector. During table entry, the DPU applies the appropriate TOF-offset and slope correction factors (see Definition of the STICS Pulse Height Analysis Word section) to the TIME-OF-FLIGHT and ENERGY pulse height data.

The M and M/Q values returned by the fast classifier are used to increment appropriate storage registers corresponding to the *High Resolution Rates*, the *Sectored Matrix Rates*, the *Omni Matrix Rates*, and the *Basic Rates*. Because these rates are derived from the event words, they are subject to the PHA trigger conditions discussed in the Definition of the STICS Event Word.

The spacecraft spin axis is perpendicular to the ecliptic plane; sixteen 22.5° equatorial (azimuthal) sectors are defined by the spacecraft sector/spin clock. Six 26.7° polar sectors are defined by the six STICS front anodes, covering ± 80° out of the ecliptic plane.

For some STICS rates, the polar angle information is condensed into three 53.3° sectors (defined by the front or rear MCP), and/or the azimuthal angle information is condensed into eight 45° sectors.

The *High Resolution Rates*, *Sectored Matrix Rates*, and *Omni Matrix Rates* are selected from a predetermined list of 36 ion "species": 35 of these species are defined by "boxes" in M *vs.* M/Q space, and the final "species" is the fully-sectored FSR (see STICS Engineering Rates Definitions section). By command, three species from the list are selected for the High Resolution Rates; three species are selected for the Sectored Matrix Rates; and the remaining 30 species default to the Omni Matrix Rates.

Some ions may be represented more than once in the species list when distinguished in the M *vs.* M/Q matrix by different E,T logic criteria: for example, O^+ with only double coincidence, O^+ with triple coincidence, and O^+ with either double or triple coincidence would be treated in the list as three separate species.

Three of the *Science Rates* include directional information. Using *only* the Front MCP ID contained in the event word (i.e., regardless of the value of the Rear MCP ID), the DPU distinguishes among six 26.7° polar sectors covering ± 80° out of the ecliptic plane. For some rates, this information is condensed by the DPU into three 53.3° polar sectors. The Front MCP ID (FMCP) states #7, 8, and 9 cross the condensed polar sectors. These states are evenly distributed by the DPU to the appropriate adjacent polar sectors.

The spacecraft spin clock provides sixteen 22.5° azimuthal (equatorial) sectors. For some rates, this information is condensed by the DPU into eight 45° equatorial sectors.

HR: There are 2 High Resolution Rates (HR0, HR1) which contain full directional (6 polar sectors x 16 equatorial sectors) information on three ion species. The first High Resolution Rate (HR0) contains one species, typically H^+. The second High Resolution Rate (HR1) is multiplexed, alternating between two sets of ion species every eight spins, in synchronization with the deflection voltage stepping sequence. (A typical 32-spin deflection voltage cycle (see Deflection Voltage Modes section) is subdivided into 4 identical sequences, each of which consists of eight voltage steps covering the entire STICS energy-per-charge range.) Usually O^+ will alternate with the FSR, giving us HR1 = O^+/FSR. Other species can be chosen by command.

SMR: There are three Sectored Matrix Rates (*SMR0, SMR1, SMR2*) which contain partial directional (3 polar sectors x 8 equatorial sectors) information on three ion species; typically He^+, He^{++}, and O^{++}.

MR: There are thirty Omnidirectional Matrix Rates (*MR0 through MR29*) which are accumulated over all sectors and contain no directional information.

BR: There are three Basic Rates (*BR0, BR1, BR2*) containing partial directional information (3 polar sectors x 8 equatorial sectors) and corresponding to the three pulse height ranges (*R0, R1, R2*). A Basic Rate is incremented by the DPU when the M and M/Q calculated for an event word falls within the appropriate pulse height range (see STICS Pulse Height Priority section).

The ranges are selected from the four pulse height priorities (*P0, P1, P2, P3*) defined in M *vs.* M/Q space. Typically, R0 = P0, R1 = P1, and R2 = P2. The default values for the priorities are:

Priority	Dominant Ions
0	CNO (Q = 5 to 7)
1	He^{++}, He^+
2	O^+, N^+, O^{++}
3	H^+

STICS Table Parameters and Conversion Factors

- These numbers are preliminary (they will depend on the final time-of-flight distance; the front foil thickness; the pulse-height-defect response of the solid state detectors; and the trimming of the ADC -- in other words, the flight sensor must be built and tested before these parameters are finalized.)

TIME and ENERGY:

Time and energy conversion factors to be used in the STICS mass and mass-per-charge calculation:

E[in keV] = Energy Channel Number * 1.5 keV/Channel
(uncompressed channels, 0 through 1023)

T[in nsec] = Time Channel Number * 0.4 nsec/Channel
(channels 0 through 1023)

For classification purposes, the DPU will specially handle channel values which fall outside of the well-defined event range (i.e., overflow channels). The location of these channels is still **TBD UMD**.

NOTE: As used here, "channel number" refers to the channel number derrived by the DPU after the energy slope correction, the time slope correction, and the TOF-offset correction have been applied to the E and T STICS Event Word channel numbers, as they come from the analog electronics. In other words, they are modified the same way as the energy and time-of-flight channels that the DPU generates for inclusion in the STICS PHA Word, except that the E Channel Number in the above algorithm is uncompressed (i.e., the above formula assumes 10 bits for E Channels instead of 9 bits or 8 bits.

(Energy Channel Number) = Energy Channel * (Energy Slope Correction + 128)
(from AE)

(Time Channel Number) = Time Channel * (Time Slope Correction + 128) + TOF-Offset
(from AE) (signed two's complement)

The time and energy "slope correction" is an 8-bit number which gets divided by 128 before being multiplied to the channel value. The default value is 128. The TOF-Offset has a default value of zero.

MASS:

The Mass (in amu) is given by the following equation (same as ICS):

$$\mathrm{Ln}(M) = A1 + A2 * \mathrm{Ln}(E) + A3 * \mathrm{Ln}(T) + A4 * \mathrm{Ln}(E) * \mathrm{Ln}(T) + A5 * [\mathrm{Ln}(E)]^2 + A6 * [\mathrm{Ln}(T)]^3$$

The preliminary defaults for this mass equation are as follows (22 March 1990):

A1 = 2.69575
A2 = -0.843766
A3 = -2.38009
A4 = 0.385641
A5 = 0.0513127
A6 = 0.0690096

MASS per CHARGE:

The Mass per Charge (in amu/e) is given by an equation of the form:

$$M/Q = C1 * [(E/Q) - C2] * T^2$$

where

T = the time of flight in nanoseconds (using the above equation to convert channel to time conversion)

C1 = 1.9159E-05

E/Q = $7.97 * [1.1160]^n$, where n = 0 to 31 is the DPPS voltage step ID number. (Specifically when the +DPPS and the -DPPS ID numbers are the same, which is the normal mode of operation. If one of the DPPSs should fail partially, we may send different step IDs to each supply. Therefore, we may like to be able to redefine these constants in flight, if that is easily done.)

C2 = For this parameter there are two options TBD between TUB and UMD.

OPTION 1 (preferred by UMD):

The DPU calculates the M/Q value using the value C2 = 1.5. If the resultant $M/Q \geq 11.0$ amu/e, then recalculate M/Q using C2 = 4.0 .

OPTION 2 (may be preferred by TUB for technical reasons):

The value of C2 = 2.5

STICS Normal Mode Telemetry Definition

	Data Item (a)	Bytes per Spin	Bits per sec (b)	Comments
2	High Resolution Rates (HR0,HR1) 6 x 16 sectors	192	512	Rates with full directional information. Species and E,T logic selectable by command; typically with HR0 = H^+ and HR1 = O^+/FSR. (c)
3	Sectored Matrix Rates (SMR0,SMR1, SMR2) 3 x 8 sectors	72	192	Rates with partial directional information. Species selectable by command; typically He^+, He^{++}, O^{++}.
30	Omnidirectional Matrix Rates (MR0 thru MR29)	30	80	E.g., O^{+6}, C^{+6}, O^+ (double coinc.), O^+ (triple coinc.), etc.
3	Basic Rates (BR0,BR1,BR2) 3 x 8 sectors	72	192	Corresponding to the three PHA ranges.
	Engineering Rates	21	56	Engineering rates are used for both science reduction and for monitoring the performance of the sensor.
3	FSR (FSR1,FSR2,FSR3)			
1	UFSR			
1	URSR			
3	RSR (RSR1,RSR2,RSR3)			
3	DCR (DCR1,DCR2,DCR3)			
3	TCR (TCR1,TCR2,TCR3)			
3	SSD (SSD1,SSD2,SSD3)			
1	MFSR			
1	MDCR			
1	MPF			
1	MPR			
48	PHA Words	192	512	
		579	1544	

(a) One byte per rate; 4 bytes per PHA word.

(b) Assumes 20 RPM.

(c) The second High Resolution Rate (HR1) is multiplexed, alternating between two sets of ion species every eight spins.

STICS Single Sensor Mode Telemetry Definition

Under the STICS single sensor operation, the telemetry division in the record mode interface is as follows:

Subsystem	Bits per Sec	Bits per EDB	Bytes per EDB
ICS	0	0	0
STICS	2496	7488	936
DPU/Common	64	192	24
Total	2560	7680	960

The STICS usage of the extra telemetry in this mode will be:

(1) The three Sectored Matrix Rates (3 x 8 sector information = 24 bytes per rate per EDB) will be converted into three additional High Resolution Rates (6 x 16 sector information = 96 bytes per rate per EDB). This yields a total of **five** High Resolution Rates (e.g., H^+, FSR, O^+, He^+, He^{+2}; although other species may be selected) and will use an additional:

3 rates x (96 bytes – 24 bytes) = 216 bytes/EDB .

In this format, none of the High Resolution Rates is multiplexed.

(2) Four omnidirectional matrix rates will be added, using 4 rates x 1 byte/rate = 4 bytes/EDB.

(3) Thirty-four PHA words will be added, yielding a total of 48 + 34 = 82 PHA/EDB, or ~27 per second. Each PHA word requires 4 bytes. Therefore, this uses an additional:

34 PHA words x 4 bytes/word = 136 bytes/EDB .

This allocation uses all but one byte of the extra telemetry (216 + 4 + 136 = 356 bytes/EDB).

The method of selecting the 39 species for the Science Rates in this EDB format mode is TBD but may entail having some redundancy existing between the High Resolution and Omni Matrix Rates since only 36 ion species are defined (see STICS Science Rate Definitions section).

	Data Item (a)	Bytes per Spin	Bits per sec (b)	Comments
5	High Resolution Rates (HR0 thru HR4) 6 x 16 sectors	480	1280	Rates with full directional information. Species and E,T logic selectable by command; typically H^+, FSR, He^+, He^{++}, O^+. (c,d)
34	Omnidirectional Matrix Rates (MR0 thru MR33)	34	90.7	E.g., O^{+6}, C^{+6}, O^+ (double coinc.), O^+ (triple coinc.) , etc. (d)
3	Basic Rates (BR0,BR1,BR2) 3 x 8 sectors	72	192	Corresponding to the three PHA ranges.
	Engineering Rates	21	56	Engineering rates are used for both science reduction and for monitoring the performance of the sensor.
3	FSR (FSR1,FSR2,FSR3)			
1	UFSR			
1	URSR			
3	RSR (RSR1,RSR2,RSR3)			
3	DCR (DCR1,DCR2,DCR3)			
3	TCR (TCR1,TCR2,TCR3)			
3	SSD (SSD1,SSD2,SSD3)			
1	MFSR			
1	MDCR			
1	MPF			
1	MPR			
82	PHA Words	328	874.7	
	Spare	1	2.7	
		936	2496	

(a) One byte per rate; 4 bytes per PHA word.

(b) Assumes 20 RPM.

(c) In this format, none of the High Resolution Rates is multiplexed.

(d) There may be some redundancy existing between the High Resolution and Omni Matrix Rates.

Deflection Voltage Modes

Mechanically, the STICS electrostatic deflection system consists of two concentric spherical segments with the following characteristics:

• Polar acceptance angle:	159°
• Mean radius (R_o):	107.75 mm
• Gap (ΔR):	4.50 mm
• Deflection angle:	125°

The upper and lower deflection plates of the electrostatic deflection system are connected to a pair of high voltage deflection plate power supplies (+*DPPS* and -*DPPS*) which set the deflection voltages of both plates simultaneously. There are thirty-two output voltages for each plate. These voltages are logarithmically spaced to take the plates from ± 330 volts to the maximum deflection voltage of ± 10 kV in order to cover the entire energy-per-charge (E/Q) range of the sensor (~10 to 230 keV/e).

The energy per charge response of the deflection system at a given output voltage is given by $E/Q = A * \Delta V$, where ΔV is the potential difference across the deflection plates and A is the analyzer constant, $A = R_o (2 * \Delta R)$. In this sensor, the design goal for A is 11.97.

The settings of the +DPPS and the -DPPS are represented by their respective step numbers. In normal flight operations, the +DPPS and the -DPPS will have the same step number (matched positive and negative voltages) at any given time. (Non-matching step numbers may be used, for example, if there is a partial failure in one of the power supplies.) For a given step number n, where $n = 0$ to 31 and is same for both ±DPPS, the energy per charge response (neglecting fabrication tolerances and fringe field effects) is given by $E/Q = 7.97 * (1.1160)^n$

The step spacing is ~11.6%; the energy-per-charge resolution, $\Delta(E/Q) / (E/Q)$, is about 5%.

Table 3

(A)

ICS PHA PRIORITY SYSTEM

		Energies (channel #'s)			
		Lowest			Highest
	Event Categories	E1	E2	E3	E4
1	Heavy nuclei	H1	H2	H3-4	H5-6
11	Medium nuclei	M1-2	M3-4	M5-7	M8-10
111	Helium nuclei	A1-2	A3-4	A5-7	A8-10
IV	Protons	P1-2	P3-4	P5-7	P8-10

(B)

Priority Ordering By Spin (Modulo 8)

	Highest			Lowest
Priority	1	2	3	4
Spin 1-2	1	11	111	1V
Spin 3-4	11	1	111	1V
Spin 5-6	111	1V	1	11
Spin 7-8	1V	1	11	111

Repeats every eight spins

(C)

Energy Priority within a 32 Spin EPIC Science Record

	Highest			Lowest
Energy Priority	1	2	3	4
Spin 1-8	E4	E3	E2	E1
9-16	E3	E2	E1	E4
17-24	E2	E1	E4	E3
25-32	E1	E4	E3	E2

There are three PHA transmitted events per sector every two spins. Priority between species is determined by (B) above. Within a single category there is an energy priority ordering that rotates every eight spins, assuring that even for very soft spectra the lowest energy channel of each species will not monopolize the PHA coverage. Thus the total priority system goes through one complete cycle in 32 spins (~96 seconds), the EPIC Science Record.

Definition of the ICS Pulse Height Analysis Word

Each ICS PHA event will be an event that falls in one of the 36 Species Rate Channels, and will consist of 24 bits of data

- 10 bits (TOF) + 9 bits (E) + 4 bits (sector) + 1 bit (head)

There are 8 PHA events per second, ordered as 3 events per sector per every two spins (48 events per 2 spins). These events are selected by a rotating priority system. This priority system has 4 levels of species priority (corresponding to protons, helium, CNO, and heavies) and 4 levels of energy priority. In a two-spin interval, events are to be chosen such that at most two of the three events reported are from the same head. This most likely will be done by disabling the interrupt for a head for a given priority bin once two events from that head have been examined. This implementation reduces the buffer needed while increasing the processor overhead slightly.

The normal (default) PHA priority system operation will attempt to achieve uniform coverage via rotation of priority by species groups, and, within these groups, by energy. The ICS PHA priority system is summarized in Table 3. The 36 ICS Species channels are assigned to 16 priority groups by Table 3. It is possible by the I_PR_OVR and I_PHACMD commands to separately fix on an Energy priority or xxxxx, fix on a species priority or xxxxx, ignore priority (assign all groups the same priority level), fix on either head, or ignore head designation.

The DPPS steps once per spin (i.e., ~every 3 seconds) and has a cycle period of 32 spins (to synchronize with the EPIC Science Record). Each voltage cycle may consist of a repeated deflection voltage sequence as long as the sequence period is an integral division of 32; i.e., the sequence period may be 1, 2, 4, 8, 16, or 32 spins long. There will be a default sequence (**TBD UMD**) stored in the DPU which is overridden when a new sequence is uploaded by ground command. The deflection voltage sequence may consist of any combination of the 32 available voltage steps (i.e., each of the 32 slots in the voltage cycle is set individually by command); however, in order to minimize settling times, it is anticipated that the sequence will normally be made up of relatively small voltage steps in the direction of decreasing E/Q to scan the energy-per-charge range of interest, followed by a relatively large step to return to the sequence's initial deflection voltage. Interleaved sequences or non-stepping (constant E/Q) sequences may also be employed. A limited number of possible voltage cycle modes will be predefined and incorporated into the macro commands.

The transition (settling) time between voltage steps depends on the size and direction of the consecutive voltage steps. For small steps, the transition time is on the order of 50 msec. For large steps, such as may be expected at the end of a voltage sequence, the transition time could be > 100 msec. During the voltage sweep, the E/Q value is undefined. Therefore, a deadtime of ~80 - 90 msec (actual value **TBD UMD**) is assumed for the sweep period, and during this time no data are accumulated. This creates a data loss of almost half a sector. The deadtime is allotted to the DPU for various functions, including servicing the spin-accumulator in the analog electronics (see STICS Rate Accumulators in the Analog Electronics section). The location of the voltage sweep deadtime is in equatorial sector zero. The position of sector zero relative to the sun pulse can be modified by the "Sun Pulse" and "Sector Adjustment" commands, which respectively define the sector containing the sun pulse and allows the adjustment by *n* degrees of the position of the sun pulse within that sector.

The E/Q values of the voltage steps are used in the DPU M/Q classification of event words. If one of the DPPSs is disabled, or if non-matching voltage steps are used on the ±DPPS, the DPU adjusts the E/Q values accordingly.

ICS Channel Structure:

The ICS measurements are to be combined by the instrument data system into data channels of several types for accumulation and transmission to the ground. These channels are given in Table 4 . The basic data from the sensor heads consists of singles counting rates, read out by the DPU from accumulators in the analog electronics, and single digitized events transferred from the ICS analog electronics to the DPU at a maximum rate of 100 KHz. These latter contain a 10 bit word defining an ion event energy and another 10 bit word defining measured ion time-of-flight, plus a bit indicating which ICS head was the source of the event. Such a digitized event can have either an energy signal with no TOF, a TOF signal with no energy, or both E and TOF signals. If only an energy or only a TOF was measurable for an event it will be counted by the DPU only in the appropriate E-Spectrum or TOF Spectrum channels. If both ion energy and TOF were measurable, then the location of the event in E-TOF space determines what species channel the event is counted in (These events are also counted in both the energy and TOF spectrum channels.)

The resulting ICS data rate is summarized in the ICS Normal Mode Definition section. For the backup case in which STICS is not providing telemetry the ICS data rate is summarized in the ICS Single Sensor Mode Definition section.

Table 4
ICS CHANNELS

E Spectrum	16 logarithmic channels per head from threshold (~25 keV) to ~3 MeV. Defined on the E signal only, without TOF coincidence requirements.
TOF Spectrum	16 logarithmic channels per head covering times-of-flight from ~2 to ~100 nsec (Ion Energies ~≥ 10 keV). Defined on TOF signal only, without energy coincidence requirements.
Species Rates	Channels defined on a combination of E and TOF signals to divide the E-TOF space into regions that each contain primarily a unique species or species group over a limited energy range, as follows. (Note that each of these species events will also be counted in both the E Spectrum and TOF Spectrum.) For each separate head the following are defined.

Protons	10	channels	(~50 keV to ~3 MeV)	P1-P10
Helium	10	"	(~70 keV to ~3 MeV)	α1-α10
Medium (CNO)	10	"	(~130 keV to ~3.3 MeV)	M1-M10
Heavies (N_e-F_e)	6	"	(~500 keV to ~4.3 MeV)	H1-H6

Singles Rates	Total counting rates useful in science analysis and the analysis of instrument operation: FSR(2), RSR(2), DCR(2), TCR(2), SSD(2), UFSR, URSR, MFSR, MDCR, ED1, ED2. 16 channels total.
Total	152 channels, each sectored into 16 spin-synchronous channels, plus two electron channels (ED1, ED2) sectored by 8.

ICS Rate Accumulators (and Definitions) in the Analog Electronics

In addition to the event words described in the Definition of the ICS Event Word section, the analog electronics transmits to the DPU various singles and coincidence rates which are used for both diagnostic purposes and scientific analysis.

The ICS AE rates require 16 channels. The channel names and definitions are the same as those used for STICS, except for the electron detector channels ED1 and ED2. Unlike STICS, however, all of these channels are sectored: by 8 for ED1-ED2, and by 16 for all other channels.

Format	Channel	Definition
C	FSR (2)	The two Front Seda Rates, one for the front MCP anode in each of the N and S ion heads. Normally summed over two spins with individual sector resolution, but subject to change by command (see Commandable Channel Telemetry Formats section)
D	RSR (2)	The two Rear Seda Rates Normally summed over sixteen spins with individual sector resolution, but subject to change by command (see Commandable Channel Telemetry Formats section)
D	DCR (2)	Double Coincidence Rates, one for each ion head, defined as a valid TOF event. Normally summed over sixteen spins with individual sector resolution, but subject to change by command (see Commandable Channel Telemetry Formats section)
D	TCR (2)	Triple Coincidence Rates, incremented when there is a valid DCR and a coincident SSD. Normally summed over sixteen spins with individual sector resolution, but subject to change by command (see Commandable Channel Telemetry Formats section)
D	SSD (2)	The Solid State Detector rates, one for each ion head SSD. Normally summed over sixteen spins with individual sector resolution, but subject to change by command (see Commandable Channel Telemetry Formats section)

D	UFSR	The Universal FSR for ICS. This is the sectored accumulation of the start signals seen by the ICS TOF circuitry; the front anodes for both heads are combined. Normally summed over sixteen spins with individual sector resolution, but subject to change by command (see Commandable Channel Telemetry Formats section)
D	URSR	The Universal RSR for ICS. This is the sectored accumulation of the stop signals seen by the ICS TOF circuitry, with both ion heads combined. Normally summed over sixteen spins with individual sector resolution, but subject to change by command (see Commandable Channel Telemetry Formats section)
D	MFSR	Counts the occurrence of Multiple UFSRs - i.e. events with more than one UFSR start signal within the 2-100 nsec ICS time analysis window. Normally summed over sixteen spins with individual sector resolution, but subject to change by command (see Commandable Channel Telemetry Formats section)
F	MDCR	Counts the occurrence of Multiple DCR's - i.e. DCR events with more than one URSR stop signal within the 2-100 nsec time analysis window defined by the initializing universal start pulse. Normally summed over thirty-two spins with individual sector resolution, but subject to change by command (see Commandable Channel Telemetry Formats section)
B	ED1	Counts energy pulses above the lowest threshold in the Electron Detector head. Essentially > 30 keV electron events. Normally reported each spin with each group of 2 sectors summed.
D	ED2	Counts energy pulses above the second (highest) threshold in the Electron Detector head. These will usually be > 100 keV electrons. Normally summed over sixteen spins with each group of 2 sectors summed, but subject to change by command (see Commandable Channel Telemetry Formats section)

Note: UFSR, URSR, MFSR and MDCR are replaced when calibrate mode accumulator readout is enabled (see Internal Calibration System section).

ICS Table Parameters and Conversion Factors

- These numbers are preliminary (they will depend on the final time-of-flight distance; the pulse-height-defect response of the solid state detectors; and the trimming of the ADC -- in other words, the flight sensor must be built and tested before these parameters are finalized.)

TIME and ENERGY:

Time and energy conversion factors to be used in the ICS channel assignments and calculation are:

E[in keV] = Energy Channel Number * 3.0 keV/Channel
(uncompressed channels, 0 through 1023), total range = 0 - 3069 keV.

T[in nsec] = Time Channel Number * 0.11 nsec/Channel
(channels 0 through 1023), total range = 0 - 112.5 nsec.

For classification purposes, the DPU will specially handle channel values which fall outside of the well-defined event range (i.e., overflow channels). The location of these channels is listed in Table 11.

NOTE: As used here, "channel number" refers to the channel number derrived by the DPU after the energy slope correction, the time slope correction, and the TOF-offset correction have been applied to the E and T ICS Event Word channel numbers, as they come from the analog electronics. In other words, they are modified the same way as the energy and time-of-flight channels that the DPU generates for inclusion in the STICS PHA Word, except that the E channel Number in the above algorithm is uncompressed (i.e., the above formula assumes 10 bits for E Channels instead of 9 bits or 8 bits.

(Energy Channel Number) = Energy Channel * (Energy Slope Correction ÷ 128)
(from AE)

(Time Channel Number) = Time Channel * (Time Slope Correction ÷ 128) + TOF-Offset
(from AE) (signed two's complement)

The time and energy "slope correction" is an 8-bit number which gets divided by 128 before being multiplied to the channel value. The default value is 128. The TOF-Offset has a default value of zero.

MASS:

The Mass (in amu) is given by the following equation (same as STICS):

$$Ln(M) = A1 + A2 * Ln(E) + A3 * Ln(T) + A4 * Ln(E) * Ln(T) + A5 * [Ln(E)]^2 + A6 * [Ln(T)]^3$$

where E is the energy in keV and T is the Time-of-Flight, as defined above.

The preliminary defaults for this mass equation are as follows (22 March 1990):

A1 = -5.70969
A2 = 0.188562
A3 = 0.634870
A4 = 0.134778
A5 = 0.0394281
A6 = 0.0381063

ICS Telemetry Allocation and Definition

ICS Normal Mode Telemetry Definition

	Data Item (a)			Bytes per Spin	Bits per sec (b)	Comments
	Science Rates					
32	Energy Channels				189.33	Details follow in Table 5
32	TOF Channels				101.33	Details follow in Table 6
20	Proton Channels				85.33	Details follow in Table 7
20	Helium Channels				85.33	Details follow in Table 8
20	Medium Z Channels				80.00	Details follow in Table 9
12	Heavy Z Channels				16.00	Details follow in Table 10
	Summed Over Both Heads					
2	Energy Channels				85.33	Details follow in Table 5
1	TOF Channels				21.33	Details follow in Table 6
6	Diagnostic Channels				0.50	Details follow in Table 11
	Engineering Rates					Engineering rates are used for both science reduction and for monitoring the performance of the sensor.
	reported->	sectors* summed	spins* summed			
2	FSR(2)	1	2		42.67	
2	RSR(2)	1	16		5.33	
2	DCR(2)	1	16		5.33	
2	TCR(2)	1	16		5.33	
2	SSD(2)	1	16		5.33	
1	UFSR	1	16		2.67	
1	URSR	1	16		2.67	
1	MFSR	1	16		2.67	
1	MDCR	1	32		1.33	
1	ED1	2	1		21.33	
1	ED2	2	16		1.33	
8	PHA events/sec				192.00	(24 bits/event)
					952.50	

Notes:

- Many data items are effected by a command option that allows read-out with twice the time resolution (3 to 48 sec) at half the angular resolution (summing to give 8 sectors rather than 16) and/or twice the time resolution by summing over both heads. There are three telemetry groups that can be commanded separately by the BC I_DIGCMD. The details are in Appendix B and the Commandable Channel Telemetry Formats section. All channels in this definition are selectable by command.

(a) One byte per rate; 3 bytes per PHA word.

(b) Assumes 20 RPM.

Energy Channels

16 consecutive channels per ion head covering the Energy range from the lowest threshold (approximately 20keV) to approximately 3000 keV. There are 12 logarithmically-spaced channels from 20 keV to 600 keV, and then 4 more logarithmically-spaced channels from 600 keV to 3000 keV.

Table 5
Energy Channels

Summed over individual heads:

Format	Channel	Range (keV)	Normal Mode sectors summed	Normal Mode spins summed	Bits per Second
C	E1	20 - 26.5	1	2	21.33
D	E2	26.5 - 35	1	16	2.67
C	E3	35 - 46.8	1	2	21.33
C	E4	46.8 - 62	1	2	21.33
D	E5	62 - 82.5	1	16	2.67
D	E6	82.5 - 109.5	1	16	2.67
D	E7	109.5 - 145.4	1	16	2.67
D	E8	145.4 - 193	1	16	2.67
D	E9	193 - 256	1	16	2.67
D	E10	256 - 340	1	16	2.67
D	E11	340 - 452	1	16	2.67
D	E12	452 - 600	1	16	2.67
D	E13	600 - 900	1	16	2.67
F	E14	900 - 1340	1	32	1.33
F	E15	1340 - 2006	1	32	1.33
F	E16	2006 - 3000	1	32	1.33
				PER HEAD TOTAL	94.67
				GRAND TOTAL	189.33

Summed over both heads:

Format	Channel	Range (keV)	Normal Mode sectors summed	Normal Mode spins summed	Bits per Second
A	E2	26.5 - 35	1	1	42.67
A	E5	62 - 82.5	1	1	42.67
				SUMMED HEAD TOTAL	85.33

Time-of-Flight Channels

16 consecutive channels per head covering the range of TOF between the minimum observable (approximately 2 nsec) and approximately 100 nsec. There are 12 logarithmically-spaced channels from 6 nsec to 60 nsec, with two more widely spaced channels both above and below this range.

Table 6
Time-of-Flight Channels

Summed over individual heads:

			Normal Mode		
Format	Channel	Range (nsec)	sectors summed	spins summed	Bits per Second
F	T1	2 - 3.5	1	32	1.33
F	T2	3.5 - 6	1	32	1.33
F	T3	6 - 7.2	1	32	1.33
F	T4	7.2 - 8.8	1	32	1.33
F	T5	8.8 - 10.7	1	32	1.33
D	T6	10.7 - 12.9	1	16	2.67
F	T7	12.9 - 15.7	1	32	1.33
D	T8	15.7 - 19	1	16	2.67
D	T9	19 - 23	1	16	2.67
D	T10	23 - 27.8	1	16	2.67
C	T11	27.8 - 33.7	1	2	21.33
D	T12	33.7 - 40.9	1	16	2.67
D	T13	40.9 - 49.5	1	16	2.67
F	T14	49.5 - 60	1	32	1.33
D	T15	60 - 77	1	16	2.67
F	T16	77 - 100	1	32	1.33
			PER HEAD TOTAL		50.67
			GRAND TOTAL		101.33

Summed over both heads:

			Normal Mode		
Format	Channel	Range (nsec)	sectors summed	spins summed	Bits per Second
B	T14	49.5 - 60	2	1	21.33
			SUMMED HEAD TOTAL		21.33

Species Rate Channels

The 36 species rate channels per ion head use the mass algorithm defined in the ICS Table Parameters and Conversion Factors section. Our species channels are nominally:

<u>Protons</u>: 10 consecutive channels; log-spaced from 20-800, and then from 800-3000. "Proton" mass range 0.5 - 2.5 AMU.

Table 7
Proton Rate Channels

<u>Summed over individual heads:</u> Normal Mode

Format	Channel	Range (keV)	sectors summed	spins summed	Bits per Second
D	P1	20 - 31.7	1	16	2.67
C	P2	31.7 - 50.3	1	2	21.33
D	P3	50.3 - 79.8	1	16	2.67
D	P4	79.8 - 126.5	1	16	2.67
D	P5	126.5 - 200.6	1	16	2.67
D	P6	200.6 - 318	1	16	2.67
D	P7	318.1 - 504.5	1	16	2.67
D	P8	504.5 - 800	1	16	2.67
F	P9	800 - 1550	1	32	1.33
F	P10	1550 - 3000	1	32	1.33
			PER HEAD TOTAL		42.67
			GRAND TOTAL		85.33

<u>Helium</u>: 10 consecutive channels; "Helium" mass range 2.5 - 8 AMU. Helium channels named A1 through A10. Measured energy coverage for each channel same as for proton channels P1 through P10 above. Read out Interval also the same.

Table 8
Helium Rate Channels

Summed over individual heads:			Normal Mode		
Format	Channel	Range (keV)	sectors summed	spins summed	Bits per Second
D	He1	20 - 31.7	1	16	2.67
C	He2	31.7 - 50.3	1	2	21.33
D	He3	50.3 - 79.8	1	16	2.67
D	He4	79.8 - 126.5	1	16	2.67
D	He5	126.5 - 200.6	1	16	2.67
D	He6	200.6 - 318	1	16	2.67
D	He7	318.1 - 504.5	1	16	2.67
D	He8	504.5 - 800	1	16	2.67
F	He9	800 - 1550	1	32	1.33
F	He10	1550 - 3000	1	32	1.33
			PER HEAD TOTAL		42.67
			GRAND TOTAL		85.33

<u>Medium Z (CNO)</u>: 10 consecutive channels; log-spaced from 20-3000 keV. "Medium" mass range 8-21 AMU.

Table 9
Medium Z Rate Channels

Summed over individual heads:			Normal Mode		
Format	Channel	Range (keV)	sectors summed	spins summed	Bits per Second
D	M1	20 - 33	1	16	2.67
C	M2	33 - 55	1	2	21.33
D	M3	55 - 90	1	16	2.67
D	M4	90 - 148	1	16	2.67
D	M5	148 - 245	1	16	2.67
D	M6	245 - 404	1	16	2.67
F	M7	404 - 667	1	32	1.33
F	M8	667 - 1100	1	32	1.33
F	M9	1100 - 1820	1	32	1.33
F	M10	1820 - 3000	1	32	1.33
			PER HEAD TOTAL		40.00
			GRAND TOTAL		80.00

Heavies (Na - Fe): 6 consecutive channels;
"Heavy" mass range 21 - 100 AMU.

Table 10
Heavy Z Rate Channels

Summed over individual heads: Normal Mode

Format	Channel	Range (keV)	sectors summed	spins summed	Bits per Second
F	H1	20 - 120	1	32	1.33
F	H2	120 - 228	1	32	1.33
F	H3	228 - 435	1	32	1.33
F	H4	435 - 830	1	32	1.33
F	H5	830 - 1575	1	32	1.33
F	H6	1575 - 3000	1	32	1.33
			PER HEAD TOTAL		8.00
			GRAND TOTAL		16.00

The above 36 species rate channels thus cover the valid regions of the TOF × E space in a continuous block.

All of the Energies given are observed (measured) energy, not incident energy. That correction will be made in ground processing. The numbers given may change after further analysis. These numbers can all be considered approximate - small variations from the levels given would not really matter.

Diagnostic Rate Channels

6 channels which are summed over 32 spins, 16 sectors, and both heads, will provide information on valid events which exceed either the lower or upper channel limit for time, energy, or mass.

Table 11
Diagnostic Rate Channels

Summed over both heads: Normal Mode

Format	Channel	Range (keV)	sectors summed	spins summed	Bits per Second
FA	E0	E < 20 keV	16	32	0.08
FA	E17	E > 3000 keV	16	32	0.08
FA	T0	T < 2 ns	16	32	0.08
FA	T17	T > 100ns	16	32	0.08
FA	ZM	M < 0.5	16	32	0.08
FA	SM	M > 100	16	32	0.08
					0.50

Channel Telemetry Fortmats

Normal Mode

Data Items Effected	"A" Format Mode	Spins Summed	Sectors Summed	# of Heads Summed
E2, E5	Normal	1	1	2

Data Items Effected	"B" Format Mode	Spins Summed	Sectors Summed	# of Heads Summed
T14, ED1	Normal	1	2	2

Data Items Effected	"C" Format Mode	Spins Summed	Sectors Summed	# of Heads Summed
E1, E3, E4, T11, P2, He2, M2, FSR	Normal	2	1	1
	Sum Over Double Sectors	1	2	1
	Sum Over 2 Heads	1	1	2
	Both	not valid	not valid	not valid

Data Items Effected	"D" Format Mode	Spins Summed	Sectors Summed	# of Heads Summed
E2, E5, E6, E7, E8, E9, E10, E11, E12, E13, T6, T8, T9, T10, T12, T13, T15, P1, P3, P4, P5, P6, P7, P8, He1, He3, He4, He5, He6, He7, He8, M1, M3, M4, M5, M6, RSR, DCR, TCR, SSD	Normal	16	1	1
	Sum Over Double Sectors	8	2	1
	Sum Over 2 Heads	8	1	2
	Both	4	2	2

Data Items Effected	"D" Format Mode	Spins Summed	Sectors Summed	# of Heads Summed
UFSR, URSR, MFSR, ED2	Normal	16	1	2
	Sum Over Double Sectors	8	2	2
	Sum Over 2 Heads	16	1	2
	Both	8	2	2

Data Items Effected	"F" Format Mode	Spins Summed	Sectors Summed	# of Heads Summed
E14, E15, E16, T1, T2, T3, T4, T5, T7, T14, T16, P9, P10, He9, He10, M7, M8, M9, M10, H1, H2, H3, H4, H5, H6	Normal	32	1	1
	Sum Over Double Sectors	16	2	1
	Sum Over 2 Heads	16	1	2
	Both	8	2	2

Data Items Effected	"F" Format Mode	Spins Summed	Sectors Summed	# of Heads Summed
MDCR	Normal	32	1	2
	Sum Over Double Sectors	16	2	2
	Sum Over 2 Heads	32	1	2
	Both	16	2	2

Data Items Effected	"FA" Format Mode	Spins Summed	Sectors Summed	# of Heads Summed
E0, E17, T0, T17, ZM, SM	Normal	32	16	2

2 ? 1 ?
4 ?

ICS Only Mode Telemetry Allocation and Definition

Under the ICS single sensor operation, the telemetry division in the record mode interface is as follows:

Subsystem	Bits per Sec	Bits per EDB	Bytes per EDB
ICS	2496	7488	936
STICS	0	0	0
DPU/Common	64	192	24
Total	2560	7680	960

ICS Only Mode Telemetry Format Summary:

Format	Read Out Description		Bits/sec.
G	27	channels read out by sector every spin (3 sec)	1152.00
C	17	channels read out by sector every 2 spins (6 sec)	362.67
H	62	channels read out by sector every 8 spins (24 sec)	330.67
D	34	channels read out by sector every 16 spins (48 sec)	90.67
F	24	channels read out by sector every 32 spins (96 sec)	32.00
	4	PHA events/sector/spin (21.33 events/sec)	512.00
		unused	16.00
		Total	2496.00

ICS Only Mode Telemetry Definition

	Data Item (a)			Bytes per Spin	Bits per sec (b)	Comments
	Science Rates					
32	Energy Channels			208.0	554.67	Science rate details follow in Table 12
32	TOF Channels			150.0	400.00	
20	Proton Channels			116.0	309.33	
20	Helium Channels			90.0	240.00	
20	Medium Z Channels			56.0	149.33	
12	Heavy Z Channels			6.0	16.00	
12	Diagnostic Channels			6.0	16.00	
	Engineering Rates					Engineering rates are used for both science reduction and for monitoring the performance of the sensor.
	reported->	sectors* summed	spins* summed			
2	FSR(2)	1	1	32.0	85.33	
2	RSR(2)	1	8	4.0	10.67	
2	DCR(2)	1	8	4.0	10.67	
2	TCR(2)	1	8	4.0	10.67	
2	SSD(2)	1	1	32.0	85.33	
1	UFSR	1	8	2.0	5.33	
1	URSR	1	8	2.0	5.33	
1	MFSR	1	16	1.0	2.67	
1	MDCR	1	16	1.0	2.67	
1	ED1	1	1	16.0	42.67	
1	ED2	1	2	8.0	21.33	
4	PHA events/sector/spin (21.33 events/sec)			192.0	512.00	(24 bits/event)
	spares			6.0	16.00	
			TOTAL	936.0	2496.00	

Notes:
- Many data items are effected by a command option that allows read-out with twice the time resolution (3 to 48 sec) at half the angular resolution (summing to give 8 sectors rather than 16) and/or twice the time resolution by summing over both heads. There are three telemetry groups that can be commanded separately by the BC I_DIGCMD. The details are in Appendix B and the Commandable Channel Telemetry Formats section. All channels in this definition are selectable by command.

(a) One byte per rate; 3 bytes per PHA word.

(b) Assumes 20 RPM.

Energy Channels

16 consecutive channels per ion head covering the Energy range from the lowest threshold (approximately 20keV) to approximately 3000 keV. There are 12 logarithmically-spaced channels from 20 keV to 600 keV, and then 4 more logarithmically-spaced channels from 600 keV to 3000 keV.

Table 12
Channel Formats

Chnl.	Format	Chnl.	Format	Chnl.	Format	Chnl.	Format	Chnl.	Format
E1	C	T1	D	P1	C	He6	H	H1	F
E2	G	T2	D	P2	G	He7	H	H2	F
E3	C	T3	D	P3	C	He8	D	H3	F
E4	C	T4	H	P4	G	He9	D	H4	F
E5	G	T5	H	P5	H	He10	D	H5	F
E6	H	T6	G	P6	H			H6	F
E7	H	T7	H	P7	H	M1	D		
E8	G	T8	C	P8	H	M2	H	E0	F
E9	H	T9	H	P9	D	M3	H	E17	F
E10	H	T10	H	P10	D	M4	C	T0	F
E11	G	T11	G			M5	H	T17	F
E12	H	T12	H	He1	H	M6	C	ZM	F
E13	H	T13	H	He2	G	M7	H	SM	F
E14	H	T14	G	He3	H	M8	D		
E15	D	T15	D	He4	G	M9	D		
E16	D	T16	D	He5	H	M10	D		

Channel Telemetry Fortmats

ICS Only Mode Telemetry Formats

Data Items Effected	"C" Format Mode	Spins Summed	Sectors Summed	# of Heads Summed
E1, E3, E4, T8, P1, P3, M4, M6, ED2*	Normal	2	1	1
	Sum Over Double Sectors	1	2	1
	Sum Over 2 Heads	1	1	2
	Both	not valid	not valid	not valid

Data Items Effected	"D" Format Mode	Spins Summed	Sectors Summed	# of Heads Summed
E15, E16, T1, T2, T3, T15, T16, P9, P10, He8, He9, He10, M1, M8, M9, M10, MFSR, MDCR	Normal	16	1	1
	Sum Over Double Sectors	8	2	1
	Sum Over 2 Heads	8	1	2
	Both	4	2	2

Data Items Effected	"F" Format Mode	Spins Summed	Sectors Summed	# of Heads Summed
H1, H2, H3, H4, H5, H6, D1, D2, D3, D4, D5, D6, FSR, SSD, ED1*	Normal	32	1	1
	Sum Over Double Sectors	16	2	1
	Sum Over 2 Heads	16	1	2
	Both	8	2	2

Data Items Effected	"G" Format Mode	Spins Summed	Sectors Summed	# of Heads Summed
E2, E5, E8, E11, T6, T11, T14, P2, P4, He2, He4	Normal	1	1	1

Data Items Effected	"H" Format Mode	Spins Summed	Sectors Summed	# of Heads Summed
E6, E7, E9, E10, E12, E13, E14, T4, T5, T7, T9, T10, T12, T13, P5, P6, P7, P8, He1, He3, He5, He6, He7, M2, M3, M5, M7, RSR, DCR, TCR, UFSR, URSR	Normal	8	1	1

* since there is only one head, the 'Sum Over 2 Heads' and 'Both' modes are the same as the 'Normal' and 'Sum Over Double Sector' modes, respectively

COMMON EPIC STATUS AND HOUSEKEEPING

There will be a number of bytes required by both subsystems for data analysis, including spin counters, sync words, etc. Other things will only be needed by one subsystem, such as the DPPS step number.

As can be seen in the subcom discussion that follows, many of the common status values are already being sent via the subcom interface. Only the information that must be reported every EDB (and thus cannot be subcommutated easily) should be included in the explicit telemetry allocation.

Below is a list of the information we will need to include in the telemetry every EDB:

Table 12. EDB-based Status Telemetry (DPU/Common telemetry allocation)

Data Description	Bits Per EDB	User
EDB Sync Pattern	16	Both
EDB Record CRC Value	8	Both
Spin Counter (total s/c spins)	8	Both
Measured EDB Counter	5	Both
EDB Counter	8	Both
Subcom Index (useful when fixed)	8	Both
Subcommutated Hskpg Data	48	Both
DPU Status & Contingency	40	Both
DPU Error Word	8	Both
Instrument Status		
Instrument Power	1	Both
STICS LVPS Status	1	STICS
ICS LVPS Status	1	ICS
+ DPPS Voltage Step	5	STICS
– DPPS Voltage Step	5	STICS
EPIC HV Enable	1	Both
Aperture motor activity	1	ICS
Spares	26.5	Both
Total	190.5	<-(23.81 bytes)

As can be seen from this preliminary list, it is possible that not all 23.81 bytes per EDB which are tentatively allocated to the status/housekeeping functions will be needed (I've shown 70.5 bits between the DPU and spares that are not presently allocated). Should we determine that these are not needed, the extra telemetry will be given back to ICS and STICS for science.

Bit 0 is the MSB and bit 7 is the LSB, this is the standard for the spacecraft.

EPIC SUBCOMMUTATED HOUSEKEEPING/STATUS DATA

The instrument will subcommutate much of the housekeeping and status information generated by the sensors and DPU over the time period defined by a Science Record. This subcommutation scheme will be discussed below.

A short review of the real time and record mode spacecraft status information is in order. The following information describes the status timing:

32 minor frames = 1 cycle frame

6 bytes ("group") EPIC status per cycle frame
(bytes 8, 9 & 10 of minor frames 27 & 28)

1 Science Record = 32 EDBs
1 spin per 3 sec (nom)

==> 1 Science Record per 96 sec

real time	record mode	Item
64	16	minor frames per second
2	0.5	cycle frames per second
12	3	status bytes per second
1152	288	status bytes per Science Record
192	48	status groups per Science Record
12	3	subcom bytes per sec

The real time status bits are thought of in groups of 6 bytes (i.e. those received in a single cycle frame). If we choose our housekeeping subcom to use two bytes per real time status group, one for a subcom index and one for the subcom data, we will have 192 subcom slots available per Science Record.

The same housekeeping information that appears in the spacecraft status bytes should also appear in the recorded science telemetry records. If we are sending 192 bytes per 32 EDBs (Science Record), then we must send 192/32= 6 bytes of subcom data per EDB (which equals 2 bytes per second). Because the science data is already spin oriented, it is not absolutely required that the subcom index be sent. It is provided, however, to allow the subcom index to be frozen by command, while the spin count continues.

Note that the record mode interface is also provided with subcommutated status information. Because this interface goes to the tape recorder, and the housekeeping information is already in the science telemetry record, the record mode spacecraft status bytes are redundant. We will send the status information anyway, but given that the interface operates at only one fourth the rate of the other housekeeping channels, it will contain only 25% of the subcom data.

Bit 0 is the MSB and bit 7 is the LSB, this is the standard for the spacecraft.

Table 13 shows the list of the data we will include in the EPIC subcommutated housekeeping and Table 14 shows a more detailed breakdown of the Digital Status bytes from Table 11. Appendix A shows the detailed subcom list including read details. Note that both the digital and analog state of the instrument is included. Also included in the subcom data is specific information (error codes) intended to aid in determining what initiated the alarm condition.

There are several approaches we can take to using this information. They are:

1. The spacecraft control team ignores this data completely until a problem is detected via the instrument alarm flag (frame 27, word 8, bit 7). The subcom information would then be looked at to determine what the problem is.

2. The spacecraft control team would routinely monitor a subset of the subcom data (for example 16 highest priority functions). If a problem is detected in the data or via the instrument alarm flag (frame 27, word 8, bit 7), the full subcom information would then be looked at to determine what the problem is.

3. The spacecraft control team would routinely monitor the full subcom data to aid in command verification. If a problem is detected via the subcom data or the instrument alarm flag (frame 27, word 8, bit 7), the subcom information would then be further used to determine what the problem is.

The agreement reached with the Japanese in January, 1988 was that approach Number 1 would be supported. Some aspects of Number 2 might also eventually be supported, but no commitments were made to this end.

The use of a subcom index byte should make the decommutation process a fairly simple one. This byte will always uniquely determine the meaning of the accompanying data value without needing to refer to the spacecraft frame counter or the instrument spin counter. On those occasions when the instrument drops a spin of data (to compensate for a spin rate greater than 20 rpm), the index will remain the same for two frames in a row, indicating that a new subcom data value has not been collected. Thus, even when the spin-synchronization complicates the telemetry decoding, the subcom decommutation remains simple.

Once the definition of the subcom data is determined, the ground software could either convert the hex data to engineering units (via table lookup), or simply provide it directly to the EPIC instrument engineers for analysis.

Bit 0 is the MSB and bit 7 is the LSB, this is the standard for the spacecraft.

Table 13. Subcom Housekeeping and Status List

		Number of channels (bytes)			
Type	Description	DPU	ICS	STICS	Total
Voltage					
	LVPS (+5, -5, +6, -6, +12, -12)		6	6	12
	Ground		0.5	0.5	1
	SSD Bias		1	1	2
	± DPPS converter levels 2 x (5-bit ID, 12-bit value)			4.25	4.25
	HV converter outputs		5	7	12
					31.25
Current					
	LVPS input *		1	1	2
	DPU logic power	S/C			0
	DPPS power (+29V)			1	1
	MCPS & TOFPS power (+29V)		1	1	2
	Motor Current		1		1
					6
HV Control					
	MCP Command Limits		5	7	12
	MCP Command Levels		5	7	12
	Supplies Commanded Enabled		0.625	1.125	1.75
					25.75
Status					
	Digital Status	1.375	7	14.625	23
	Calibration (8-bit E, 4-bit T)		1.5	1.5	3
	Energy Thresholds		3	2.25	5.25
	Valid Command Count	1			1
	Last Valid Cmd Codes	3			3
	Invalid Command Count	1			1
	Last Invalid Cmd Code	2			2
	DPU Memory Statistics	6			6
	Alarms Enabled	5			5
	Alarm Condition Buffer	5			5
	First Alarm Code & Value	2.75			2.75
	Science Record Counter	3			3
	BYTE6 Pointer	3			3
	Checksum Limits	6			6
	Program Address	3			3
	Real-time Status Bytes	3			3
	Spin Offset	2			2
					77

* The LVPS input current is checked by the DPU once per EDB to determine if an alarm condition exists but is reported in the telemetry once per Science Record (similar to other channels).

Bit 0 is the MSB and bit 7 is the LSB, this is the standard for the spacecraft.

Table 13. Subcom Housekeeping and Status List (continued)

Type	Description	DPU	ICS	STICS	Total
		Number of channels (bytes)			
Temperatures					
	Sensor		3	3	6
	Electronics		1	1	2
					8
Latch-up					
	S_LATCH				
	I_LATCH		1	1	2
					2
Alarm Limits					
	Sensor Temperatures (U & L)		2	2	4
	High Voltages (Upper)		5	7	12
	LVPS +6 Supply (Up & Low)		2	2	4
	LVPS Currents (Up & Low)		2	2	4
	MCPPS Current (Upper)		1	1	2
	DPPS Current (Upper)			1	1
	Motor Current (Upper)		1		1
					28
Table Params					
	Index	1			1
	Parameters (per Science Record)	8			8
					9
Spares					5
Total					192

Bit 0 is the MSB and bit 7 is the LSB, this is the standard for the spacecraft.

Table 14. Preliminary Digital Parameter List

		Number of bits		
Description	DPU	ICS	STICS	Total
Valid Event Mode		3	3	6
Low Rate Enable		1	1	2
Multiple Start & Stop Enable		2	2	4
Energy Calibrate Power		1		1
Time Calibrate Power		1	1	2
Logic Calibrate Enable		1	1	2
Calibrate Accumulators Enable		1		1
Energy Preamp Power		3	3	6
Time Preamp Power		4	5	9
Main Bias Power			1	1
Individual Bias Power			3	3
Bias Voltage High Enable		1	1	2
LVPS Over-current		1	1	2
PHA Range			6	6
PHA Priority Definition			72	72
Rate Format Mode		6		6
PHA Energy Freeze		5		5
PHA Species Freeze		5		5
PHA Status		3		3
DPPS Stepping Sequence			2	2
DPPS Discharge Count (2 x (1-bit overflow,3-bit count))			8	8
Auto Aperture Control		1		1
Reduced Aperture Movement		1		1
Motor Use Enable		1		1
Position Sensor Power		1		1
Aperture Status		8	1	9
				0
Instrument Power Enable	1			1
Multispin Summation	2			2
Internal Spin Clock Enable	1			1
Alarm Enable	1			1
Sensor Mode	2			2
Data Compression Algorithm		2	2	4
Latch-up Recovery Enabled	1			1
Program PROM Selected	1			1
Event Processor Mode	2			2
spares		4	4	8
Total bits	11	56	117	184
Total bytes	1.375	7	14.625	23

Bit 0 is the MSB and bit 7 is the LSB, this is the standard for the spacecraft.

SUBSYSTEM CONTROL

The STICS and ICS subsystems of the EPIC experiment communicate with the DPU through two serial interfaces. These interfaces are a high speed PHA data interface, and a low speed control/housekeeping interface.

The high speed PHA data interface transferrs Pulse Height Analysis data from the subsystem to the DPU. It operates with a clock speed of 3.0 MHz and transferrs 28 bits of data with a minimum dead-time between transferrs of 2 clock cycles, making the maximum repetitive event rate 100 kHz. The DPU is only a listener on this interface.

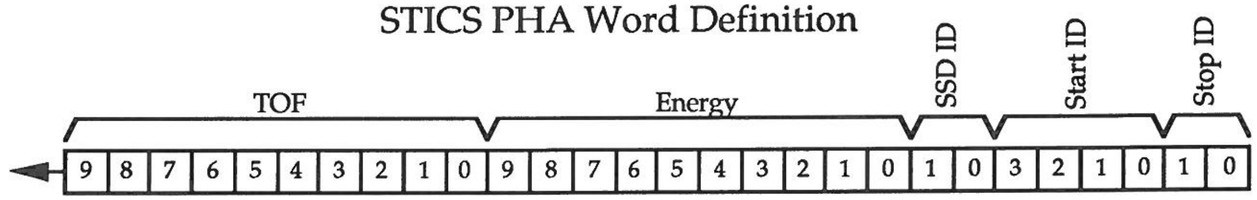
The low speed control/housekeeping interface is used to send control commands from the DPU to the subsystems and to send requested information from the subsystem to the DPU. This requested information consists of the subsystem status (Housekeeping) and accumulator contents (Engineering Rate data).

PHA Data Interface

Definition of the STICS Event Word
(AE ⇒ DPU)

The **STICS EVENT WORD** contains the STICS pulse height information which is generated by the analog electronics and is sent by the analog electronics (AE) to the data processing unit (DPU). The format is as follows:

ENERGY	E	=	10 bits
TIME-OF-FLIGHT	T	=	10 bits
SSD ID	DET	=	2 bits
FRONT (START) MCP ID	FMCP	=	4 bits
REAR (STOP) MCP ID	RMCP	=	2 bits
STICS EVENT WORD		=	28 bits


STICS PHA Word Definition

Notes:

1. *TIME-OF-FLIGHT*. The "TIME-OF-FLIGHT" represents the travel time of the incident ion from the front foil to the solid state detector. The pulse-height-analyzed output signal of the timing discriminator is transmitted to the DPU as a 10-bit binary number (called the time "channel number" or "channel address"). This number is approximately proportional to the original pulse amplitude and hence to the travel time. See STICS Table Parameters and Conversion Factors section for the TOF to Chn # conversion.

2. *ENERGY*. The "ENERGY" represents the residual energy deposited by the incident ion in one of the three solid state detectors. The pulse-height-analyzed output signal of the solid state detector is transmitted to the DPU as a 10-bit binary number (called the energy "channel number" or "channel address"). This number is approximately proportional to the original pulse amplitude and hence to the measured energy. See STICS Table Parameters and Conversion Factors section for the Energy to Chn # conversion.

3. *SSD ID*. The "SSD ID" identifies 4 solid state detector states:

SSD:	None	Det 1	Det 2	Det 3
Orientation:	--	S	Eq.	N
States:	0	1	2	3

Only four states are allowed, because more than one detector cannot fire at a given time. The first detector to fire locks out analysis by any other detector.

4. *MCP ID.* The "MCP IDs" in the STICS event word are associated with the time-of-flight analysis and identify:

   (a) 10 "FRONT (START) MCP" states, requiring 4 bits.

   (b) 4 "REAR (STOP) MCP" states, requiring 2 bits.

5. *FRONT (START) MCP ID.* There are six front (start) anodes associated with the three front (start) MCPs. The 10 FMCP (Front MCP) states identify which of these anodes has fired:

Front MCP:	{1}	{2}	{3}		There are three front (start) MCPs.
Orientation:	S	Eq.	N		
Anodes:	[1][2]	[3][4]	[5][6]		Anodes #1 and #2 are associated with front MCP 1, etc.
States:	1 2	3 4	5 6	=	indicate which single front anode fired (e.g., State=1 means anode #1, and only anode #1, fired).
States:	7	8	9	=	indicate a simultaneous firing by two anodes of the same front MCP (i.e., State=7 means anodes #1 and #2 fired together; State=8 means anodes #3 and #4 fired together; State=9 means anodes #5 and #6 fired together).
State:			0	=	indicates no anode fired.

There are partitions separating the three TOF telescopes. Other states (anodes from different front MCPs firing, or more than two front anodes firing) are normally considered invalid events and are not sent by the AE to the DPU. They therefore do not appear in any rate or PHA word generated by the DPU from the event words. However, they may appear in certain rates generated by the analog electronics (see STICS Rate Accumulators in the Analog Electronics, and Engineering Rate Definitions sections). By command, multiple events (multiple front MCPs; multiple rear MCPs; multiple front and rear MCPs) will be considered valid by the AE, and FMCP states will be assigned to: anodes #2 and #3 firing together; anodes #4 and #5 firing together; MCPs 1 and 2 firing together; MCPs 1 and 3 firing together; MCPs 2 and 3 firing together; and MCPs 1, 2 and 3 firing together. It is **TBD UMD** how these additional states will be treated by the DPU.

When the instrument is in Internal Calibrate mode (see STICS Internal Calibration System section), a test timing pulse may be sent on command to the start constant fraction discriminator. In this case, no start signals are fired. However, the logic can be enabled, by command, to assign IDs (on a rotating basis) to these events.

6. *REAR (STOP) MCP ID.* There are four RMCP (Rear MCP) states associated with the 3 rear (stop) MCPs:

Rear MCP:	{1}	{2}	{3}		There are three rear (stop) MCPs.
Orientation:	S	Eq.	N		
Anodes:	[1]	[2]	[3]		Each rear MCP has one rear anode associated with it.
States:	1	2	3	=	indicate which single rear (stop) MCP anode fired (e.g., State=1 means the anode associated with rear MCP 1 fired, and only that anode fired).
State :			0	=	indicates that no rear MCP anode fired.

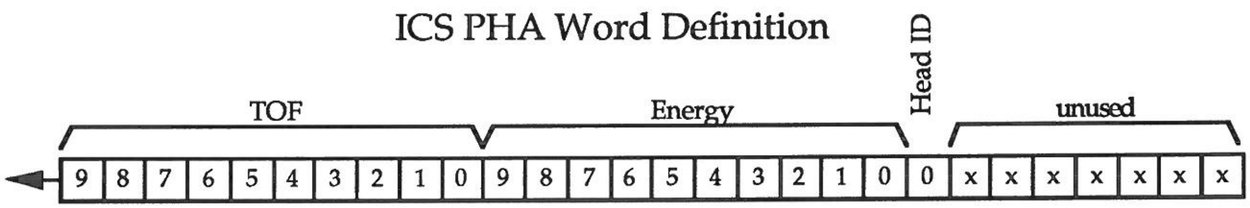
Other states (multiple rear MCP anodes firing) are not considered valid by the AE, except by command (see above). When validated by command, the multiple firing will be assigned state 0. By checking the command status for allowing multiple rear events, and determining that the T pulse height is above some TBD noise threshold and the FMCP is not zero, the state RMCP = 0 can be distinguished from having no firings *vs.* multiple firings. It is **TBD UMD** how this additional status is to be treated by the DPU.

When the instrument is in Internal Calibrate mode (see STICS Internal Calibration System section), a test timing pulse may be sent by command to the stop constant fraction discriminator. In this case, none of the stop signals will fire. However, the logic can be enabled, by command, to assign IDs (on a rotating basis) to these events.

Definition of the ICS Event Word
(AE ⇒ DPU)

The **ICS EVENT WORD** contains the ICS pulse height information which is generated by the analog electronics and is sent by the analog electronics (AE) to the data processing unit (DPU). The format is as follows:

ENERGY	E	=	10 bits
TIME-OF-FLIGHT	T	=	10 bits
HEAD ID	HID	=	1 bit
unused	--	=	7 bits
ICS EVENT WORD		=	28 bits


ICS PHA Word Definition

Notes:

1. *TIME-OF-FLIGHT*. The "TIME-OF-FLIGHT" represents the travel time of the incident ion from the front foil to the solid state detector. The pulse-height-analyzed output signal of the timing discriminator is transmitted to the DPU as a 10-bit binary number (called the time "channel number" or "channel address"). This number is approximately proportional to the original pulse amplitude and hence to the travel time. See ICS Table Parameters and Conversion Factors section for the TOF to Chn # conversion.

2. *ENERGY*. The "ENERGY" represents the residual energy deposited by the incident particle in one of the two solid state detectors. The pulse-height-analyzed output signal of the solid state detector is transmitted to the DPU as a 10-bit binary number (called the energy "channel number" or "channel address"). This number is approximately proportional to the original pulse amplitude and hence to the measured energy. See ICS Table Parameters and Conversion Factors section for the Energy to Chn # conversion.

3. *HEAD ID*. The "Head ID" identifies which of the two heads is associated with the event. The North head is given value 0 and the South head is given value 1. Head determination is performed using the following equation:

   Head ID = 1 for SSD(S) + (START(S) • STOP(S) • DC)

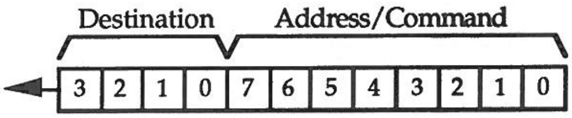
   Head ID = 0 otherwise.

   This translated to "the Head ID is South when either the SSD signal came from the South head, or there is both a start and a stop from the South head and there was a Double Coincidence (valid TOF), otherwise the Head ID is North."

Control and Housekeeping Interface

The control and housekeeping interface sends 12-bit control commands from the DPU to the subsystem and returns requested information from the subsystem to the DPU. These control commands have the following form and are described in detail in appendix C.

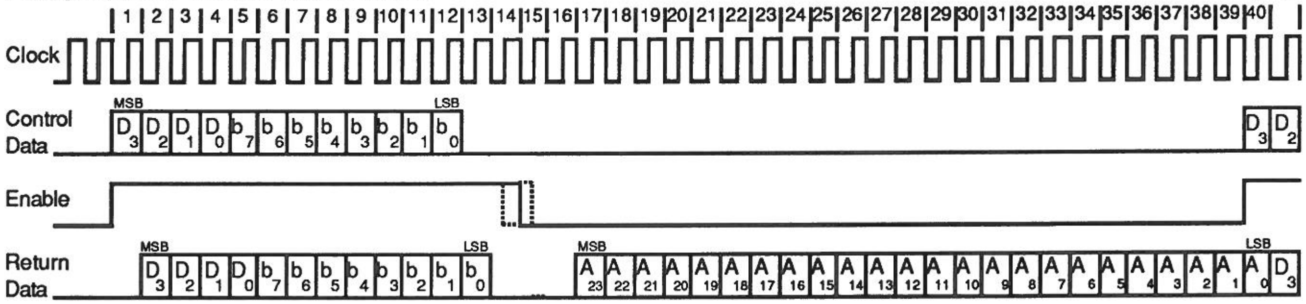
Control Command Definition



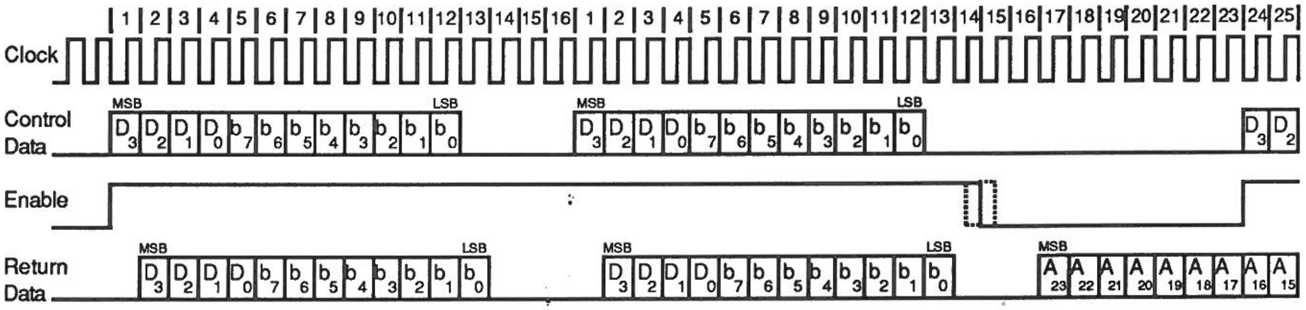
The requested information being returned to the DPU can be either 0-bits (for state-setting commands), 8-bits, 12-bits, or 24-bits. Additionally, control commands are echoed back to the DPU for verification and command acceptance/rejection. The DPU is permitted to try a command twice before giving up and reporting this as an error (see Error Detection section.)

The following timing diagrams describe the operation of this interface:

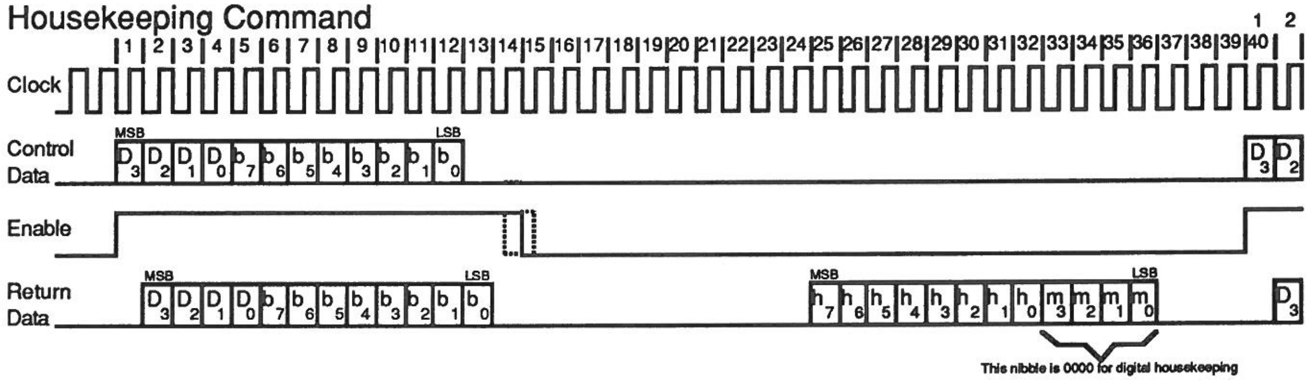
Accumulator Read Command



Accumulator Read Command - illustrating command error handling

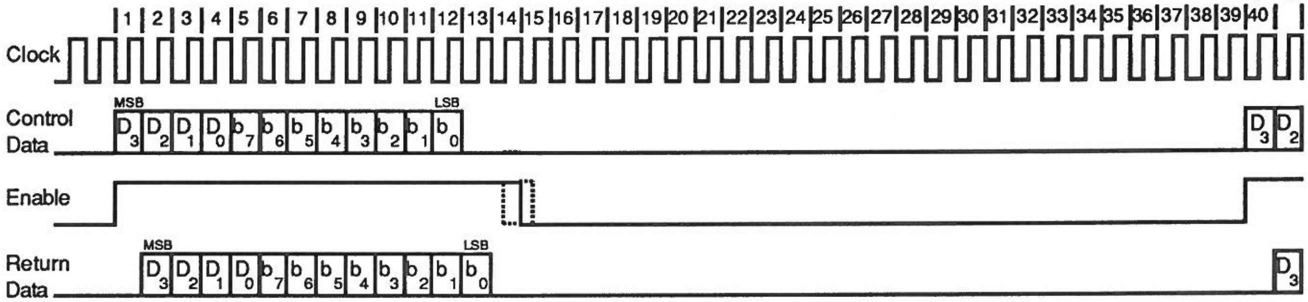


Housekeeping Command



This nibble is 0000 for digital housekeeping and can be ignored for analog housekeeping except for +DPPS and -DPPS

Set Command



SECTOR DEFINITION

The EPIC instrument will divide the spin plane into 16 sectors, each 22.5 degrees wide. The sectoring will be fixed relative to the sun; this means the STICS DPPS dead-time will always appear in the same sector (0).

Both ICS and STICS will use this common sector definition for pointing and counting purposes, but they are not required to have the same measurement dead-time in each sector. ICS will therefore count during the STICS DPPS dead-time in sector 0.

The sector definitions shall be commandable such that the sun pulse may occur within any given sector. In addition, the angular offset within the sector shall be commandable with a 0.1 degree resolution. These sector offsets and designations will be determined based on science requirements of STICS. ICS will use the same settings. See DC D_SUNSET command.

The DPU has a backup phase clock which is synchronized to the telemetry counter. The DPU automatically defers to the S/C phase clock when it is available, although such changes will only be allowed at the Science Record boundaries.

SPIN VARIATION

The software will be optimized for a spin rate of 20 RPM, but will be able to handle spin rates less than 30 RPM. When the incoming science data is being generated faster than can be sent via the telemetry interface, the DPU will selectively drop whole spin periods worth of data. When a spin is dropped, the software will not increment the spin parameters until the following spin is completed. In this way, the operational telemetry collection and formatting will not be affected (e.g. the DPPS will operate at step "n" on one spin, then "n+1" for the next; if this spin is dropped in telemetry, the following spin will also be done at level "n+1"). The subcom index will likewise not increment for the EDB following the dropped spin.

When the incoming science data is being generated slower than the telemetry interface can send it, the DPU will pad the telemetry where necessary with zeroes. No additional science data will be sent in their place. The result of this scheme is that the EPIC telemetry format will be independent of spin rate for rates less than 30 RPM.

TELEMETRY DETAILS

An Experiment Data Block is defined as the data collected over 1 spin. Over the course of 1 EPIC Science Record, defined as 32 EDBs, all major status and housekeeping information should be available and complete.

Commands will be echoed back in the subcom housekeeping telemetry. Commands shall be buffered so that all received commands may be verified in the telemetry. The "executed valid command counter" shall be updated (MOD 256) to reflect the number of commands executed in the associated Science Record. The last valid command received shall be repeated until a new command is received.

Parameter tables will be trickle-read-out through the subcom via a deeper subcom process, tentatively set with an index and 16 values read out during a Science Record. The 16 slots allows one parameter type to be completely read within a Science Record. Additionally, a parameter update (see BC D_PRGLD command) will change the index so the updated parameter list will be sent in the next Science Record. Analog subcom measurements shall be distributed throughout the 32-spin Science Record to provide greater temporal distribution.

DPU Processing Tasks Done on Sector Basis

	Sector															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
DPPS stepping	x															
ICS Motor Stepping	x															
ICS Singles rates																
FSR(1)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
FSR(2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
RSR(1)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
RSR(2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
DCR(1)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
DCR(2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
TCR(1)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
TCR(2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
SSD(1)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
SSD(2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
UFSR	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
URSR	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
MFSR	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
MDCR	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
ED(1)	x*	x	x*	x	x*	x	x*	x	x*	x	x*	x	x*	x	x*	x
ED(2)	x*	x	x*	x	x*	x	x*	x	x*	x	x*	x	x*	x	x*	x
STICS Singles Rates																
FSR(1)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
FSR(2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
FSR(3)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
FSR(4)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
FSR(5)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
FSR(6)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
UFSR	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
URSR	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Housekeeping value reported	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
LVPS current monitor read	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

* These rate may be read every other sector, or read every sector and summed over two.

AUTONOMOUS CONTROL

The nature of the mission and spacecraft interface require the DPU to be able to independently monitor the instrument operation and performance. Under varying conditions, the DPU must be able to safely shut the instrument off, resume operation (including high voltage supply stepping) from a standby mode, respond to spacecraft fault conditions, and monitor analog and digital telltales.

The spacecraft is expected to enter the Earth's shadow twice a week during the near tail portion of the mission. If the shadow lasts more than a few minutes, it puts a strain on the spacecraft's ability to provide power to the various subsystems and instruments. It is therefore planned that the spacecraft will require the EPIC instrument to cut is power consumption drastically during these shadow periods; power will be available, at most, to operate the DPU in a low-power mode, with no power available to either ICS or STICS except for heaters.

The high voltage supplies can not be controlled properly without signals provide by the analog electronics. The DPU must therefore step down the high voltage outputs and disable the supplies before the analog electronics power is removed. This command overhead makes it difficult and undesirable to cycle power to the instrument solely by ground command.

To allow the DPU to safely change the instrument configuration in this way without ground command, therefore, there shall be the capability to save the instrument operational state description in permanently-power RAM. When the DPU receives the "save configuration" command, it shall write a complete description of all the analog threshold settings, logic conditions, high voltage levels, etc. in RAM. When the "resume configuration" command is later received, operation will be resumed in the same operational state as described in the RAM. Following the regeneration of the classification tables, the instrument will start a new Science Record. If no configuration was previously saved or the configuration checksum is incorrect, this command shall be ignored, and an error flag will be set in the telemetry.

ICS Aperture Motor Control

Introduction

The EPIC ICS Sensor contains two independent stepper motors. Each motor is mounted on a detector head and is used for:

1). Post launch release of the front foil acoustic seal

2). Positioning of the aperture wheel during normal on-orbit mission operations.

This section describes the method that will be used to control the motors so they will perform their intended functions reliably and within the instrument's operational constraints.

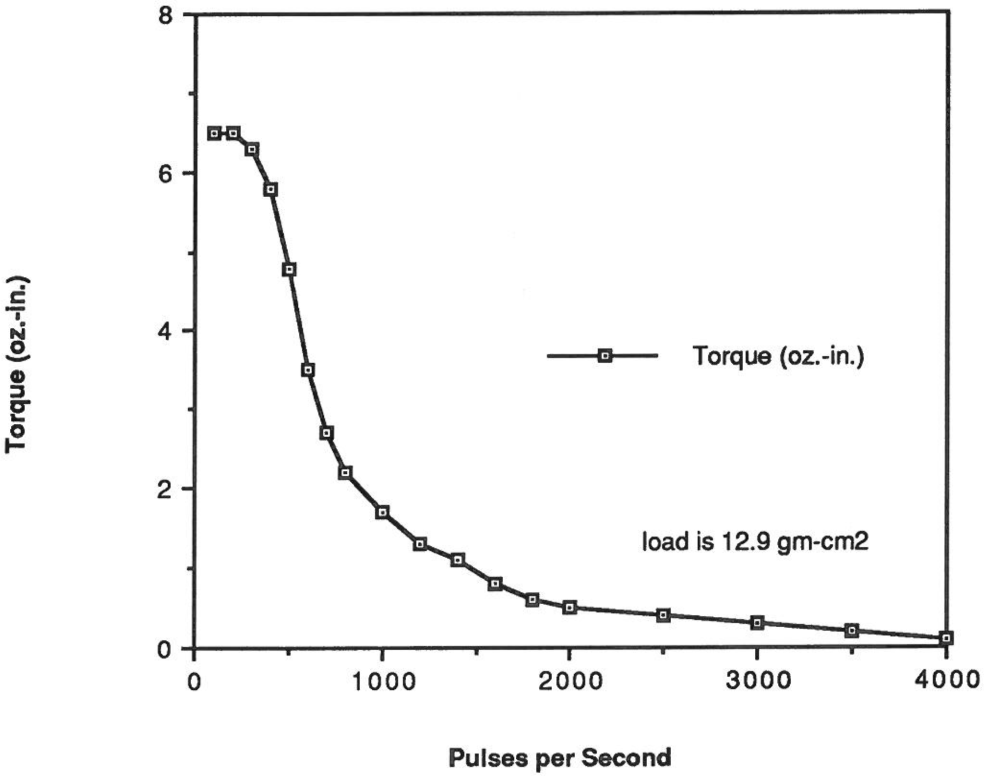
The Motor and Associated Loads

The selected motor for this application is a two phase bipolar stepper motor manufactured by Clifton Precision. Its part number is 11-SHBD-45. Pertinent specs are a 1.8 degree step size, dynamic torque at 100 pulses per second of 5.9 oz-in using 4.14 watts of input power per phase, a detent torque of 0.36 oz-in, and a mass of 95 gms. The torque curve is shown below. The motor drives the aperture wheel gear through a 4 to 1 gear reducer, resulting in a 0.45 degree step size at the wheel. When the aperture wheel is in its acoustic seal mode (for launch), the torque required at the aperture wheel gear to turn the wheel and release the acoustic seal is 6.3 oz-in. This is a calculated value based on worst case conditions. The actual value still needs to be measured experimentally. The torque required at the motor is then 2 oz-in, which takes into account the 4 to 1 gear reducer and an estimate of 80 percent for gear reducer efficiency. When the wheel is released the torque required is much less, and has been calculated to be 0.9 oz-in at the aperture wheel gear and 0.3 oz-in at the motor. This value will also be measured experimentally.

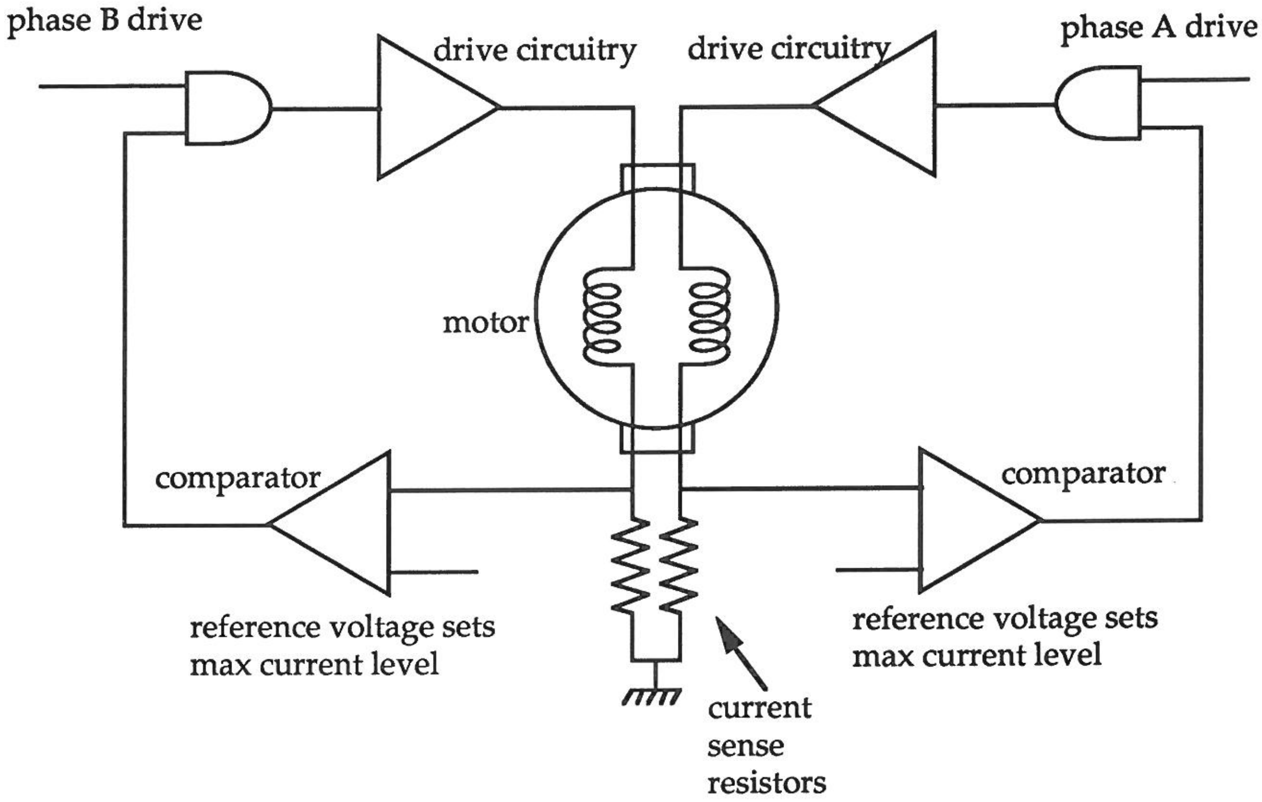
Power Considerations

The input power of 8.28 watts total required for development of the full torque is substantial. In addition, the motor is designed to normally be operated in a DC mode using 13.8 volts. Since 29 volts is the only supply available for motor operation, a regulator would be required to drop the voltage to 13.8 volts and the regulator would dissipate about 8 watts of power, making the total power consumption 16 watts. Although this power consumption might be acceptable for the one time initial release of the motor, it is not acceptable or necessary for normal mission operation.

Clifton Type 11-SHBD-45 Stepper Motor
Step Rate/Torque curve



In order to solve this problem the motor's current is dynamically limited with a chopping circuit. A block diagram of the system is shown below. The chopping circuit allows the motor current to be continuously variable from 8.28 watts (full torque) to about 2 watts which would supply just enough power to overcome the detent torque of the motor and to also develope enough torque to move the aperture wheel. This approach allows the motor to be run off of 29 volts and eliminates the regulator.



Commanding Capability

As shown in the diagram above, each motor has a number of different control and sense lines which are described below. Also included in the table are the control and sense lines for the aperture wheel position sensing assemblies which are also located on each detector head and are used for positioning of a wheel at one of four possible apertures.

- **29 volt power on/off** - The motor and most associated drive circuitry operates off of 29 volts. This power can be turned on or off independently to the two motors.
- **29 volt current sensor** - A single current sensor is in the 29 volt line to both motors and is located prior to the point where the line bifurcates and goes to the motor power switches. This sensor will measure the total current draw of the motors. Assuming that only one motor will be on at any given time, the sensor effectively measures the current used by an individual motor during operation. For the chopper circuit, this current monitor helps to verify that the current regulation is working properly.
- **Phase A Control Line** - This line controls the direction of current flow through an individual winding of a motor. It is a CMOS logic level signal with Vdd = 5 volts.

- **Phase B Control Line** - This line controls the direction of current flow through the other winding of the motor. It is usually switched 90 degrees out of phase with the Phase A control line in order to get the motor to step.

- **Motor Current Reference** - Each motor has a comparator which forms a portion of the chopper circuitry. One input of the comparator is a reference signal which determines the current trip point for the chopper circuitry. This reference voltage (0 to 4.92 volts analog) is supplied by a D/A converter in the Interface Controller.

- **Position Assembly +5 Volt Power ON/OFF** - A switch is used to turn logic power on and off to the three pairs of light emitting diodes and photo transistors which compose the position assembly on each wheel. The assemblies are normally turned on only during motor operation, since they draw relatively large amounts of power. Most of the power is used by the LED's to produce sufficient light to trigger the phototransistors. The motor control circuitry also uses this 5 volt power as well, thus the position assembly power must be on prior to powering a motor.

- **Phototransistor Signals 1, 2, and 3** - The three phototransistors in a position assembly send back an analog signal which is proportional to the intensity of light reflected off of the aperture wheel surface and into the lens of the phototransistor. CMOS logic gates in the Analog Electronics impose a fixed threshold on these signals such that a "1" at the gate output signifies the phototransistor is illuminated while a "0" indicates it is not. All three phototransistors function identically, with the pattern on the wheel basically determining which phototransistors are illuminated.

The Interface Controller (IF) in the ICS Analog Electronics is the device responsible for converting these signal lines to a command and telemetry format compatible with the DPU. Control commands from the DPU allow all the control lines to be set appropriately and all the sense signals to be transferred back to the DPU in a predefined telemetry word. The pertinent commands from the DPU/Interface Controller control list are shown below. See Control and Housekeeping Interface section and Appendix C for further details.

Command #	Command Name	Notes
5xx	Motor 1 power level	Sets N head current level
6xx	Motor 2 power level	Sets S head cuurent level
C20-C23	Motor power: North,South	29 volt motor power on/off
C3B-C38	Motor phase: A/B	sets phase lines high or low
C69-C68	Position LED power	turns on +5 V to LEDS, etc.
D05	Motor position	reads phototransistor status
D8C	Motor current	reads 29 volt motor current

Thus, the DPU has total control over the operation of the motors, allowing for relatively easy use during normal operation and for very flexible control in the event of degraded motor performance or unforeseen uncaging or positioning problems. The aperture wheel can be operated directly via ground command or autonomously under DPU control. The ground commands listed in Appendix B of the System Control Document which apply to aperture wheel positioning are as follows:

Command Code		Command name
46	I_DIGCMD	Send digital control command
	bits 4-7, hex 9	Autonomous aperture control selected
	bits 4-7, hex A	Aperture selection linked between two heads
	bits 4-7, hex B	Enable motor use
47	I_PWRCMD	Send power control command
	bits 4-7, hex 8	LED position sensor power
4B	I_MTRCMD	Basic motor movement command
	bits 0-1	Select one of four motor positions
	bit 3	Select direction
	bit 4	Select head (0=North, 1=South)
4C	I_DIRMOT	Direct motor rotation control command
	bit 0	Select head (0=North, 1=South)
	bit 7	Select direction
	bits 0-7	1 to 256 motor steps

It is anticipated that the ground commands will be used for initial release of the acoustic seals on the two detector heads. It is possible that the ground commands may also be used for motor operation in the event of a problem during the mission.

Basic Motor Movement

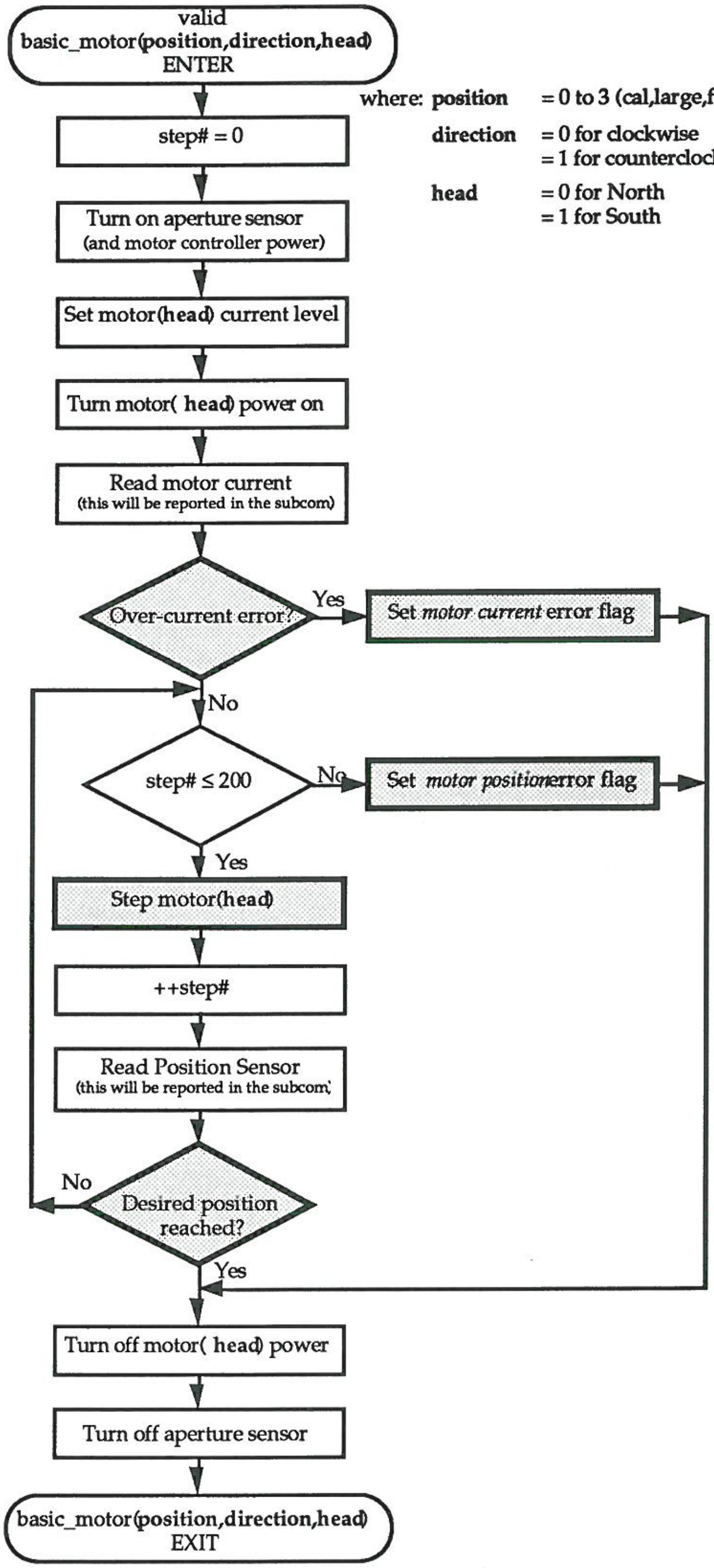
The basic motor movement subroutine will be used in the DPU to move to a desired aperture, regardless of whether the DPU is moving the wheel as a result of direct ground command or under automatic control. This section describes a flowchart for this operation. This will be used by the main aperture wheel routine which handles autonomous control as well as the BC I_MTRCMD command. This flowchart and later ones in this section are intended to be generic and can be adapted to the particular programming environment in which the code is generated.

Data should not be recorded while a motor is moving. The EDB-based Status Telemetry (DPU/Common telemetry allocation) is allotted one byte to indicate motor activity. This byte consists of two nibbles, each representing the number of steps for each head during the EDB. This provides activity information, head ID, and number of steps.

The motor can be made to run backwards by simply toggling the Phase B line 90 degrees in advance of the Phase A line, rather than lagging the Phase A line by 90 degrees. The toggling of the phase lines is completely under the control of the DPU. In the autonomous control case the DPU should determine the direction which will reach the desired aperture in the shortest time and then pass that direction to the basic motor movement routine.

The step rate of the motor is controlled directly by how fast the phase lines are toggled. The rate that they can be toggled is dependent on the DPU and on the command line clock speed. A probable maximum rate, based on a cursory study, would be about 200 1.8°steps per second or 250 milliseconds to move one aperture position.

Basic Motor Movement Flowchart



where: **position** = 0 to 3 (cal,large,foil,small with foil)
direction = 0 for clockwise
= 1 for counterclockwise
head = 0 for North
= 1 for South

The key interaction in this flowchart occurs between moving the wheel and reading the position. This flowchart moves the wheel only 1.8 degrees at a time before checking the phototransistors. This scheme has the advantage of not needing to know how many steps are required to reach the desired aperture (which would be useful were a power failure to occur when between apertures) but at the expense of increased DPU processor overhead. Another advantage to moving 1.8 degrees or multiples of 1.8 degrees at a time is that the the phase control lines both start at logic 0 and return to logic 0 at the end of a 4 sub-step (or 1.8 degree) sequence.

The following describes the highlighted flowchart subsections in detail:

- "Over-current error?" -- this compares the motor current reading to the alarm limit set by the BC D_ALRLIM.

- "Set *motor current* error flag" and "Set *motor position* error flag" -- these set the specified error flag and unselect the motor autonomous aperture control.

- "Step motor(**head**)" -- this amounts to the following 8 steps, with the control command sent from the DPU to the sensor in brackets:

  1 forward: set phase B line high, phase A line low [C3A]
  reverse: set phase B line low, phase A line high [C39]

  2 wait for selected time (e.g. 10 msec would be a 100 Hz step rate)

  3 forward: set phase A line high, phase B line high [C3B]
  reverse: set phase A line high, phase B line high [C3B]

  4 wait for selected time

  5 forward: set phase B line low, phase A line high [C39]
  reverse: set phase B line high, phase A line low [C3A]

  6 wait for selected time

  7 forward: set phase A line low, phase B line low [C38]
  reverse: set phase A line low, phase B line low [C38]

  8 wait for selected time

  Note that the head ID is not used here but is used to supply power to the head being moved.

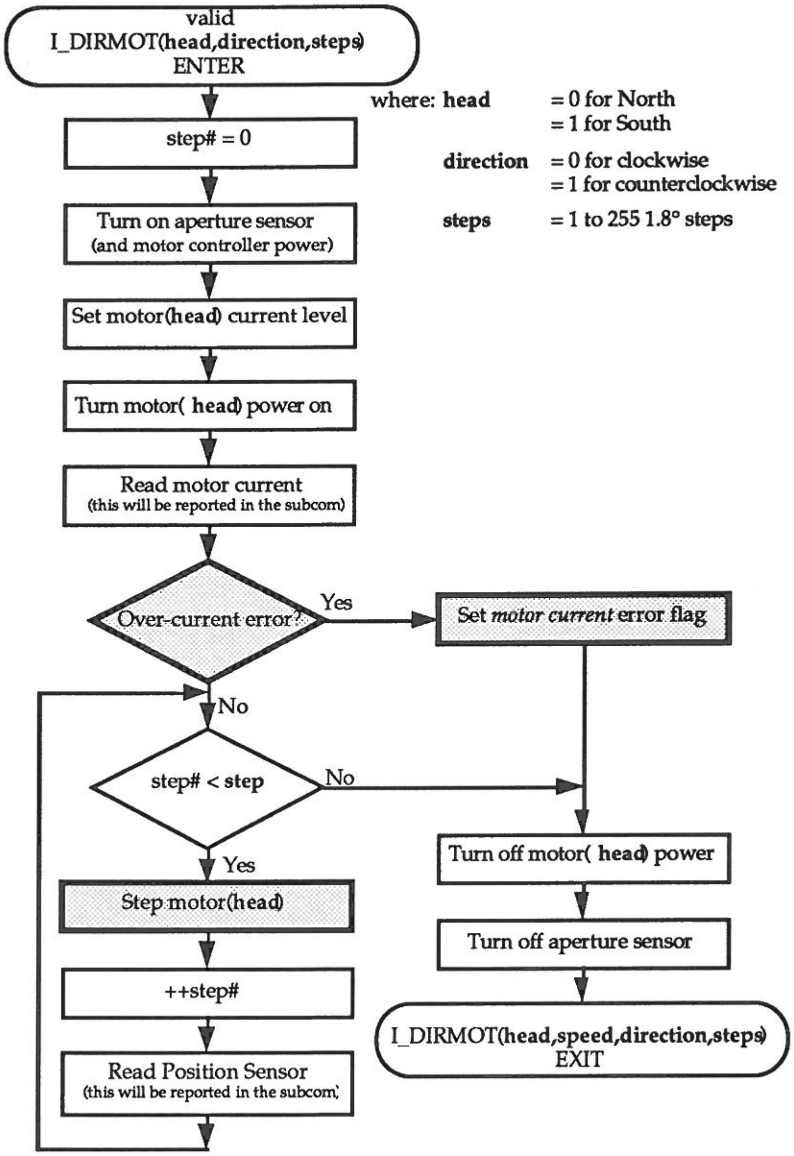
- "Desired position reached?" -- this converts the position sensor value to a position and compares it to the desired position. The conversion matrix is as follows:

Aperture Position	Description	Position Sensor 1	Position Sensor 2	Position Sensor 3
0	closed/cal	OFF	OFF	ON
1	open	ON	ON	ON
2	foil	OFF	ON	ON
3	10% +foil	ON	OFF	ON

Direct Motor Rotation Control

The direct motor movement subroutine will be used to move an aperture wheel a desired number of steps. This will be used by the BC I_DIRMOT command when locking the aperture wheels closed and if the aperture sensor stops working correctly. This section describes a flowchart for this operation where the highlighted sections are described in the Basic Motor Movement discussion.

Direct Motor Rotation Flowchart



This flowchart moves the wheel only 1.8 degrees per step. The phototransistors are checked only to provide this information in the subcom housekeeping.

<u>Automatic-Control</u>

The automatic control mode of operation will be disabled prior to launch and before the acoustic seal has been released (the default value stored in the DPU at launch for automatic control is DISABLED). Thus, the first commands to the motor, which presumably would be used to release the acoustic seal and turn the wheel to the starting aperture, would come from the ground station. Once the wheel is released and successfully in place, the next series of commands would enable automatic control. Automatic control would be left enabled until another ground command disables it, until an error condition occurred in the motor movement routine, or upon occurence of a DPU power on reset.

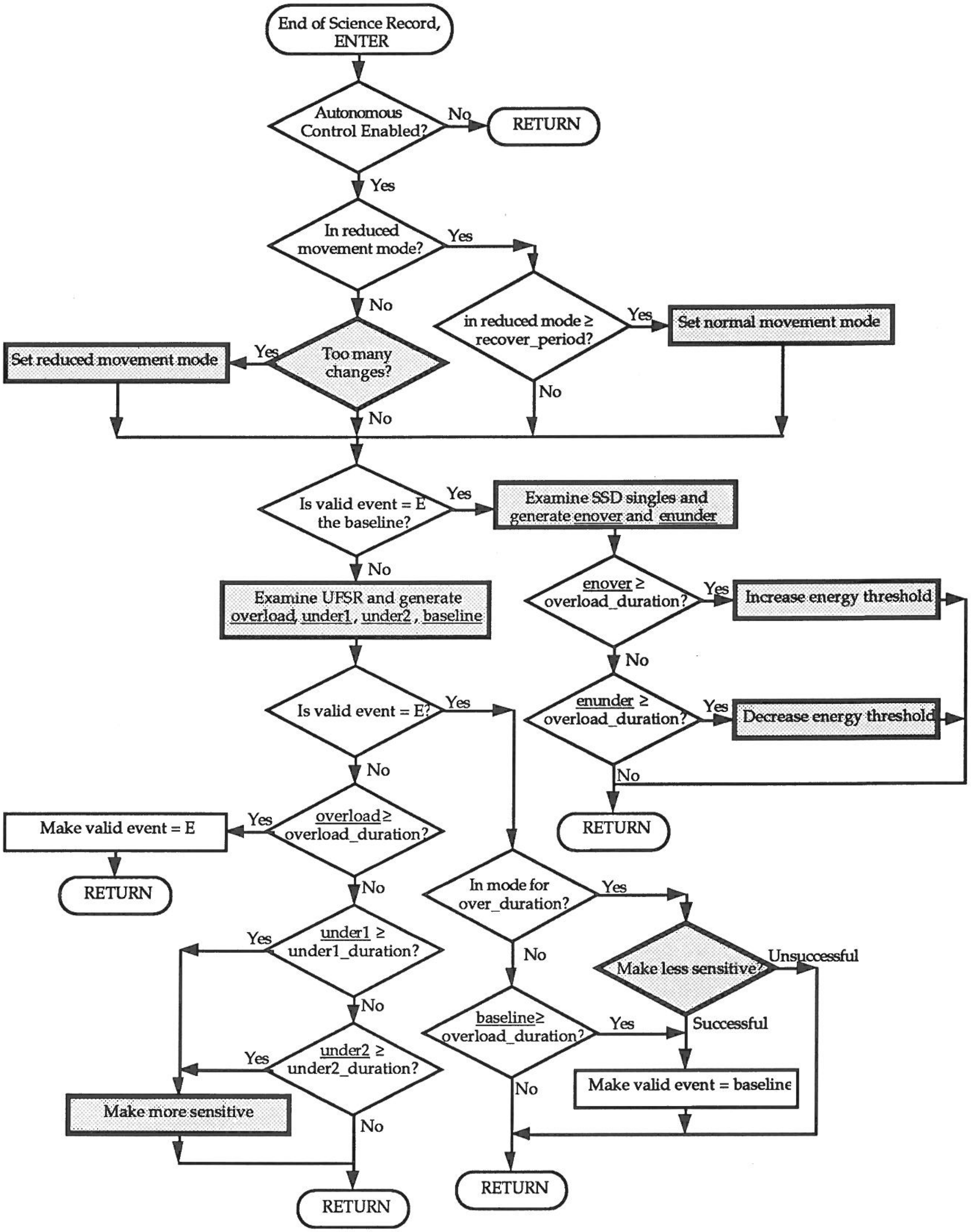
The following parameters are used by the algorithm and are supplied by the BC D_PARLD command:

Parameter	Default	General description
changes_allowed	8	aperture changes allowed in change_period hours
change_period	12	hours that aperture changes are accumulated
recover_period	12	hours to remain in the reduced movement mode
baseline_sectors	0	number of sectors where baseline_count applies
baseline_count	1E6*	count level where the condition applies
overload_sectors	2	number of sectors where overload_count applies
overload_count	1.4E6*	count level where the condition applies
overload_duration	2	number of Science Records where condition applies
under_sectors	0	number of sectors where under_count applies
under1_count	5E2*	count level where the condition applies
under1_duration	14	number of Science Records where under1_count applies
under2_count	5E4*	count level where the condition applies
under2_duration	75	number of Science Records where under2_count applies
over_duration	7	number of Science Records where valid event is in E mode

* The count levels are in the range from 0 to 17E6 and can be represented using 8 bits with 3 bits mantissa and 5 bits exponent, all unsigned.

A high-level flowchart for automatic control is shown below. It is followed by the details of the highlighted blocks. They follow the control criteria outlined by R. W. McEntire and already supplied to TUB. The algorithm makes a decision whether or not to move both aperture wheels at each Science Record boundary. Additionally, the PHA valid event mode and energy thresholds can be changed by this algorithm.

High-level Autonomous Control Flowchart



- "Set normal movement mode" -- this restores the aperture algorithm to the normal mode by the following steps:

  1). Reset the Reduced Movement bit in the subcom housekeeping

  2). Restore the duration requirements to the values in the parameter table

  3). Reset the overload, under1, and under2 statistics used by the conditionals

- "Too many changes" -- this evaluates the following equation:

  $$\text{motor changes}_{[\text{during change\_period}]} \geq \text{changes\_allowed}$$

- "Set reduced movement mode" -- this reduces the aperture activity by the following steps:

  1). Set the Reduced Movement bit in the subcom housekeeping

  2). Set these duration requirements to the following values:
      overload_duration = 10 (Science Records)
      under1_duration = 150 (Science Records)
      under2_duration = 150 (Science Records)

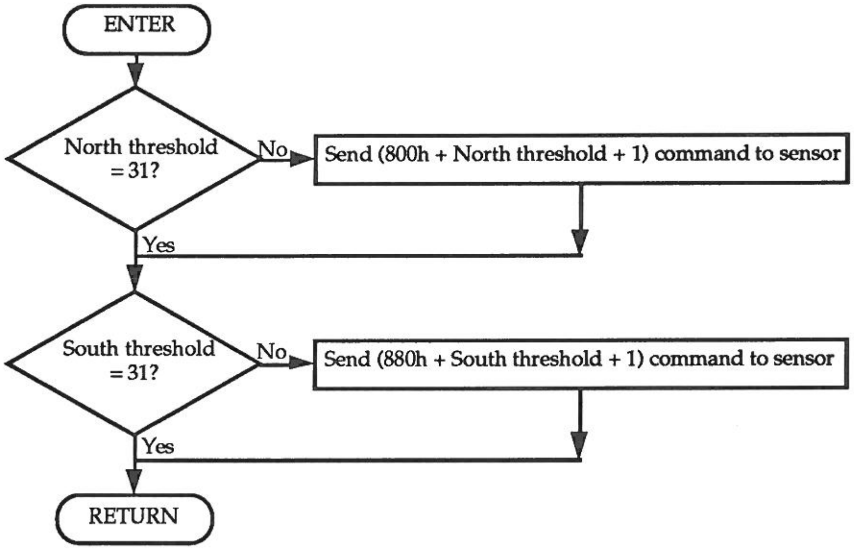
  3). Reset the overload, under1, and under2 statistics used by the conditionals

- "Examine SSD singles and generate <u>enover</u>, and <u>enunder</u>" -- this examines the SSD singles counts for each of the sectors, summed over both heads for the Science Record, and prepares the following statistics that are used by the conditionals:

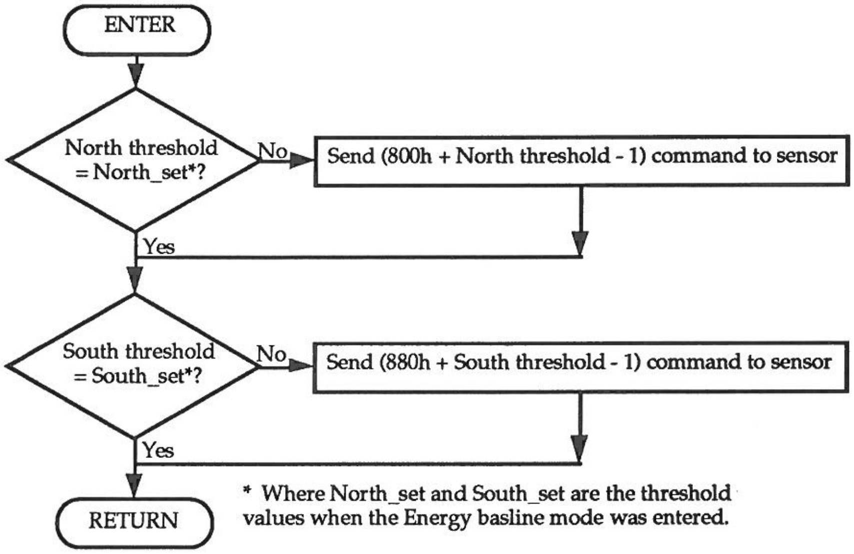
<u>enover</u> = total number of consecutive Science Records where the number of $\text{sectors}_{[\text{with count} \geq \text{overload\_count}]} \geq \text{overload\_sectors}$

<u>enunder</u> = total number of consecutive Science Records where the number of $\text{sectors}_{[\text{with count} > \text{baseline\_count}]} \leq \text{under\_sectors}$

- "Increase energy threshold?" -- this uses the following flowchart:



- "Decrease energy threshold?" -- this uses the following flowchart:



* Where North_set and South_set are the threshold values when the Energy basline mode was entered.

- "Examine UFSR and generate overload, under1, under2, baseline" -- this examines the UFSR counts for each of the sectors, summed over the Science Record, and prepares the following statistics that are used by the conditionals:

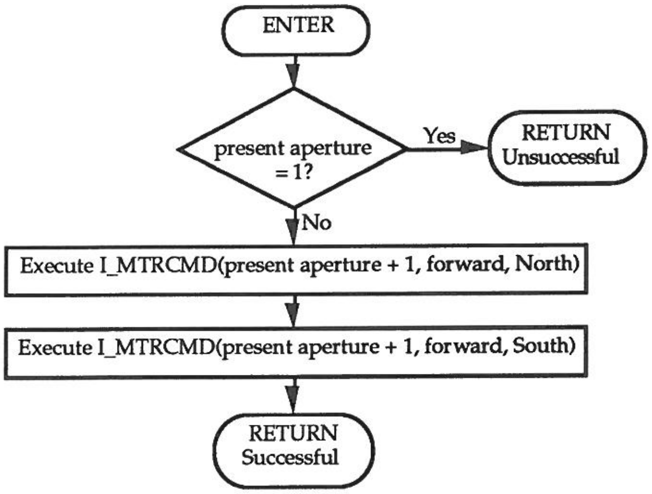
  overload = total number of consecutive Science Records where the number of sectors$_{[\text{with count} \geq \text{overload\_count}]}$ ≥ overload_sectors

  under1 = total number of consecutive Science Records where the number of sectors$_{[\text{with count} > \text{under1\_count}]}$ ≤ under_sectors

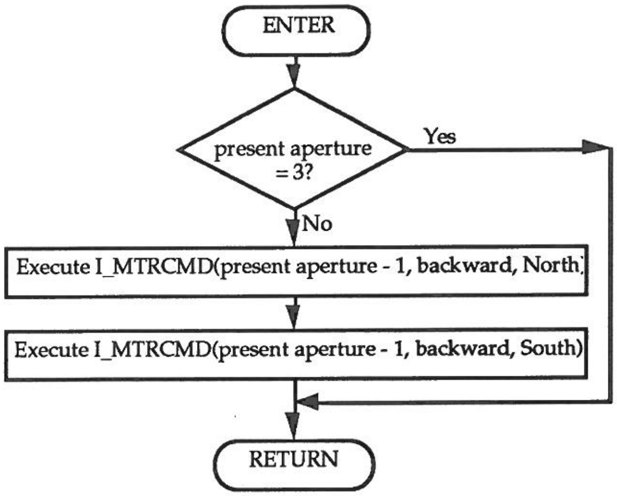
  under2 = total number of consecutive Science Records where the number of sectors$_{[\text{with count} > \text{under2\_count}]}$ ≤ under_sectors

  baseline = total number of consecutive Science Records where the number of sectors$_{[\text{with count} \geq \text{baseline\_count}]}$ ≤ baseline_sectors

- "Make less sensitive?" -- this uses the following flowchart:



- "Make more sensitive" -- this uses the following flowchart:



In order to avoid changing the apertures too often, the integrated count values over which the apertures are expected to operate overlap, thus providing a type of control system deadband. The parameter values are settable by the BC D_PARLD command. It is expected that experience with on-orbit front MCP rates will be required in order to be able to set the count parameters intelligently.

Once the algorithm has decided to move a wheel, the actual repositioning is performed by calling the basic motor movement subroutine. The repositioning of the wheel should be performed at the beginning of a Science Record in order to minimize loss of science data.

Presumably, the differential intensity encountered during the mission will not be changing so frequently that aperture wheel positioning occurs every Science Record, even if the selected duration before action parameters would allow it. However, should excessive motor movement occur, the automatic selection of large duration parameters would reduce aperture repositioning to a satisfactory level.

HV CONTROL

There will be operational constraints on how quickly the DPU may step high voltage supplies from one level to the next. This is necessary to prevent stressing the detector components and avoid arcing.

The DPU shall step the MCP output supply voltage up to a higher level and down to a lower level at a defined rate of 2 steps per spin. This rate applies for direct HV ground commands (i.e. go to level X on supply #n) and programmed operation. This step rate will always be used for flight and ground operation.

UVC

When the spacecraft primary power bus voltage is too low, it sends a signal, known as the Under Voltage Condition (UVC) flag to all the science instruments. Under these conditions, the EPIC DPU must remove all power loads from the bus except the heater power and PIM logic power. The software has 200 msec to configure the power switch relays in their open position. Should the DPU not respond to this interrupt in software, a hardware circuit will open the EPIC power switches. When power is reapplied, all subsystems will be off. The heater switches are not affected by this signal.

LATCH-UP

The DPU latch-up detection circuit will trigger a DPU protection algorithm. This algorithm will power-cycle the switchable DPU +5 volt power, while leaving the sensors status and power unchanged. This cycle will occur in less than 1 second. The DPU will use the instrument configuration data stored in the PIM RAM to reestablish its previous operational mode.

This function can be enabled/disabled by the DC commands LUD-EN and LUD-DIS.

ALARM MONITOR

The DPU shall implement an alarm monitor function. This will compare up to 40 measured instrument analog parameters with commandable limits and digital parameters, and set an alarm flag bit in the EPIC real-time and recorded telemetry stream. This flag will be used on the ground to indicated the presence of a fault condition in the EPIC instrument. The flag will remain set until cleared by ground command; power cycling the instrument power will not clear the flag. An error code identifying the detected fault condition shall be included in the subcom data. The six-bit identifier and two byte value will describe the first fault detected, and another 5 bytes will show the digital status of all alarm channels. Two bytes for the value allow rejected control commands to be reported (12-bit command, sensor identifier, and 3 spare bits).

The DPU shall be capable of selectively turning off portions of the instrument hardware based upon the fault detected. The parameters monitored and the actions required are described below:

EPIC Alarm Monitor Response Table

Index	Error Condition		Action
0	D_ALARMS, TEMPS S_SE	upper limit	Turn off STICS HV & LVPS
1		lower limit	Turn on STICS energy calibrator
2	D_ALARMS, TEMPS I_SE	upper limit	Turn off ICS HV & LVPS
3		lower limit	Turn on ICS energy calibrator
	D_ALARMS, VOLTS		
4	S_LVPS +6	upper limit	Turn off STICS HV & LVPS
5		lower limit	Turn off STICS HV & LVPS
6	S_MCPPS N-St	upper limit	Turn off STICS N-St MCPPS *
7	S_MCPPS N-Sp	upper limit	Turn off STICS N-Sp MCPPS *
8	S_MCPPS E-St	upper limit	Turn off STICS E-St MCPPS *
9	S_MCPPS E-Sp	upper limit	Turn off STICS E-Sp MCPPS *
10	S_MCPPS S-St	upper limit	Turn off STICS S-St MCPPS *
11	S_MCPPS S-Sp	upper limit	Turn off STICS S-Sp MCPPS *
12	S_TOFPS	upper limit	Turn off STICS TOFPS *
13	S_LATCH	lower limit	Turn off HV power, cycle LVPS and restore
14	spare		
15	I_LVPS +6	upper limit	Turn off ICS HV & LVPS
16		lower limit	Turn off ICS HV & LVPS
17	I_MCPPS N-St	upper limit	Turn off ICS N-St MCPPS *
18	I_MCPPS N-Sp	upper limit	Turn off ICS N-Sp MCPPS *
19	I_MCPPS S-St	upper limit	Turn off ICS S-St MCPPS *
20	I_MCPPS S-Sp	upper limit	Turn off ICS S-Sp MCPPS *
21	I_TOFPS	upper limit	Turn off ICS TOFPS *
22	I_LATCH	lower limit	Turn off HV power, cycle LVPS and restore
23	spare		
	D_ALARMS, CURRENTS		
24	S_LVPS	upper limit	Turn off STICS HV & LVPS
25		lower limit	Turn off STICS HV & LVPS
26	S_MCPPS	upper limit	Turn off STICS MCPPS
27	S_DPPS	upper limit	Turn off STICS DPPS
28	I_LVPS	upper limit	Turn off ICS HV & LVPS
29		lower limit	Turn off ICS HV & LVPS
30	I_MCPPS	upper limit	Turn off ICS MCPPS
31	I_MOTOR	upper limit	Turn off ICS Motor Power
32	spare		
	DIGITAL		
33	Watchdog timeout		(Hardware reset)
34	Memory Checksum		Regenerate memory tables
35	Restart Checksum		Clear restart memory, go to standby
36	STICS Control Command		
	HVPS control		Turn off STICS HVPS
	????		????
	other		none
37	ICS Control Command		
	HVPS control		Turn off ICS HVPS
	Motor control		Turn off ICS HV & LVPS
	other		none
38	Motor Position		none
39	spare		

* individual MCPPS should first be shut down, if error continues, turn MCPPS power off

The DPU shall use a bit mask to determine which alarm channels are active at any given time. This bit mask shall be modifiable by ground command, macros or by the alarm processor response algorithm.

When a channel is determined to exceed one of its limits, the DPU shall repeat the measurement in the following two spins. If all three readings exceed the programmed limit, the alarm flag will be activated.

The LVPS current monitor outputs will be measured by the DPU once per sector. If the current exceeds allowable limits, the supply power will be turned off.

HV PROTECTION

The DPU will process all HV level commands with the following template algorithm (assume supply #n is to be commanded):

```
IF HV is enabled, THEN
    IF HV power is ON, THEN
        IF HV #n supply is enabled (ON), THEN
            IF HV #n level is below stored HV #n limit, THEN
                Set HV #n to level commanded
            ELSE Increment invalid command counter.
        ELSE Take no action
    ELSE Take no action
ELSE Take no action
```

Because the EPIC instrument is so complex, there can be a great deal of flexibility in configuring and commanding it. While it is desirable to have the ability to individually command preamps, calibrators, etc. on and off, the command sequences would become unacceptably long just to put the sensors in a standard configuration. To avoid this, the DPU shall contain a number of predefined command sequences, called macros; in this way, only one command will be needed to do most of the work.

The "commands" issued from the macros do not pass through the normal command processor, but are directly implemented in the DPU software. Thus, the command counter will increment by only one count when the macro is run, even though a number of functions are being implemented. All macros will be defined prior to launch, and stored in program PROM.

The number of macros (and their contents) are still TBD at this time, however a preliminary list is shown below with some detailed macros in Appendix D.

MACROS

- Single sensor operation with ICS
- Single sensor operation with STICS
- Configure ICS electronics to be operational
- Configure STICS electronics to be operational
- Configure both sets of electronics to be operational
- Save Instrument Configuration
- Resume Saved Instrument Configuration
- Step ICS high voltage to nominal levels
- Step STICS high voltage to nominal levels
- ICS Calibration cycle - 1 execution only
- ICS Calibration cycle - periodic execution
- STICS Calibration cycle - 1 execution only

DPU INITIALIZATION

A period of (TBD) minutes shall be allowed upon turning on DPU power to allow the processor to generate classification tables. The telemetry stream will contain housekeeping and status information within TBD seconds of power application.

SINGLE SENSOR OPERATION

The DPU shall be capable of modifying the standard telemetry format to better allocate the available telemetry bits when only one subsystem (STICS or ICS) is active. No additional accumulators will be accessed in these modes, but additional resolution may be provided for rate data already in the DPU memory. Additional PHA events and greater visibility to the STICS DPPS voltage outputs will be provided in telemetry. See STICS and ICS Telemetry Allocation and Definition sections for details. This telemetry modification shall not affect the DPU status or subcommutated housekeeping data.

PRE-FLIGHT TEST FEATURES

The capability for increased time and spatial resolution in the telemetry data will be incorporated into the single sensor modes. No special telemetry or command algorithms will be available for special ground tests. (See Single Sensor Mode Section).

Should additional visibility be needed into the instrument operation or science telemetry, the GSE may be used to directly access DPU memory contents via the RAM-check mode.

REPROGRAMMABILITY

The processor code shall have the capability of being modified in flight via program loads to the permanently power RAM. At least 2K bytes of RAM shall be available for this purpose. It is therefore necessary that the software be appropriately divided into modules so as to allow complete replacement of any piece of processor code. The operating software should be able to jump to this memory space to access the updated code.

MEMORY PROTECTION

Processor RAM and PROM and classification RAM shall be protected via a **TBD TUB**-bit Hamming code attached to each byte. This will be able to correct 1-bit errors and detect 2-bit errors. This correction takes place only when the memory location is accessed.

Due to the critical nature of the control software in the EPIC DPU, the processor program PROM shall be fully redundant. The active PROM will be selected in hardware by a discrete command.

Memory load operations will be limited via software to RAM addresses only. Both RAM and PROM contents may be verified by using the S/C RAM check mode. Protection shall be provided with the software to prevent erroneous entry into designated "dangerous" software modules (i.e. HV control).

TIME TAGGING OF DATA

All EDB data blocks will be synchronized to begin at the beginning of an Editor B minor frame boundary. The DPU shall measure the time between the beginning of a major frame (F(4Xn), W0 = 0) and the beginning of an EDB, and provide this offset in the EDB telemetry. Since the S/C provides timing information in the header of each major frame, this should give absolute knowledge of when data events were collected.

DATA COMPRESSION

There will be two rate compression algorithms available in the DPU operating code. The two subsystems, ICS and STICS, may independently select, by command, which algorithm to use on each of two predefined rate groups; every rate channel will belong to one of these two groups. The group assignments are listed in the Rate Compression Codes section.

ERROR DETECTION

The DPU shall detect and report non-fatal error conditions that are part of normal operations. Typical errors would be motor scanning error, analog electronics command interface rejection, etc. Additional items may be added as necessary. No action will be taken within the DPU on some of these errors, however their occurrence will be flagged in the telemetry stream.

APPENDIX A DETAILED SUBCOM HOUSEKEEPING AND STATUS LIST

Housekeeping Parameter	Procedure to Read Source	Description	Set By Command	Bits
S_HVPS1 Limit	DPU		BC S_HV_LIM	8
S_HVPS2 Limit	DPU		BC S_HV_LIM	8
S_HVPS3 Limit	DPU		BC S_HV_LIM	8
S_HVPS4 Limit	DPU		BC S_HV_LIM	8
S_HVPS5 Limit	DPU		BC S_HV_LIM	8
S_HVPS6 Limit	DPU		BC S_HV_LIM	8
S_HVPS7 Limit	DPU		BC S_HV_LIM	8
S_HVPS1 Level	DPU		BC S_HV_LEV	8
S_HVPS2 Level	DPU		BC S_HV_LEV	8
S_HVPS3 Level	DPU		BC S_HV_LEV	8
S_HVPS4 Level	DPU		BC S_HV_LEV	8
S_HVPS5 Level	DPU		BC S_HV_LEV	8
S_HVPS6 Level	DPU		BC S_HV_LEV	8
S_HVPS7 Level	DPU		BC S_HV_LEV	8
S_HVPS1 Voltage	STICS AE	D80 return byte h0 - h7		8
S_HVPS2 Voltage	STICS AE	D81 return byte h0 - h7		8
S_HVPS3 Voltage	STICS AE	D82 return byte h0 - h7		8
S_HVPS4 Voltage	STICS AE	D83 return byte h0 - h7		8
S_HVPS5 Voltage	STICS AE	D84 return byte h0 - h7		8
S_HVPS6 Voltage	STICS AE	D85 return byte h0 - h7		8
S_HVPS7 Voltage	STICS AE	D86 return byte h0 - h7		8
S_Energy Thresh. 1	DPU		BC S_EN_THS	6
S_Energy Thresh. 2	DPU		BC S_EN_THS	6
S_Energy Thresh. 3	DPU		BC S_EN_THS	6
S_Energy Cal. level	DPU		BC S_ECAL	8
S_TOF Cal. level	DPU		BC S_TCAL	4
S_Digital Target Value				
S_N Start MCPPS en.	DPU		BC S_HVCMD	1
S_E Start MCPPS en.	DPU		BC S_HVCMD	1
S_S Start MCPPS en.	DPU		BC S_HVCMD	1
S_N Stop MCPPS en.	DPU		BC S_HVCMD	1
S_E Stop MCPPS en.	DPU		BC S_HVCMD	1
S_S Stop MCPPS en.	DPU		BC S_HVCMD	1
S_TOFPS enable	DPU		BC S_HVCMD	1
NEG DPPS Enable	DPU		BC S_HVCMD	1
POS DPPS Enable	DPU		BC S_HVCMD	1

Appendix A Detailed Subcom Housekeeping and Status List (continued)

Housekeeping Parameter	Procedure to Read Source	Description		Set By Command	Bits
S_Digital Status					
S_N Start MCPPS en.	STICS AE	D00	return bit h0	BC S_HVCMD	
S_E Start MCPPS en.	STICS AE		return bit h1	BC S_HVCMD	
S_S Start MCPPS en.	STICS AE		return bit h2	BC S_HVCMD	
S_N Stop MCPPS en.	STICS AE		return bit h3	BC S_HVCMD	
S_E Stop MCPPS en.	STICS AE		return bit h4	BC S_HVCMD	
S_S Stop MCPPS en.	STICS AE		return bit h5	BC S_HVCMD	
S_TOFPS enable	STICS AE		return bit h6	BC S_HVCMD	
spare	STICS AE		return bit h7		
NEG DPPS Enable	STICS AE	D01	return bit h0	BC S_HVCMD	
POS DPPS Enable	STICS AE		return bit h1	BC S_HVCMD	
S_SSD N. Preamp pow.	STICS AE		return bit h2	BC S_PWRCMD	1
S_SSD E. Preamp pow.	STICS AE		return bit h3	BC S_PWRCMD	1
S_SSD S. Preamp pow.	STICS AE		return bit h4	BC S_PWRCMD	1
S_Logic Cal. enable	STICS AE		return bit h5	BC S_DIGCMD	1
unused	STICS AE		return bit h6		1
S_LVPS Over-current	STICS AE		return bit h7		1
S_Time Preamp 1 pow.	STICS AE	D02	return bit h0	BC S_PWRCMD	1
S_Time Preamp 2 pow.	STICS AE		return bit h1	BC S_PWRCMD	1
S_Time Preamp 3 pow.	STICS AE		return bit h2	BC S_PWRCMD	1
S_Time Preamp 4 pow.	STICS AE		return bit h3	BC S_PWRCMD	1
S_Time Preamp 5 pow.	STICS AE		return bit h4	BC S_PWRCMD	1
spare	STICS AE		return bit h5		
spare	STICS AE		return bit h6		
spare	STICS AE		return bit h7		
S_Main Bias power	STICS AE	D03	return bit h0	BC S_PWRCMD	1
S_Detector Bias High	STICS AE		return bit h1		1
S_Mult. Start enable	STICS AE		return bit h2	BC S_DIGCMD	1
S_Mult. Stop enable	STICS AE		return bit h3	BC S_DIGCMD	1
S_Low Rate Mode	STICS AE		return bit h4	BC S_DIGCMD	1
S_T-cal power/Osc en.	STICS AE		return bit h5	BC S_PWRCMD	1
unused	STICS AE		return bit h6		1
spare	STICS AE		return bit h7		1
spare	STICS AE	D04	return bit h0		1
spare	STICS AE		return bit h1		
S_North Bias Disable	STICS AE		return bit h2	BC S_PWRCMD	1
S_Equa. Bias Disable	STICS AE		return bit h3	BC S_PWRCMD	1
S_South Bias Disable	STICS AE		return bit h4	BC S_PWRCMD	1
spare	STICS AE		return bit h5		
spare	STICS AE		return bit h6		
spare	STICS AE		return bit h7		

Appendix A Detailed Subcom Housekeeping and Status List (continued)

Housekeeping	Procedure to Read		Set By	
Parameter	Source	Description	Command	Bits
S_APERTURE STATUS	STICS AE	D05 return bit h0		1
unused	STICS AE	return bit h1		
unused	STICS AE	return bit h2		
unused	STICS AE	return bit h3		
unused	STICS AE	return bit h4		
unused	STICS AE	return bit h5		
unused	STICS AE	return bit h6		
unused	STICS AE	return bit h7		
S_PHA Range	DPU		BC S_RANGE	6
S_Priority Def.	DPU	3 x 24	BC S_PRIDEF	72
S_DPPS Stepping Seq.	DPU		BC S_DF_SEQ	2
S_DPPS Discharge Cnt.	STICS AE	2 x 4 bits		8
S_Compress. Algorithm	DPU		BC D_CMPRSS	2
S_Valid Event mode	DPU		BC S_VALID	3
S_SUPPLY VOLT				
+5.2 VOLT	STICS AE	D9A return byte h0-h7		8
-5.2 VOLT	STICS AE	D9B return byte h0-h7		8
+6 VOLT	STICS AE	D98 return byte h0-h7		8
-6 VOLT	STICS AE	D99 return byte h0-h7		8
+12 VOLT	STICS AE	D9C return byte h0-h7		8
-12 VOLT	STICS AE	D9F return byte h0-h7		8
0 VOLT (ground)	STICS AE	D8A return byte h0-h7		4
BIAS VOLTAGE	STICS AE	D9D return byte h0-h7		8
S_DPPS CONV LEV	DPU/S_AE	2 X (5-bit ID, 12-bit value)		34
S_LVPS CURR	STICS AE	D9E return byte h0-h7		8
S_MCPPS CURR	STICS AE	D87 return byte h0-h7		8
S_DPPS CURR	STICS AE	D8C return byte h0-h7		8
S_TEMP #1 (AE)	STICS AE	D90 return byte h0-h7		8
S_TEMP #2 (SENS)	STICS AE	D91 return byte h0-h7		8
S_TEMP #3 (SENS)	STICS AE	D92 return byte h0-h7		8
S_TEMP #4 (SENS)	STICS AE	D93 return byte h0-h7		8
S_COFFS	DPU	see D_Param. Readback	BC D_PARLD	

Appendix A Detailed Subcom Housekeeping and Status List (continued)

Housekeeping	Procedure to Read		Set By	
Parameter	Source	Description	Command	Bits
I_HVPS1 Limit	DPU		BC I_HV_LIM	8
I_HVPS2 Limit	DPU		BC I_HV_LIM	8
I_HVPS3 Limit	DPU		BC I_HV_LIM	8
I_HVPS4 Limit	DPU		BC I_HV_LIM	8
I_HVPS5 Limit	DPU		BC I_HV_LIM	8
I_HVPS1 Level	DPU		BC I_HV_LEV	8
I_HVPS2 Level	DPU		BC I_HV_LEV	8
I_HVPS3 Level	DPU		BC I_HV_LEV	8
I_HVPS4 Level	DPU		BC I_HV_LEV	8
I_HVPS5 Level	DPU		BC I_HV_LEV	8
I_HVPS1 Voltage	ICS AE	D80 return byte h0 - h7		8
I_HVPS2 Voltage	ICS AE	D81 return byte h0 - h7		8
I_HVPS3 Voltage	ICS AE	D82 return byte h0 - h7		8
I_HVPS4 Voltage	ICS AE	D83 return byte h0 - h7		8
I_HVPS5 Voltage	ICS AE	D84 return byte h0 - h7		8
I_Energy Thresh. 1	DPU		BC I_EN_THS	6
I_Energy Thresh. 2	DPU		BC I_EN_THS	6
I_Energy Thresh. 3	DPU		BC I_EN_THS	6
I_Energy Thresh. 4	DPU		BC I_EN_THS	6
I_Energy Cal. level	DPU		BC I_ECAL	8
I_TOF Cal. level	DPU		BC I_TCAL	4
I_Digital Target Value				
I_N Start MCPPS en.	DPU		BC I_HVCMD	1
I_S Start MCPPS en.	DPU		BC I_HVCMD	1
I_N Stop MCPPS en.	DPU		BC I_HVCMD	1
I_S Stop MCPPS en.	DPU		BC I_HVCMD	1
I_TOFPS enable	DPU		BC I_HVCMD	1
I_Digital Status				
I_N Start MCPPS en.	ICS AE	D00 return bit h0	BC I_HVCMD	
I_S Start MCPPS en.	ICS AE	return bit h1	BC I_HVCMD	
I_N Stop MCPPS en.	ICS AE	return bit h2	BC I_HVCMD	
I_S Stop MCPPS en.	ICS AE	return bit h3	BC I_HVCMD	
I_TOFPS enable	ICS AE	return bit h4	BC I_HVCMD	
unused	ICS AE	return bit h5		
unused	ICS AE	return bit h6		
spare	ICS AE	return bit h7		
unused	ICS AE	D01 return bit h0		
unused	ICS AE	return bit h1		
I_SSD N. Preamp pow.	ICS AE	return bit h2	BC I_PWRCMD	1
I_SSD E. Preamp pow.	ICS AE	return bit h3	BC I_PWRCMD	1
I_SSD S. Preamp pow.	ICS AE	return bit h4	BC I_PWRCMD	1
I_Logic Cal. enable	ICS AE	return bit h5	BC I_DIGCMD	1
I_Energy Cal. power	ICS AE	return bit h6	BC I_PWRCMD	1
I_LVPS Over-current	ICS AE	return bit h7		1

Appendix A Detailed Subcom Housekeeping and Status List (continued)

Housekeeping Parameter	Source	Procedure to Read Description	Set By Command	Bits
I_Time N Stop disable	ICS AE	D02 return bit h0	BC I_PWRCMD	1
I_Time N Start disable	ICS AE	return bit h1	BC I_PWRCMD	1
I_Time S Start disable	ICS AE	return bit h2	BC I_PWRCMD	1
unused	ICS AE	return bit h3		1
I_Time S Stop disable	ICS AE	return bit h4	BC I_PWRCMD	1
spare	ICS AE	return bit h5		
spare	ICS AE	return bit h6		1
spare	ICS AE	return bit h7		1
unused	ICS AE	D03 return bit h0		1
I_Detector Bias High	ICS AE	return bit h1	BC I_DIGCMD	1
I_Mult. Start enable	ICS AE	return bit h2	BC I_DIGCMD	1
I_Mult. Stop enable	ICS AE	return bit h3	BC I_DIGCMD	1
I_Low Rate Mode	ICS AE	return bit h4	BC I_DIGCMD	1
I_T-cal power/Osc en.	ICS AE	return bit h5	BC I_PWRCMD	1
I_Position Sensor power	ICS AE	return bit h6		1
spare	ICS AE	return bit h7		
spare	ICS AE	D04 return bit h0		
spare	ICS AE	return bit h1		
Motor Phase A	ICS AE	return bit h2		
Motor Phase B	ICS AE	return bit h3		
unused	ICS AE	return bit h4		
spare	ICS AE	return bit h5		
spare	ICS AE	return bit h6		
spare	ICS AE	return bit h7		
I_Position Sense N1	ICS AE	D05 return bit h0	BC I_MTRCMD,	1
I_Position Sense N2	ICS AE	return bit h1	BC I_DIRMOT,	1
I_Position Sense N3	ICS AE	return bit h2	autonomous control	1
North Motor enable	ICS AE	return bit h3		1
I_Position Sense N1	ICS AE	return bit h4	BC I_MTRCMD,	1
I_Position Sense N2	ICS AE	return bit h5	BC I_DIRMOT,	1
I_Position Sense N3	ICS AE	return bit h6	autonomous control	1
South Motor enable	ICS AE	return bit h7		1
I_Accums Cal	DPU		BC I_DIGCMD	1
I_Auto Aper. Control	DPU		BC I_DIGCMD	1
I_Reduced Movement	DPU			1
I_Motor Use Enable	DPU		BC I_DIGCMD	1
I_PHA Energy Freeze	DPU	4 bits level, 1 bit freeze	BC I_PR_OVR	5
I_PHA Species Freeze	DPU	4 bits level, 1 bit freeze	BC I_PR_OVR	5
I_PHA Status	DPU	2 bits head, 1 bit FIFO mode	BC I_PHACMD	3
I_Rate Format Mode	DPU	3 x 2 bits (sum head/sector)	BC I_DIGCMD	6
I_Valid Event mode	DPU		BC I_VALID	3
I_Compress. Algorithm	DPU		BC D_CMPRSS	2

Appendix A Detailed Subcom Housekeeping and Status List (continued)

Housekeeping Parameter	Source	Procedure to Read Description	Set By Command	Bits
I_SUPPLY VOLT				
+5.2 VOLT	ICS AE	D9A return byte h0-h7		8
-5.2 VOLT	ICS AE	D9B return byte h0-h7		8
+6 VOLT	ICS AE	D98 return byte h0-h7		8
-6 VOLT	ICS AE	D99 return byte h0-h7		8
+12 VOLT	ICS AE	D9C return byte h0-h7		8
-12 VOLT	ICS AE	D9F return byte h0-h7		8
0 VOLT (ground)	ICS AE	D8A return byte h0-h7		4
BIAS VOLTAGE	ICS AE	D9D return byte h0-h7		8
I_LVPS CURR	ICS AE	D9E return byte h0-h7		8
I_MCPPS CURR	ICS AE	D87 return byte h0-h7		8
I_MOT CURR	ICS AE	D8C return byte h0-h7		8
I_TEMP #1 (AE)	ICS AE	D90 return byte h0-h7		8
I_TEMP #2 (SENS)	ICS AE	D91 return byte h0-h7		8
I_TEMP #3 (SENS)	ICS AE	D92 return byte h0-h7		8
I_TEMP #4 (SENS)	ICS AE	D93 return byte h0-h7		8
I_MOTOR COFFS	DPU	see D_Param. Readback	BC D_PARLD	
I_COFFS	DPU	see D_Param. Readback	BC D_PARLD	

Appendix A Detailed Subcom Housekeeping and Status List (continued)

Housekeeping Parameter	Source	Procedure to Read Description	Set By Command	Bits
D_WORD 1	DPU	DPU MEMORY STATISTICS		8
D_WORD 2	DPU	DPU MEMORY STATISTICS		8
D_WORD 3	DPU	DPU MEMORY STATISTICS		8
D_WORD 4	DPU	DPU MEMORY STATISTICS		8
D_WORD 5	DPU	DPU MEMORY STATISTICS		8
D_WORD 6	DPU	DPU MEMORY STATISTICS		8
D_VAL COMD COUNT	DPU			8
D_LAST VAL CMD 1	DPU			8
D_LAST VAL CMD 2	DPU			8
D_LAST VAL CMD 3	DPU			8
D_INVALID CMD CNT	DPU			8
D_LAST INVALID CMD 1	DPU			8
D_LAST INVALID CMD 2	DPU			8
D_Alarms Enabled	DPU		BC D_ALRLIM	40
D_ALARM COND BUF.a	DPU			8
D_ALARM COND BUF.b	DPU			8
D_ALARM COND BUF.c	DPU			8
D_ALARM COND BUF.d	DPU			8
D_ALARM COND BUF.e	DPU			8
D_First Alarm Code	DPU			6
D_First Alarm Value	DPU			16
D_Sci Rec Cntr	DPU			24
D_Real-time status bytes	DPU	Repeat of 3-byte status		24
D_BYTE6 Pointer	DPU			24
D_Checksum Limits				
Lower	DPU			24
Upper	DPU			24
D_Program Address	DPU	MSB needed, others useful		24
D_Digital Status				
Multispin summation	DPU		BC D_DIGCMD	2
Spin Clock	DPU		BC D_DIGCMD	1
Alarm Enable	DPU		BC D_DIGCMD	1
Sensor Mode	DPU		BC D_DIGCMD	2
Program PROM Selected	DPU		DC TOGGLE, DC PRS1,DC PRS2	1
Event Processor mode	DPU		BC D_PWRCMD	2
Latch-recovery Enable	DPU		DC LUD-EN/DIS	1
Instrument Power Enable	DPU		DC EPC-ON/OFF	1
D_SUN OFFSET	DPU		BC D_SUNSET	16
D_Param. Readback	DPU	1-byte index, 8-byte param.	BC D_PARLD	72
D_ALARMS, TEMPS I_SE	DPU	upper and lower limit	BC D_ALRLIM	16
D_ALARMS, TEMPS S_SE	DPU	upper and lower limit	BC D_ALRLIM	16

Appendix A Detailed Subcom Housekeeping and Status List (continued)

Housekeeping Parameter	Procedure to Read Source	Description	Set By Command	Bits
D_ALARMS, VOLTS				
S_LVPS +6	DPU	upper/lower limit	BC D_ALRLIM	16
S_MCPPS N-St	DPU	upper limit	BC D_ALRLIM	8
S_MCPPS N-Sp	DPU	upper limit	BC D_ALRLIM	8
S_MCPPS E-St	DPU	upper limit	BC D_ALRLIM	8
S_MCPPS E-Sp	DPU	upper limit	BC D_ALRLIM	8
S_MCPPS S-St	DPU	upper limit	BC D_ALRLIM	8
S_MCPPS S-Sp	DPU	upper limit	BC D_ALRLIM	8
S_TOFPS	DPU	upper limit	BC D_ALRLIM	8
I_LVPS +6	DPU	upper/lower limit	BC D_ALRLIM	16
I_MCPPS N-St	DPU	upper limit	BC D_ALRLIM	8
I_MCPPS N-Sp	DPU	upper limit	BC D_ALRLIM	8
I_MCPPS S-St	DPU	upper limit	BC D_ALRLIM	8
I_MCPPS S-Sp	DPU	upper limit	BC D_ALRLIM	8
I_TOFPS	DPU	upper limit	BC D_ALRLIM	8
D_ALARMS, CURRENTS				
S_LVPS	DPU	upper/lower limit	BC D_ALRLIM	16
S_MCPPS	DPU	upper limit	BC D_ALRLIM	8
S_DPPS	DPU	upper limit	BC D_ALRLIM	8
I_LVPS	DPU	upper/lower limit	BC D_ALRLIM	16
I_MCPPS	DPU	upper limit	BC D_ALRLIM	8
I_MOTOR	DPU	upper limit	BC D_ALRLIM	8
D_ALARMS, LATCH-UP				
S_LATCH	STICS AE	D8D return byte h0-h7	BC D_ALRLIM	8
I_LATCH	ICS AE	D8D return byte h0-h7	BC D_ALRLIM	8

TOTAL SETTABLE ALARMS 30

AVAILABLE SLOTS = 192

TOTAL BYTES	187
SPARE BYTES	5
SPARE BITS	40