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DEVELOP AND FABRICATE A RADIATION DOSE MEASUREMENT SYSTEM FOR SATELLITES

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13. ABSTRACT *(Maximum 200 words)*

A second generation Dosimeter has been designed to fulfill the need for accurate radiation dose measurements. Two identical Dosimeters, a flight unit and a backup unit, are being fabricated, tested and calibrated. The flight Dosimeter is to be integrated into the payload of the Advanced Photovoltaic and Electronic Experiments (APEX) satellite, as part of the Photovoltaic Array Space Power Plus Diagnostics (PASP Plus) experiment.

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1. INTRODUCTION

Accurate characterization of the space radiation environment is one of the important inputs into the design of space systems that utilize complex electronic components. Radiation dose information can be used to optimize the design of a space system in terms of its expected lifetime, the types of electronic parts that can be used, and the shielding required for its critical components.

Electronic devices, photovoltaic power systems, and spacecraft power systems are susceptible to damage due to the received radiation dose from incident energetic protons and electrons. In addition, many types of electronic parts, particularly microprocessors and associated memory units, are subject to single-event-upsets (SEU's) caused by the passage of single high-energy heavy ions through the device or high energy proton induced "nuclear star" events. The instantaneous radiation dose rate and the associated total accumulated dose provide important information for the estimation of satellite lifetime and for real-time decisions regarding satellite integrity. This information can be used to provide advance warning of when critical components are approaching failure due to radiation damage, and it can also provide confidence in the reliable operation of a component by showing that the radiation damage is not yet significant. In the case of solar flares, a dose measurement could show that radiation exposure has (perhaps suddenly) become very important and that the consequences must be addressed.

The increasing use of complex solid-state electronic devices in the space radiation environment makes it important to have reliable data on the radiation doses these devices will receive behind various thicknesses of shielding. As part of the effort to obtain this data, a Dosimeter was designed, fabricated, calibrated, and integrated into the payload of a Defense Meteorological Satellite Program (DMSP) satellite by Panametrics, Inc., for the Geophysics Laboratory, under contract number F19628-78-C-0247. A second, essentially identical, Dosimeter was designed, fabricated, calibrated, and integrated into the payload of the Combined Release and Radiation Effects Satellite (CRRES) by Panametrics, Inc., for the Geophysics Laboratory, under contract number F19628-82-C-0090. The DMSP and CRRES Dosimeters, which measure the accumulated radiation dose in four silicon solid-state detectors behind four different thicknesses of aluminum shielding (one solid-state detector behind each shield), are described in Refs. 1 and 2, respectively.

The general objective of the current contract is the design and fabrication of an improved, second-generation Dosimeter intended to fulfill the need for accurate radiation dose measurements. This system is to have the following characteristics:

1) Separately measure the total accumulated dose due to electrons and protons,

2) Detect and measure energy deposition of large-energy deposition events (possible SEU's),

3) Accurately measure the dose during normal activity periods and during large solar flare events (such as August 1972 or March 1989),

4) Be easily adaptable mechanically and electronically to different spacecraft and different radiation environments (for example, orbits inside or outside the radiation belts),

5) Have modest telemetry requirements.

The specific objectives of this contract are as follows:

1) Conceptual design of a Dosimeter instrument which meets the five requirements listed above,

2) Detailed design of the Dosimeter instrument,

3) Fabrication, testing and delivery of the protoflight[1] Dosimeter unit,

4) Fabrication, testing and delivery of the backup[1] flight Dosimeter unit.

The protoflight[1] Dosimeter is to be integrated into the payload of the Advanced Photovoltaic and Electronic Experiments (APEX) satellite, as part of the Photovoltaic Array Space Power Plus Diagnostics (PASP Plus) experiment.

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[1]The "protoflight" and "backup" designations are specified in the contract. The "protoflight" Dosimeter and "backup" Dosimeter are both fully qualified flight instruments.

2. PROGRESS TO DATE

2.1 Detection System

An isometric drawing of the Dosimeter is shown in Figure 1. The interface control drawing is shown in Figure 2, and the instrument's block diagram is shown in Figure 3.

The integral particle flux and radiation dose is measured by solid-state detectors located behind degraders and backed by a large amount of shielding, which reduces the response to rear entry particles. As shown in Figures 1 and 3, the instrument has four degraders (3 hemispherical and 1 planar, all of which are referred to as "domes") with solid-state detectors located underneath them. Dome 1 was specially configured as a planar Al shield 4.3 mils thick to allow accurate dosimetry measurements of the particles (5-10 Mev protons) most likely to cause solar cell degradation. This was necessary to meet PASP Plus requirements. The two thinnest domes have two detectors under each dome, one with a large sensitive volume and one with a small volume. The purpose of this arrangement is to ensure a large dynamic range of the instrument; the small detector will work reliably even with very high flux levels that may saturate the larger detector. A summary of the detector characteristics is give in Table 1. A cross sectional view of D1, the planar and thinnest dome, is shown in Figure 4. A cross sectional view of D3, which is typical of the three hemispherical domes except that there are two solid-state detectors under D2, is shown in Figure 5.

Protons and electrons that penetrate the degraders will deposit, on the average, different amounts of energy in the solid-state detectors, so their contributions to the total dose can be separated. The solid-state detectors are approximately 400 μm thick and most penetrating electrons deposit less than 1 MeV of energy in them, while most penetrating protons deposit between 1 and 10 MeV. A summary of the dome moderators utilized, with the resultant threshold energies, is given in Table 2. Energy deposition curves for the four domes are shown in Figures 6-9. The electron flux measurements with the thicker domes may not be reliable due to the production of bremsstrahlung by low-energy, non-penetrating electrons. The total electron radiation dose will, however, still be correctly determined. The flexibility of this design approach is that the same physical envelope of the dome-detector assembly can be used for very different degrader thicknesses and detector configurations. Thus, a simple mechanical change can be used to tailor the proton and electron thresholds to the specific mission requirements.

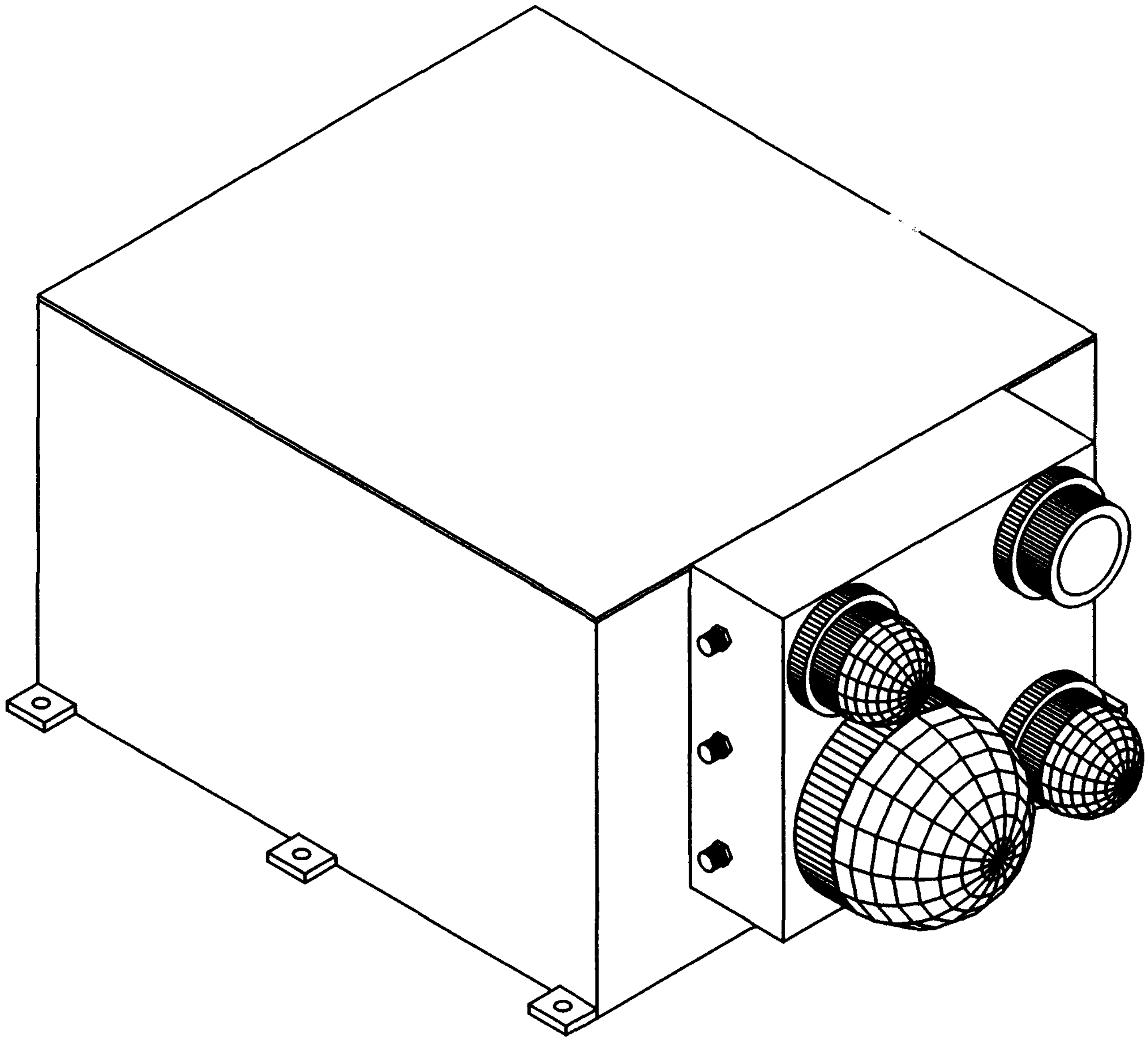

Figure 1. ISOMETRIC VIEW OF DOSIMETER

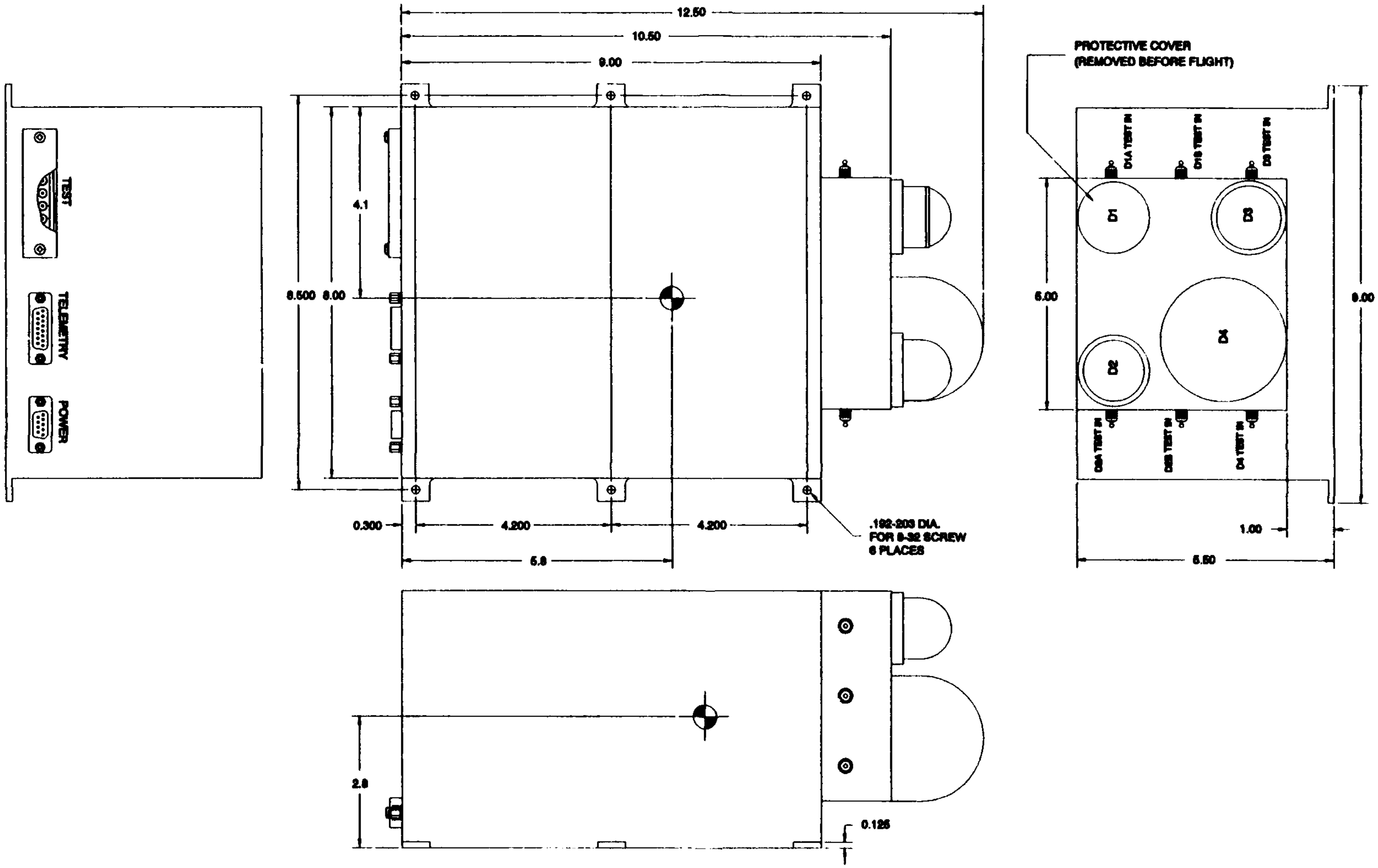

Figure 2. DOSIMETER INTERFACE CONTROL DRAWING

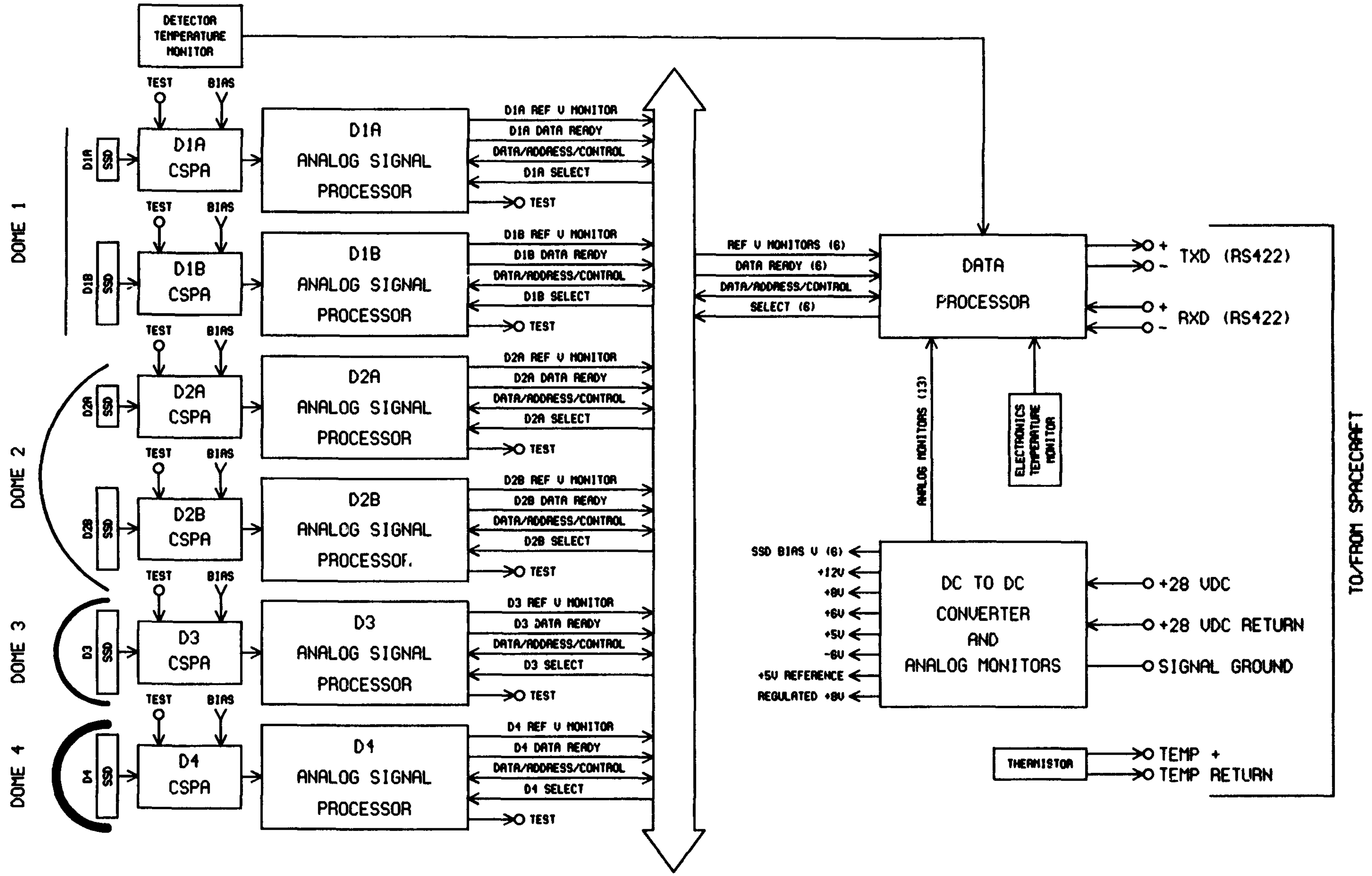

Figure 3. ELECTRONICS BLOCK DIAGRAM

Table 1.
SUMMARY OF DETECTOR CHARACTERISTICS

Dome	Detector			Dose at Overflow (Rads Si)		Flux at Overflow (particles/cm²-s)		
	Data Channel Designation	Area (cm²)	Geometric Factor (cm²-sr)	LOLET	HILET	TOTAL	LOLET	HILET
D1	D1A	0.008	0.03	10^6	10^7	10^9	10^8	10^8
D1	D1B	0.051	0.16	10^5	10^6	10^8	10^7	10^7
D2	D2A	0.008	0.08	10^6	10^7	10^9	10^8	10^8
D2	D2B	0.051	0.35	10^5	10^6	10^8	10^7	10^7
D3	D3	0.051	0.35	10^5	10^6	10^8	10^7	10^7
D4	D4	1.000	4.4	10^4	10^5	10^7	10^6	10^6

Table 2.
DOME MODERATORS AND ENERGY RANGES

Dome	Detectors	Aluminum Shields		Electron threshold	Proton energy range	VHILET threshold
		(g/cm²)	Shape	(MeV) (LOLET)	(MeV) (HILET)	(MeV)
D1	D1A, D1B	0.0294	flat	0.15	5 - 80	40, 40
D2	D2A, D2B	0.55	hemisphere	1.0	20 - 115	40, 40
D3	D3	1.55	hemisphere	2.5	32 - 120	40
D4	D4	3.05	hemisphere	5.0	52 - 125	75

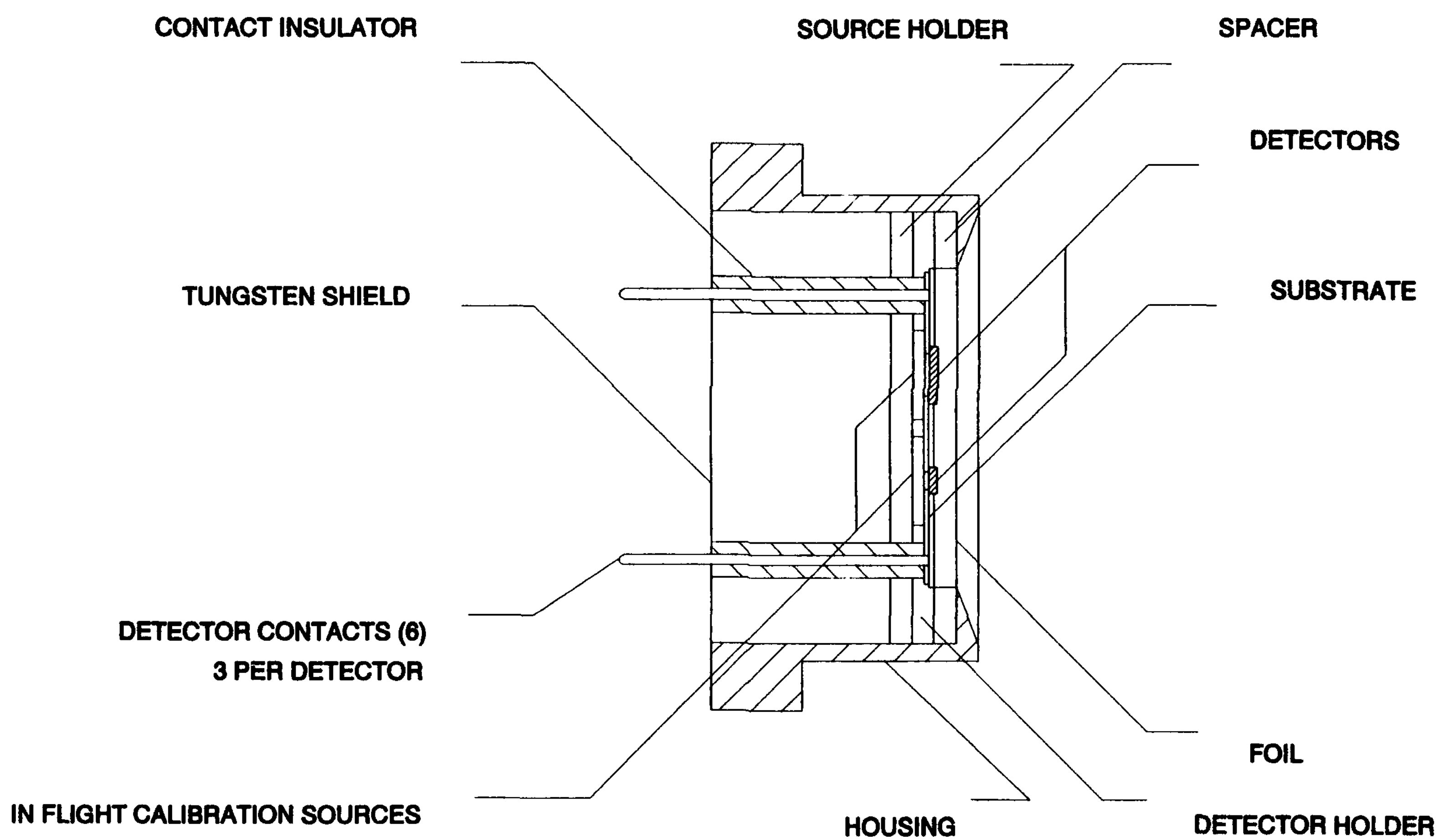

Figure 4. DOME 1 CROSS SECTION

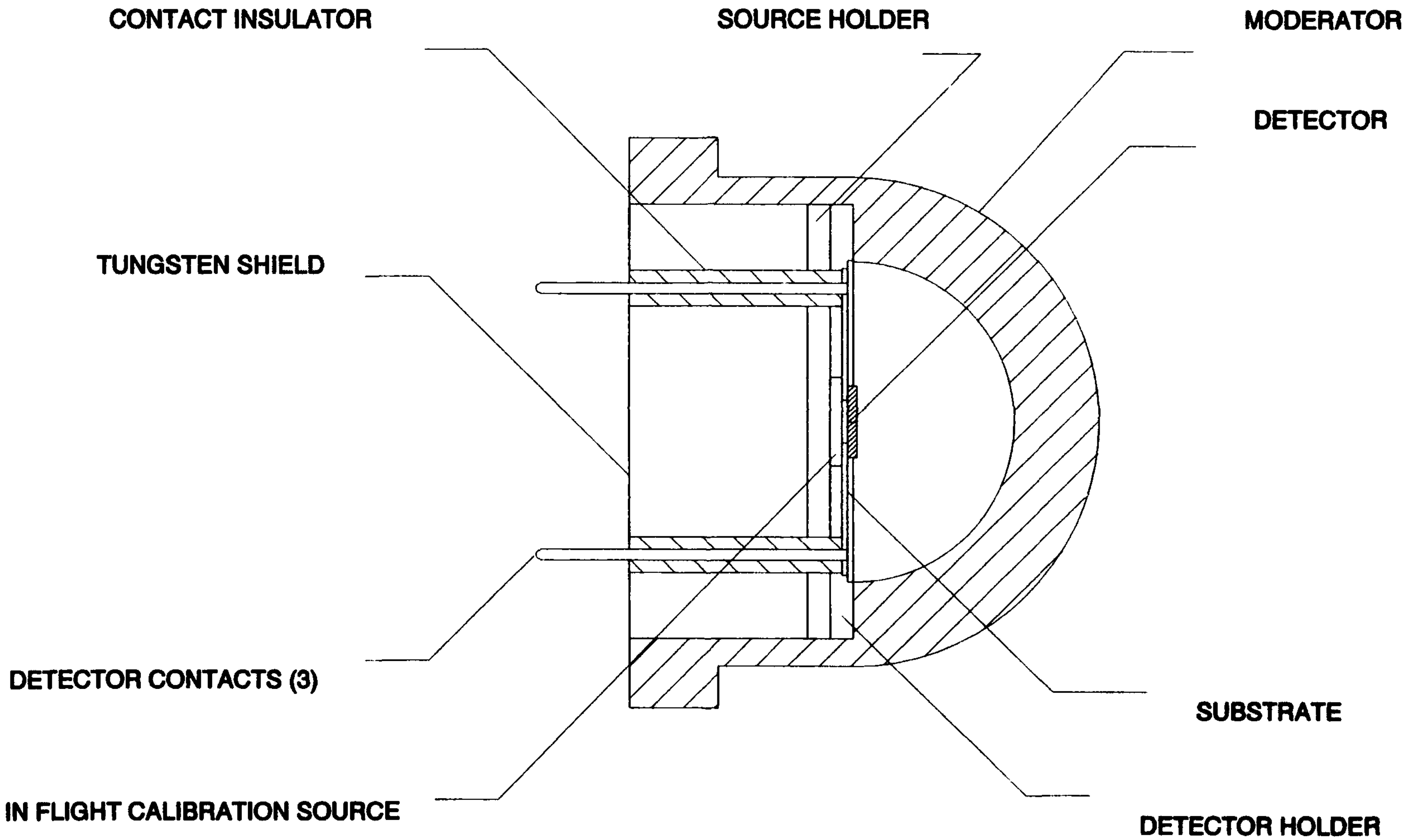

Figure 5. DOME 3 CROSS SECTION

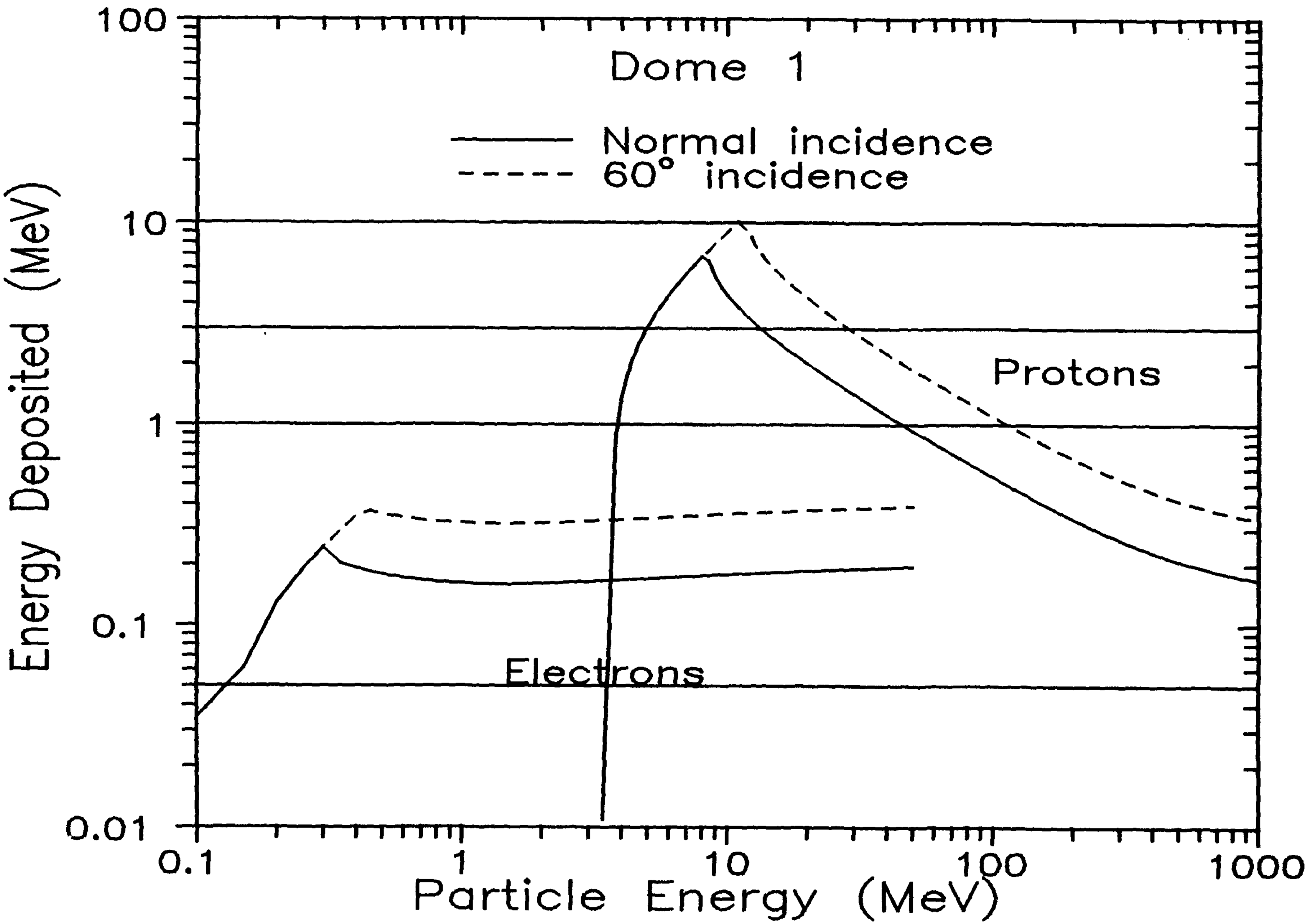

Figure 6. DOME 1 ENERGY DEPOSITION CURVES

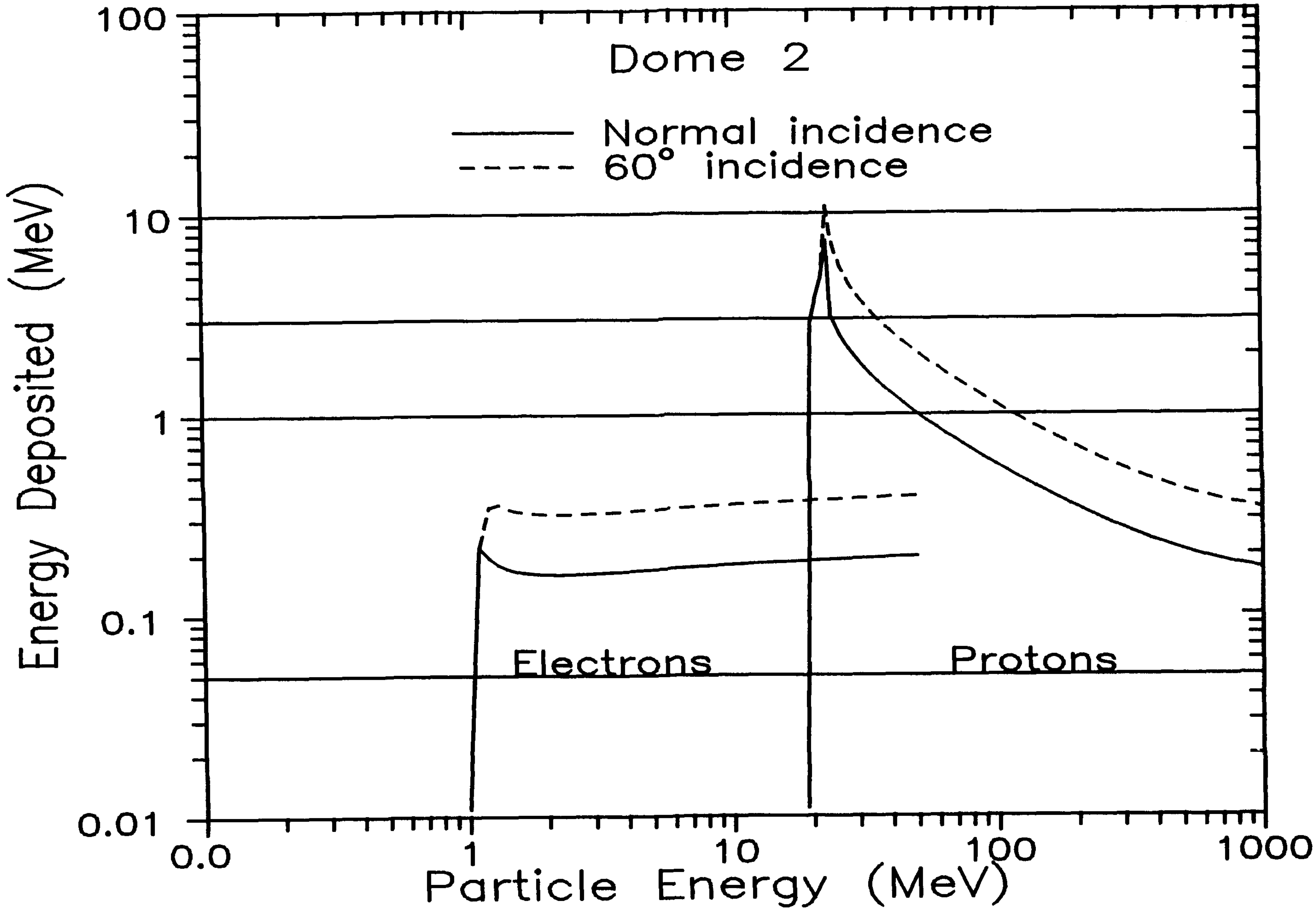

Figure 7. DOME 2 ENERGY DEPOSITION CURVES

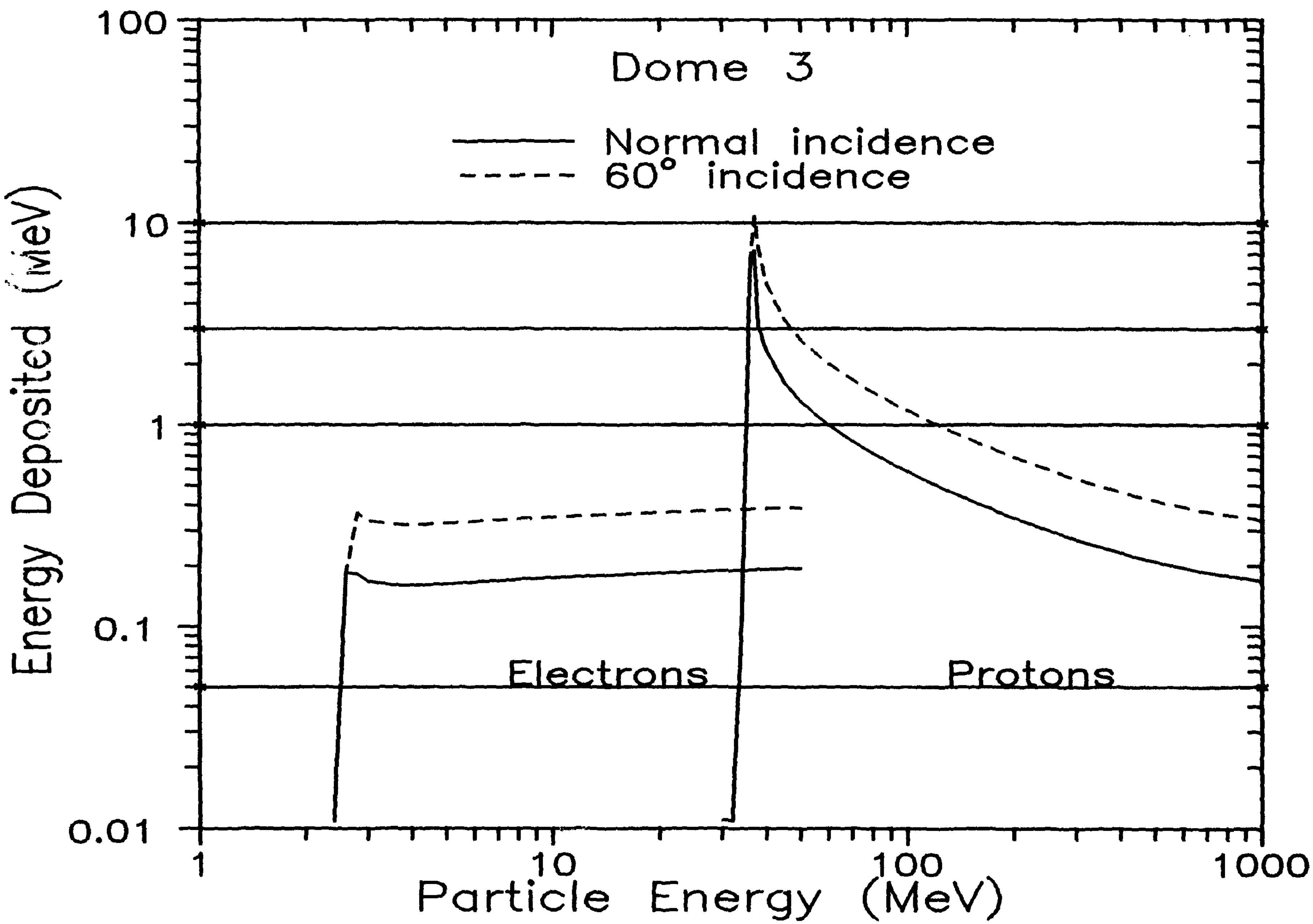

Figure 8. DOME 3 ENERGY DEPOSITION CURVES

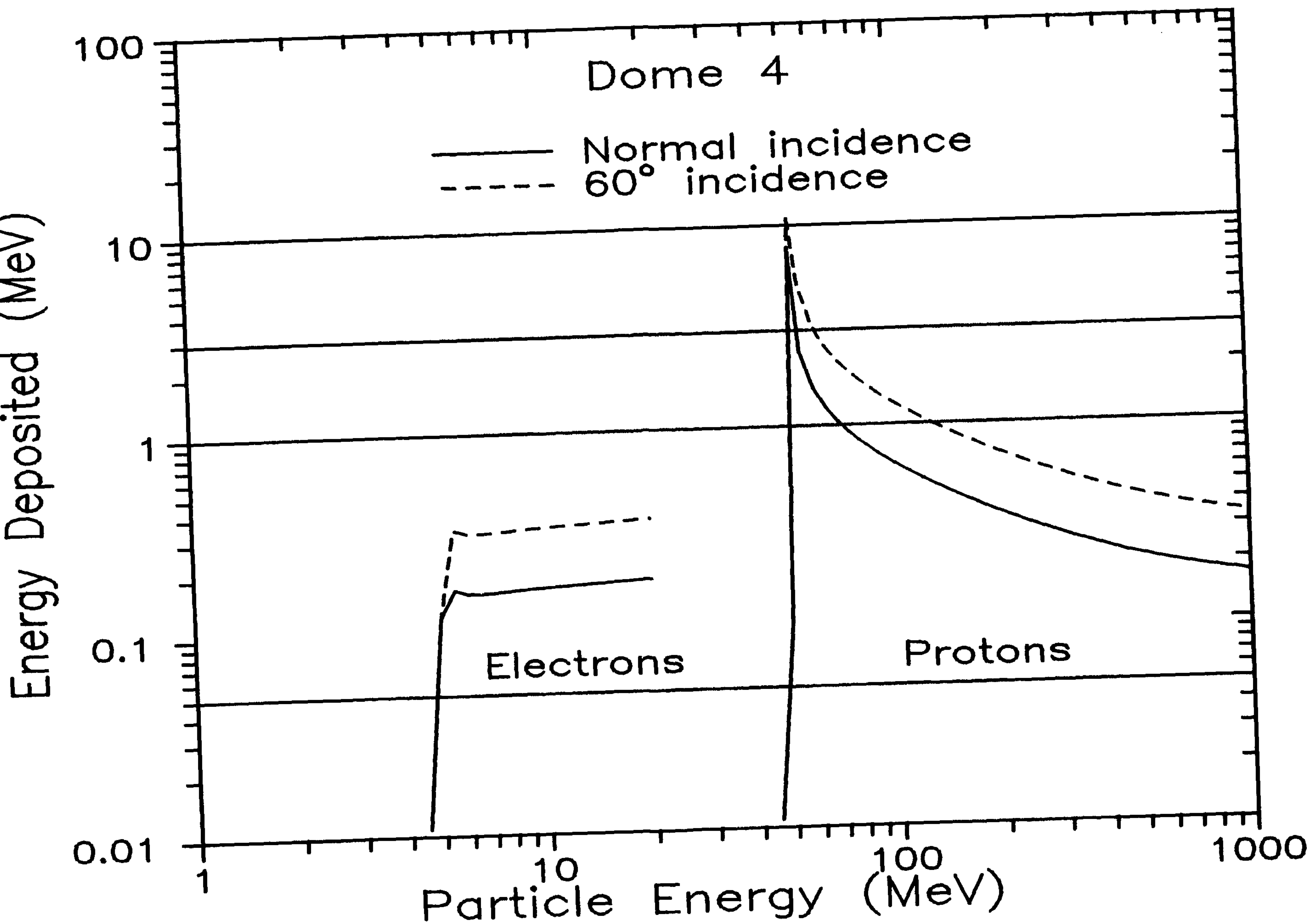

Figure 9. DOME 4 ENERGY DEPOSITION CURVES

2.2 Signal Processing

2.2.1 Charge Sensitive Pre-Amplifier and Analog Signal Processor

A block diagram of the Charge Sensitive Pre-Amplifier (CSPA) and Analog Signal Processor (ASP) circuitry is shown in Figure 10. A signal-processing timing diagram is shown in Figure 11. The SSD generates a charge signal proportional to the energy deposited in its sensitive volume by an incident particle. The CSPA collects the charge pulse and converts it to an amplified unipolar voltage pulse, which is further amplified and converted to a bipolar pulse by the shaping amplifiers. Particles that deposit more than 50 keV in the SSD trigger the 50 keV level discriminator, which increments a 24-bit event counter (TOTAL COUNT) and enables the zero-cross discriminator. The zero-cross discriminator fires on the subsequent bipolar signal zero crossing, strobing the flash 8-bit analog to digital converter (ADC) such that the delayed bipolar signal is sampled at its peak amplitude. The ADC data (DOSE) is latched, and a data processor interrupt signal is generated. The data processor subsequently reads the ADC data and resets the data latch and timing circuitry – enabling the ASP to process the next event. Note that the ADC normally "freeruns" at 20 kHz in order to reduce power consumption. Particles which deposit more than 40 MeV (75 Mev for D4) in the SSD trigger the 40 MeV level discriminator, which increments an 8-bit counter (VHILET COUNT). The data processor reads and resets the 24-bit TOTAL COUNT and 8-bit VHILET COUNT counters every 6 seconds. There are six (6) identical CSPA/ASP's, one for each Solid-State Detector (SSD). The six (6) CSPA's are contained on a single printed circuit board, while there are six (6) identical ASP printed circuit boards. A temperature monitor on the CSPA printed circuit board is subcommutated in the telemetered data.

2.2.2 Data Processor

A block diagram of the data processing circuitry is shown in Figure 12. The data processor is built around United Technology's 1750A microprocessor. The 1750A is available radiation-hardened, and is single-event-upset immune. It is a CMOS, 16-bit, Harvard Architecture (separate program and data memory), Reduced Instruction Set Computer (RISC), which can run at speeds of up to 12 MHz. It contains a Universal Asynchronous Receiver/Transmitter (UART) and two timers.

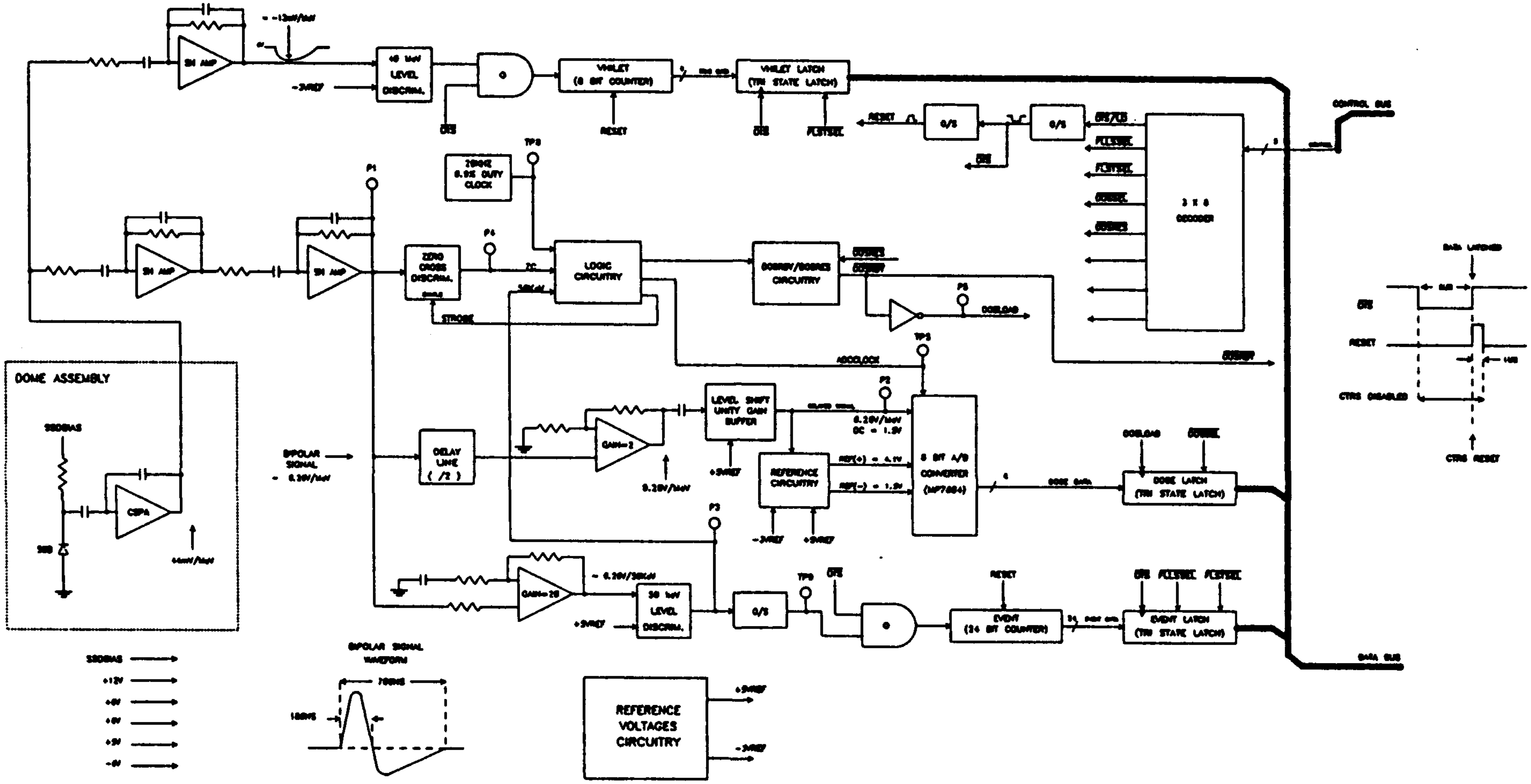

Figure 10. CHARGE SENSITIVE PREAMPLIFIER AND ANALOG SIGNAL PROCESSOR BLOCK DIAGRAM

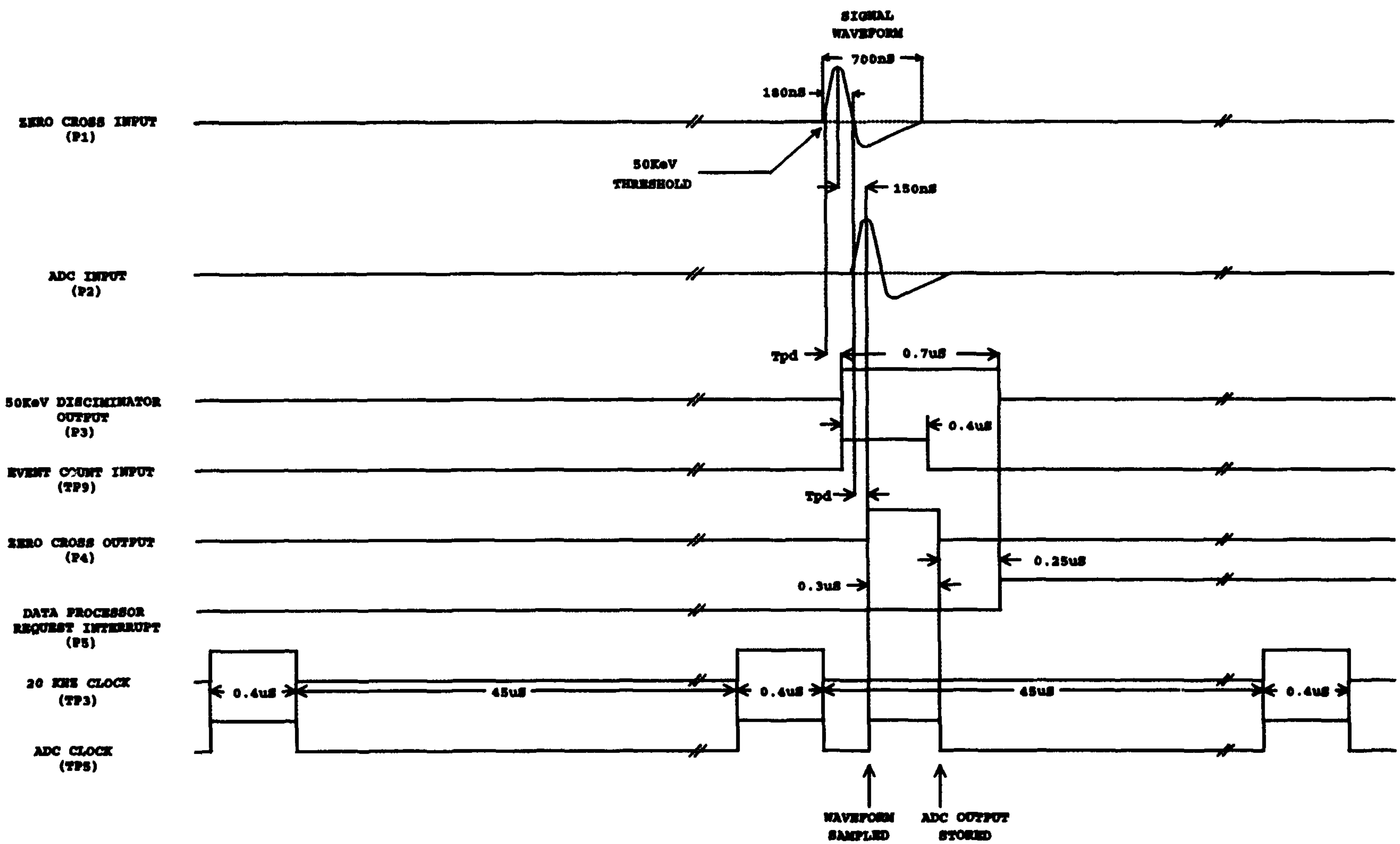

Figure 11. ANALOG SIGNAL PROCESSING TIMING DIAGRAM

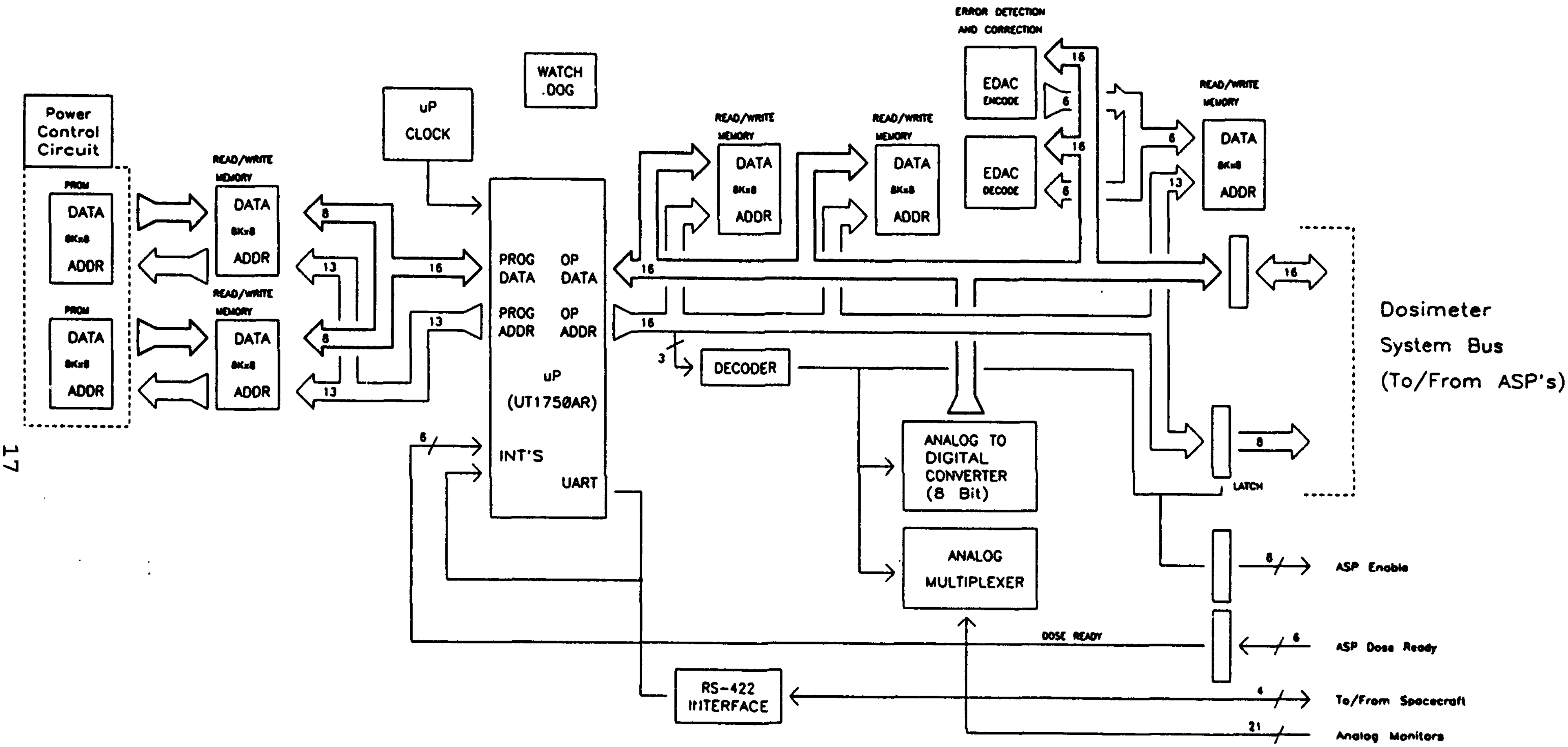

Figure 12. DATA PROCESSOR BLOCK DIAGRAM

A 24 MHz crystal-controlled oscillator is divided by 2 to provide a 12 MHz clock (uP CLOCK) to the microprocessor. There are 8K (8192 16-bit words) of program rad-hard bipolar programmable read only memory (PROGRAM PROM) and 8K (8192 16-bit words) of program low-power CMOS read/write memory (PROGRAM RAM). Program execution may be from either PROGRAM PROM or PROGRAM RAM, as selected by ground command. In normal operation PROGRAM PROM is loaded into PROGRAM RAM, and PROGRAM PROM is powered off to reduce power consumption (program execution is out of PROGRAM RAM). Program changes may be uplinked by ground command. There are also 8K (8192 16-bit words) of data read/write memory (DATA RAM). PROGRAM RAM and DATA RAM are single-event-upset immune. Error Detection and Correction (EDAC) corrects all single bit DATA RAM errors. Uncorrectable multi-bit DATA RAM errors are reported in the telemetered data. The EDAC is enabled/disabled by ground command.

ASP data collection and control are provided via the system data/address bus. The UART provides the spacecraft command/data communications link, via an EIA RS-422 balanced electrical interface. Twenty one (21) critical analog monitors are digitized and incorporated in the telemetered data. A watchdog circuit provides positive indication of proper program execution.

The software flowcharts are shown in Figures 13, 14 and 15. The power-up sequence and the program executive (the main microprocessor loop) are shown in Figure 13. Following the power-up sequence, telemetry output and various housekeeping tasks are handled in the main loop, which runs in the background. Each of the six ASP's, as well as the serial command/data interface, are handled via fast polling loops and interrupt latches.

The ASP processing flow chart is shown in Figure 14. If a detector is struck by an incident particle that deposits more than 50 keV in the detector, an interrupt flag is latched. The resulting dose is read by the microprocessor and various counters are incremented appropriately. Eight (8) data entities, as shown in Table 3, are generated for each detector.

The serial-input processing flow chart is shown in Figure 15. An interrupt flag is latched whenever a command is received from the spacecraft. Of the several commands that have been defined, as shown in Table 4, only the first two (the telemetry packet request commands) are addressed in Figure 15. Under normal conditions, telemetry packet request commands are to be received from the spacecraft at a fixed rate of once per second. Housekeeping

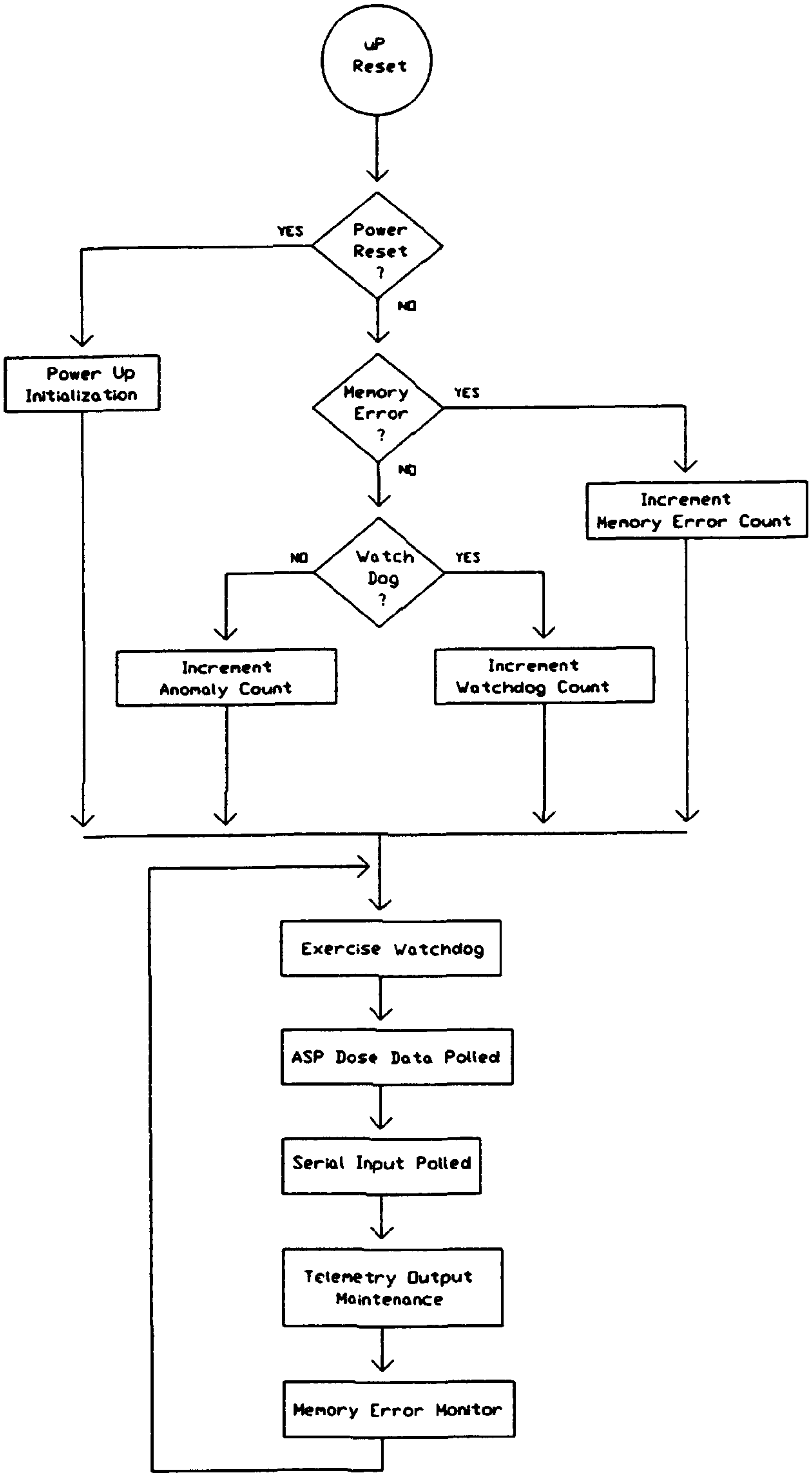

Figure 13. POWER UP AND PROGRAM EXECUTIVE SOFTWARE FLOW CHART

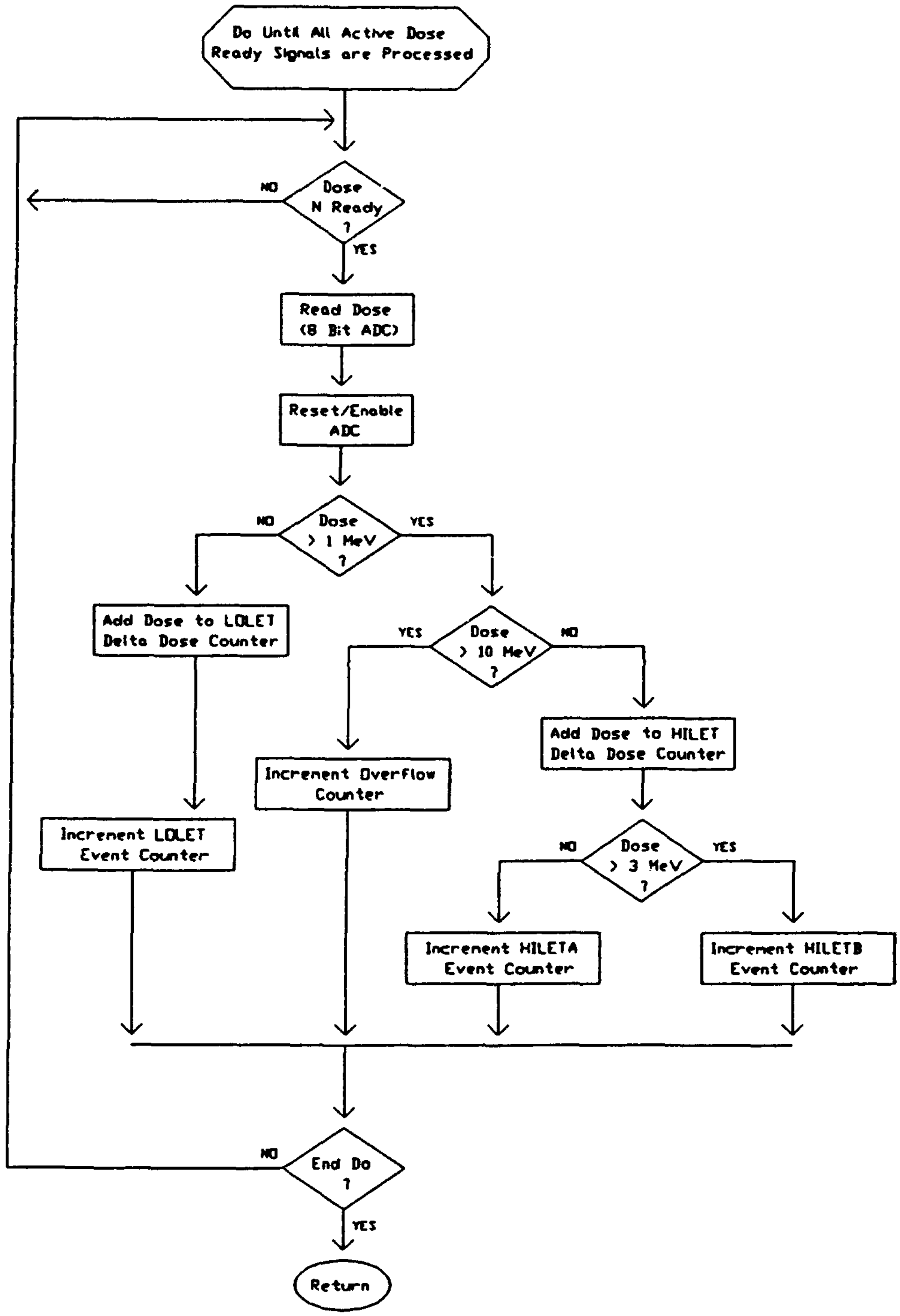

Figure 14. ASP PROCESSING SOFTWARE FLOW CHART

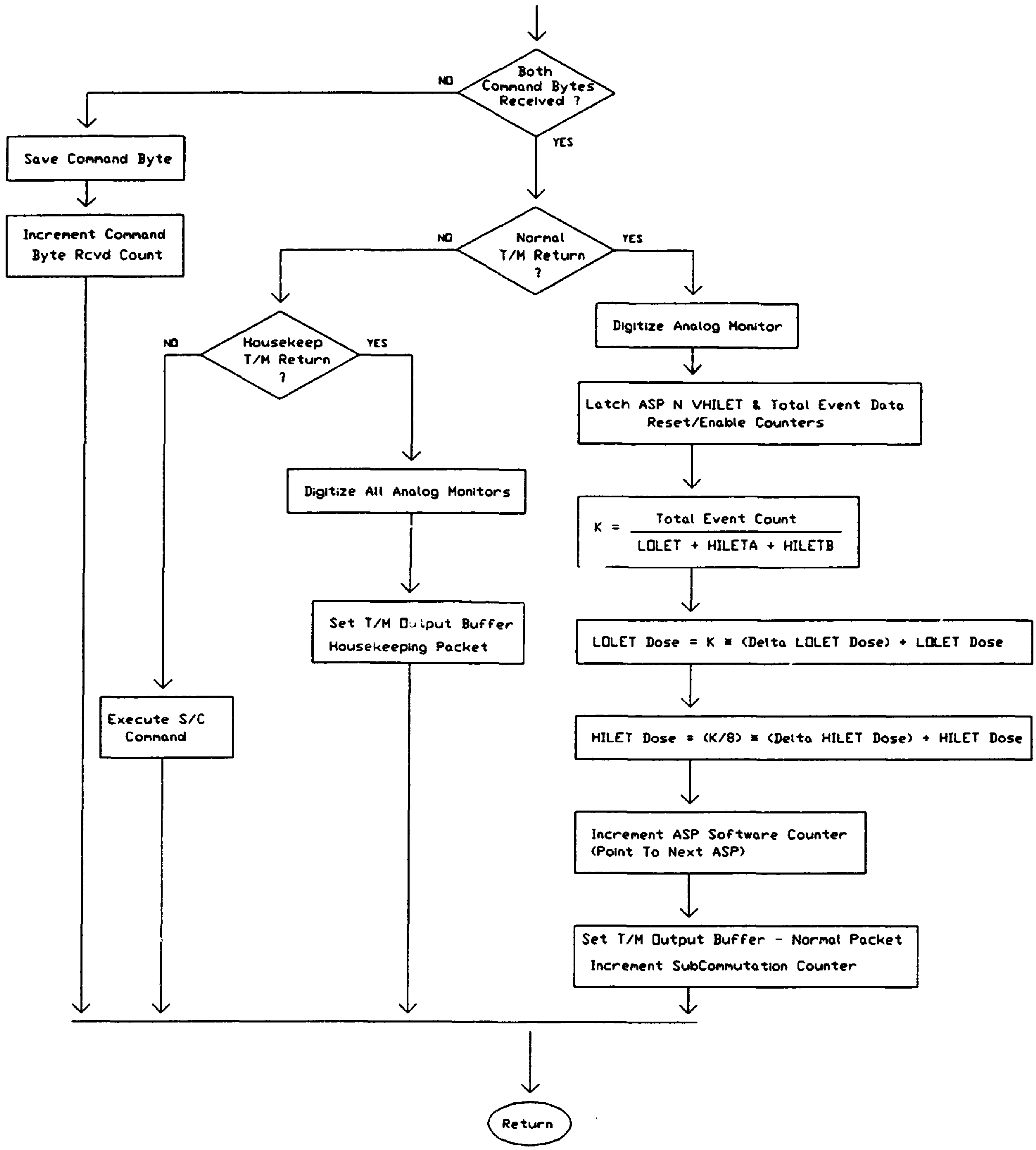

Figure 15. SERIAL COMMAND/DATA SOFTWARE FLOW CHART

Table 3. PRIMARY SCIENCE DATA ENTITIES	
Entity	Mnemonic
Processed 50 keV to 1 MeV Event Count	LOLET COUNT
Processed 1 MeV to 3 Mev Event Count	HILETA COUNT
Processed 3 Mev to 10 MeV Event Count	HILETB COUNT
Processed Digital to Analog Converter Overflow Event Count (≥ 10 MeV)	OVERFLOW COUNT
Very High Energy Deposition Event Count (≥ 40 MeV for D1A, D1B, D2A, D2B and D3) (≥ 75 MeV for D4)	VHILET COUNT
Total Event Count (≥50 keV)	TOTAL COUNT
50 keV to 1 MeV Dose	LOLET DOSE
1 MeV to 10 MeV Dose	HILET DOSE

Table 4.
DOSIMETER COMMANDS

Second Byte MSB LSB 8 7 6 5 4 3 2 1	First Byte MSB LSB 8 7 6 5 4 3 2 1	Action/Response/Comments
0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0	Return normal telemetry packet Note - This command must be sent at 1 second ± 0.01 second intervals for normal Dosimeter operation
0 0 1 0 0 0 0 0	0 0 0 0 0 0 0 0	Return housekeeping telemetry packet
0 1 0 0 0 0 0 0	0 0 0 0 0 0 0 0	Reset dose counters
0 1 0 0 0 0 1 1	0 0 0 0 0 0 0 0	Enable data memory EDAC
0 1 0 0 0 1 0 0	0 0 0 0 0 0 0 0	Disable data memory EDAC
0 1 0 0 0 1 0 1	0 0 0 0 0 0 0 0	Reset fault flags
0 1 0 0 0 1 1 0	0 0 0 0 0 0 0 0	Test watchdog
0 1 1 A A A A A	A A A A A A A A	Power down PROM and run out of RAM (AA...A = 13 bit starting address)
1 0 0 A A A A A	A A A A A A A A	Power up PROM and run out of PROM (AA...A = 13 bit starting address)
1 0 1 C C C C C 1 1 0 A A A A A 1 1 1 0 0 0 0 0 . . . . 1 1 1 0 0 0 0 0	C C C C C C C C A A A A A A A A D D D D D D D D . . . . D D D D D D D D	Upload block of data to Dosimeter RAM (CC...C = 13 bit data byte count) (AA...A = 13 bit starting address) (DD...D = 8 bit data byte) Program data must be sent in byte pairs with the least significant byte sent first, followed by the most significant byte

Bit 8 is the Most Significant Bit (MSB)
Bit 1 is the Least Significant Bit (LSB)
LSB (Bit 1) is the first bit shifted out

telemetry packets, as defined in Table 5, will be used extensively to verify proper instrument operation at initial turn-on. They will also be used, to a lesser extent, to verify proper operation at all subsequent turn-ons. Once proper Dosimeter operation is established, normal data packets, as defined in Tables 6 and 7, are used to transfer all primary science data (PSD) and some housekeeping data to the spacecraft. Note that the PSD is time multiplexed. The PSD for one detector is transferred to the spacecraft in each normal data packet. Thus six (6) data packets (6 seconds) are required to read all of the PSD, and each detector's PSD is accumulated for six (6) seconds. The normal telemetry packet data accumulation and transfer timing is shown in Figure 16.

2.2.3 DC to DC Converter

A block diagram of the DC to DC Converter is shown in Figure 17. The input bus filter attenuates bus transients and ripple. The high efficiency (~89%) switching regulator generates five (5) output voltages (+12 +8, +6, +5 and -6 volts). Feedback from the +5V output provides line and load regulation for that output, and line regulation for the remaining outputs. Post regulators generate two (2) well regulated output voltages (+8VREF and +5VREF). A Cockroft-Walton voltage multiplier generates an unregulated +300V which is applied to six (6) high-voltage regulators, which provide regulated bias voltages for the solid-state detectors. Analog monitors for all output voltages (13 total) are subcommutated in the telemetered data. Secondary return (signal ground) is isolated from primary return (+28V return). Input current is limited to 150% of the worst case nominal input current. Two (2) temperature monitors are provided, one unconditioned (passive) the other conditioned (active). The passive temperature monitor is read directly by the spacecraft, allowing the Dosimeter's temperature to be determined whether the Dosimeter power is on or off. The active temperature monitor is subcommutated in the telemetered data.

Table 5.
HOUSEKEEPING TELEMETRY PACKET DATA ASSIGNMENT

Byte No.	Bits	Contents
1	0-7	Frame ID, MSB (Bit 7) = 1 identifies housekeeping packet
2	0-7	D1A Detector Bias Voltage Monitor
3	0-7	D1B Detector Bias Voltage Monitor
4	0-7	D2A Detector Bias Voltage Monitor
5	0-7	D2B Detector Bias Voltage Monitor
6	0-7	D3 Detector Bias Voltage Monitor
7	0-7	D4 Detector Bias Voltage Monitor
8	0-7	D1A Reference Voltage Monitor
9	0-7	D1B Reference Voltage Monitor
10	0-7	D2A Reference Voltage Monitor
11	0-7	D2B Reference Voltage Monitor
12	0-7	D3 Reference Voltage Monitor
13	0-7	D4 Reference Voltage Monitor
14	0-7	+12V Monitor
15	0-7	+8V Monitor
16	0-7	+6V Monitor
17	0-7	+5V Monitor
18	0-7	+5V Reference Monitor
19	0-7	-6V Monitor
20	0-7	Regulated +8V Monitor
21	0-7	Detector Temperature Monitor
22	0-7	Electronics Temperature Monitor
23	0-3	Watchdog Count
23	4-7	Program Memory Fault Count
24	0-3	Data Memory Single Bit Fault Count
24	4-7	Data Memory Multiple Bit Fault Count

LSB (Bit 0) is the first bit shifted out
Byte 1 is the first byte shifted out

Table 5 (continued). HOUSEKEEPING TELEMETRY PACKET DATA ASSIGNMENT

Byte No.	Bits	Contents
25	0	Data EDAC Memory Enable Flag (Active Lo) (0 = EDAC Memory Enabled, 1 = EDAC Memory Disabled)
25	1	Data EDAC Enable Flag (0 = EDAC Disabled, 1 = EDAC Enabled)
25	2	Program Memory ID (0=PROM, 1=RAM)
25	3	Spare
25	4	PROM Power On Flag
25	5-7	Spare
26	0-7	Last Command Most Significant Byte (Data Byte)
27	0-7	Last Command Least Significant Byte (Command Byte)
28	0	Program RAM Fault Flag
28	1	Serial Input Fault
28	2	Data Memory Single Bit Fault Flag
28	3	Data Memory Multiple Bit Fault Flag
28	4	Program Anomaly Fault
28	5	Data Memory EDAC Fault Flag
28	6	Watchdog Test Fault Flag
28	7	Watchdog Bite Flag
29	0-7	First Program Memory Error Least Significant Address Bits
30	0-4	First Program Memory Error Most Significant Address Bits
30	5-7	Number of Program Memory Errors Detected
31	0-7	First Data Memory Error Least Significant Address Bits
32	0-4	First Data Memory Error Most Significant Address Bits
32	5-7	Number of Data Memory Errors Detected
33	0-7	Telemetry Packet Checksum, Most Significant Byte
34	0-7	Telemetry Packet Checksum, Least Significant Byte

LSB (Bit 0) is the first bit shifted out
Byte 1 is the first byte shifted out

Table 6.
NORMAL TELEMETRY PACKET DATA ASSIGNMENT

Byte No.	Contents	Description
1	FRAME ID	MSB (Bit 7) = 0 identifies NORMAL telemetry packet Primary Science Data (PSD) Channel Identifier (= 0, 6, 12, 18 for D1A PSD data readout) (= 1, 7, 13, 19 for D1B PSD data readout) (= 2, 8, 14, 20 for D2A PSD data readout) (= 3, 9, 15, 21 for D2B PSD data readout) (= 4, 10, 16, 22 for D3 PSD data readout) (= 5, 11, 17, 23 for D4 PSD data readout) Also, Housekeeping Subcommutator Frame Identifier (see Table 7)
2	VHILET COUNT	PSD Very High Energy Deposition Event Count
3-5*	TOTAL COUNT	PSD Total Event Count (≥ 50 keV)
6-8*	LOLET COUNT	PSD Processed 50 keV to 1 MeV Event Count
9-11*	HILETA COUNT	PSD Processed 1 MeV to 3 Mev Event Count
12-14*	HILETB COUNT	PSD Processed 3 MeV to 10 MeV Event Count
15-19*	LOLET DOSE	PSD 50 keV to 1 MeV Dose
20-24*	HILET DOSE	PSD 1 MeV to 10 MeV Dose
25-26*	OVERFLOW COUNT	PSD A to D Converter Overflow Count (≥ 10 MeV)
27	COMMAND MSB	Last Command MSB (Data Byte)
28	COMMAND LSB	Last Command LSB (Command Byte)
29	FAULT FLAGS	Bit 0 = Program RAM Fault Flag Bit 1 = Serial Input Fault Flag Bit 2 = Data Memory Single Bit Fault Flag Bit 3 = Data Memory Multiple Bit Fault Flag Bit 4 = Program Anomaly Flag Bit 5 = Data Memory EDAC Fault Flag Bit 6 = Watchdog Test Fault Flag Bit 7 = Watchdog Bite Flag
30	PRG CKSUM MSB	Program Checksum, Most Significant Byte
31	PRG CKSUM LSB	Program Checksum, Least Significant Byte
32	HOUSEKEEPING	Subcommutated Housekeeping Data (see Table 7)
33	TM CKSUM MSB	Telemetry Packet Checksum, Most Significant Byte
34	TM CKSUM LSB	Telemetry Packet Checksum, Least Significant Byte

LSB (Bit 0) is the first bit shifted out
Byte 1 is the first byte shifted out
* First byte shifted out (low numbered byte) is the least significant byte

Table 7.
NORMAL TELEMETRY PACKET SUBCOMMUTATED DATA ASSIGNMENT

Frame ID (Byte 1 of Normal Telemetry Packet)	Bits	Housekeeping Data (Byte 32 of Normal Telemetry Packet)
0	0-7	D1A Detector Bias Voltage Monitor
1	0-7	D1B Detector Bias Voltage Monitor
2	0-7	D2A Detector Bias Voltage Monitor
3	0-7	D2B Detector Bias Voltage Monitor
4	0-7	D3 Detector Bias Voltage Monitor
5	0-7	D4 Detector Bias Voltage Monitor
6	0-7	D1A Reference Voltage Monitor
7	0-7	D1B Reference Voltage Monitor
8	0-7	D2A Reference Voltage Monitor
9	0-7	D2B Reference Voltage Monitor
10	0-7	D3 Reference Voltage Monitor
11	0-7	D4 Reference Voltage Monitor
12	0-7	+12V Monitor
13	0-7	+8V Monitor
14	0-7	+6V Monitor
15	0-7	+5V Monitor
16	0-7	+5V Reference Monitor
17	0-7	-6V Monitor
18	0-7	Regulated +8V Monitor
19	0-7	Detector Temperature Monitor
20	0-7	Electronics Temperature Monitor
21	0-3	Watchdog Count
21	4-7	Program Memory Fault Count
22	0-3	Data Memory Single Bit Fault Count
22	4-7	Data Memory Multiple Bit Fault Count
23	0	Data EDAC Memory Enable Flag (Active Lo)
23	1	Data EDAC Enable Flag
23	2	Program Memory ID, 0=PROM, 1=RAM
23	3	Spare
23	4	PROM Power On Flag
23	5	Spare
23	6	Spare
23	7	Spare
LSB (Bit 0) is the first bit shifted out		

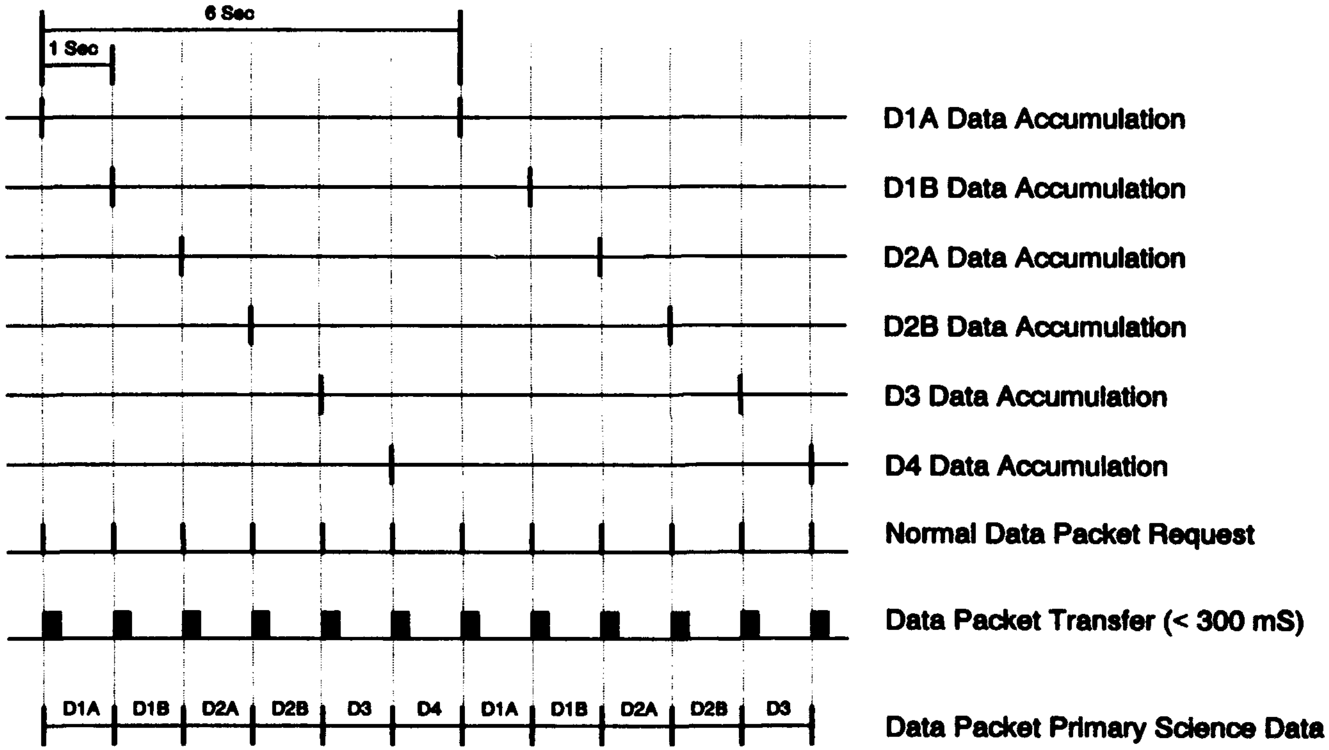

Figure 16. NORMAL TELEMETRY PACKET DATA ACCUMULATION AND TRANSFER TIMING

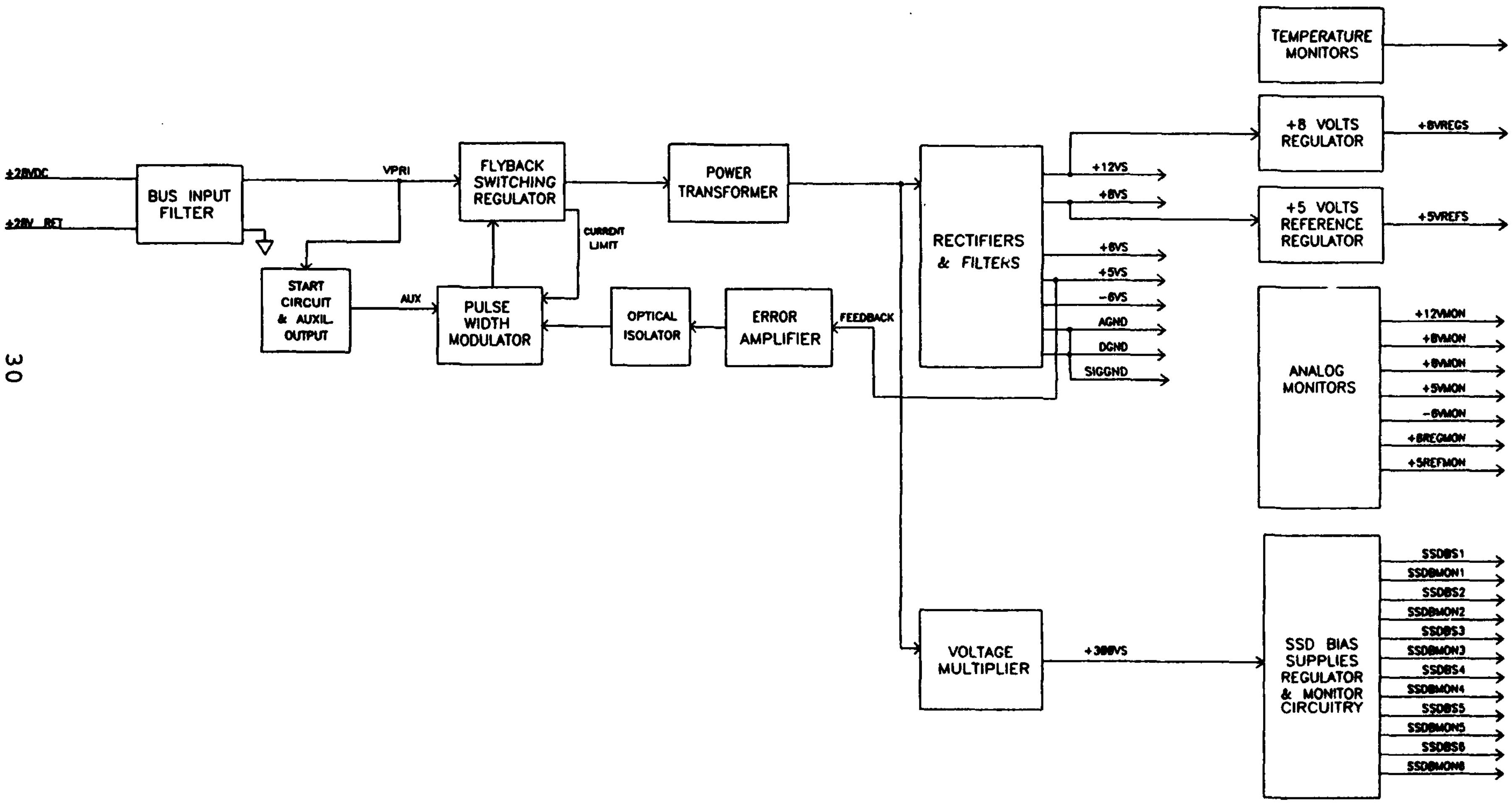

Figure 17. DC TO DC CONVERTER BLOCK DIAGRAM

2.3 Detailed Electrical Design

2.3.1 Charge-Sensitive Pre-Amplifier and Analog Signal Processor

The charge-sensitive pre-amplifier (CSPA) design is essentially identical to an existing Panametrics design and is therefore complete. The design of the analog signal processor (ASP) has been completed, and schematic drawings have been generated. A breadboard of the CSPA and ASP circuitry has been fabricated and tested. Extensive tests at room ambient temperature and over the temperature range of -55°C to +100°C have been completed. The CSPA/ASP operates properly over this extended temperature range, and its stability over the anticipated Dosimeter operating temperature range (-25°C to +35°C) is well within that required for accurate dose measurements. CSPA printed circuit board layout has been completed, and flight boards have been ordered and received.

Analog Signal Processor printed circuit board layout has also been completed. Since 12 (total for 2 Dosimeters) of these boards are required, a single "engineering model" printed circuit board was fabricated and tested thoroughly. Some minor modifications were incorporated into the printed circuit layout following completion of the "engineering model" printed circuit board tests. Flight ASP printed circuit boards have been ordered and received.

2.3.2 Data Processor

A preliminary Data Processor design, based on an 80C86 microprocessor, was completed, and schematic drawings were generated. A breadboard was also fabricated. Harris Semiconductor, the 80C86 vendor, had assured us that radiation-hardened, single-event-upset immune 80C86's would be available. However, just as the breadboard was completed, we were informed that the 80C86 microprocessor, although radiation-hardened, is quite susceptible to single-event-upsets. Therefore, the 80C86 based design was abandoned.

A new Data Processor design, based on the United Technology's 1750A microprocessor, was then undertaken. The 1750A is available radiation-hardened, and is single-event-upset immune. It is a 16-bit, Harvard Architecture, Reduced Instruction Set Computer (RISC), which can run at speeds of up to 12 MHz. It includes an on-board Universal Asynchronous Receiver/Transmitter (UART) and two timers. The ASP data throughput rate will be significantly higher with the 1750A than it would have been with the 80C86.

Data Processor design, based on the United Technology's 1750A microprocessor, has been completed. Rather than fabricating and testing a "conventional" breadboard of this circuitry, an initial printed circuit board layout was completed, and a "breadboard" printed circuit board was fabricated. Testing of the "breadboard" printed circuit board has been completed, and the printed circuit board layout has been modified as required. Flight printed circuit boards have been ordered and received.

2.3.3 DC to DC Converter

The DC to DC Converter design has been completed, and schematic drawings have been generated. A breadboard has been fabricated and tested. Extensive tests at room ambient temperature, and over the temperature range of -55°C to +125°C, have been completed. The DC to DC Converter operates properly over this extended temperature range.

DC to DC Converter printed circuit board layout has been completed. Flight printed circuit boards have been ordered and received.

2.3.4 Motherboard

The other printed circuit boards plug into the motherboard, which provides the interboard connections. Motherboard printed circuit board layout has been completed. Flight printed circuit boards have been ordered and received.

2.4 Detailed Mechanical Design

The detailed mechanical design has been completed. All machined parts have been ordered and received.

2.5 Software Development

Flight software and ground support equipment software development have been completed.

2.6 Protoflight Dosimeter

Assembly and testing of all Protoflight Dosimeter printed circuit boards has been completed.

Assembly and wiring, functional testing, calibration, and qualification testing of the Protoflight Dosimeter have been completed. Qualification testing consisted of the following:

Baseline Comprehensive Performance Test
Electromagnetic Compatibility Tests
Post EMI Comprepreheensive Performance Test
3-Axis Random Vibration
Post Random Vibration Comprehensive Performance Test
Thermal Vacuum Test
Final Comphehensive Performance Test

The Electromagnetic Compatibility Tests, Random Vibration Test Levels, and Thermal Vacuum Test Profile are defined in Table 8, Table 9, and Figure 18, respectively.

The Protoflight Dosimeter has been delivered to Orbital Sciences Corporation for integration into the payload of the Advanced Photovoltaic and Electronic Experiments (APEX) satellite, as part of the Photovoltaic Array Space Power Plus Diagnostics (PASP Plus) experiment.

2.7 Backup Dosimeter

Backup Dosimeter printed circuit board fabrication has been completed. Printed circuit board testing is nearly complete. The status of this work is shown in Table 10. Backup Dosimeter assembly and wiring is also complete. Backup Dosimeter functional testing is in process.

3. SUMMARY

A second generation Dosimeter has been designed to fulfill the need for accurate radiation dose measurements. Two identical Dosimeters, a protoflight unit and a backup unit, are being fabricated, tested and calibrated. The protoflight Dosimeter is to be integrated into the payload of the Advanced Photovoltaic and Electronic Experiments (APEX) satellite, as part of the Photovoltaic Array Space Power Plus Diagnostics (PASP Plus) experiment. A summary of the second-generation Dosimeter's characteristics is given in Table 11.

Table 8.
Protoflight Dosimeter EMI Tests

Test	Test Method
Radiated Emissions, Magnetic Field, 0.03 to 50 kHz	RE01
Radiated Emissions, Electric Field, 0.014 to 10,000 MHz	RE02
Radiated Susceptibility, Magnetic Field, 0.03 to 50 kHz	RS01
Radiated Susceptibility, Magnetic and Electric Fields, Spikes and Power Frequencies	RS02
Radiated Susceptibility, Electric Field, 0.014 to 10,000 MHZ	RS03
Conducted Emissions, Power and Interconnecting Leads, 0.03 to 15 kHZ	CE01
Conducted Emissions, Power and Interconnecting Leads, 0.015 to 50 MHZ	CE02
Conducted Emissions, Power Leads, Spikes, Time Domain	CE07
Conducted Susceptibility, Power Leads, 0.03 to 50 kHz	CS01
Conducted Susceptibility, Power Leads, 0.05 to 400 MHz	CS02
Conducted Susceptibility, Spikes, Power Leads	CS06

Table 9.
Protoflight Dosimeter Random Vibration Levels

Frequency Range	Level
20 to 50 Hz	+6 dB/Octave
50 to 1000 Hz	0.025 g^2/Hz
1000 to 2000 Hz	-6 dB/Octave
Composite Level = 6.10 g RMS Duration = One Minute Per Axis	

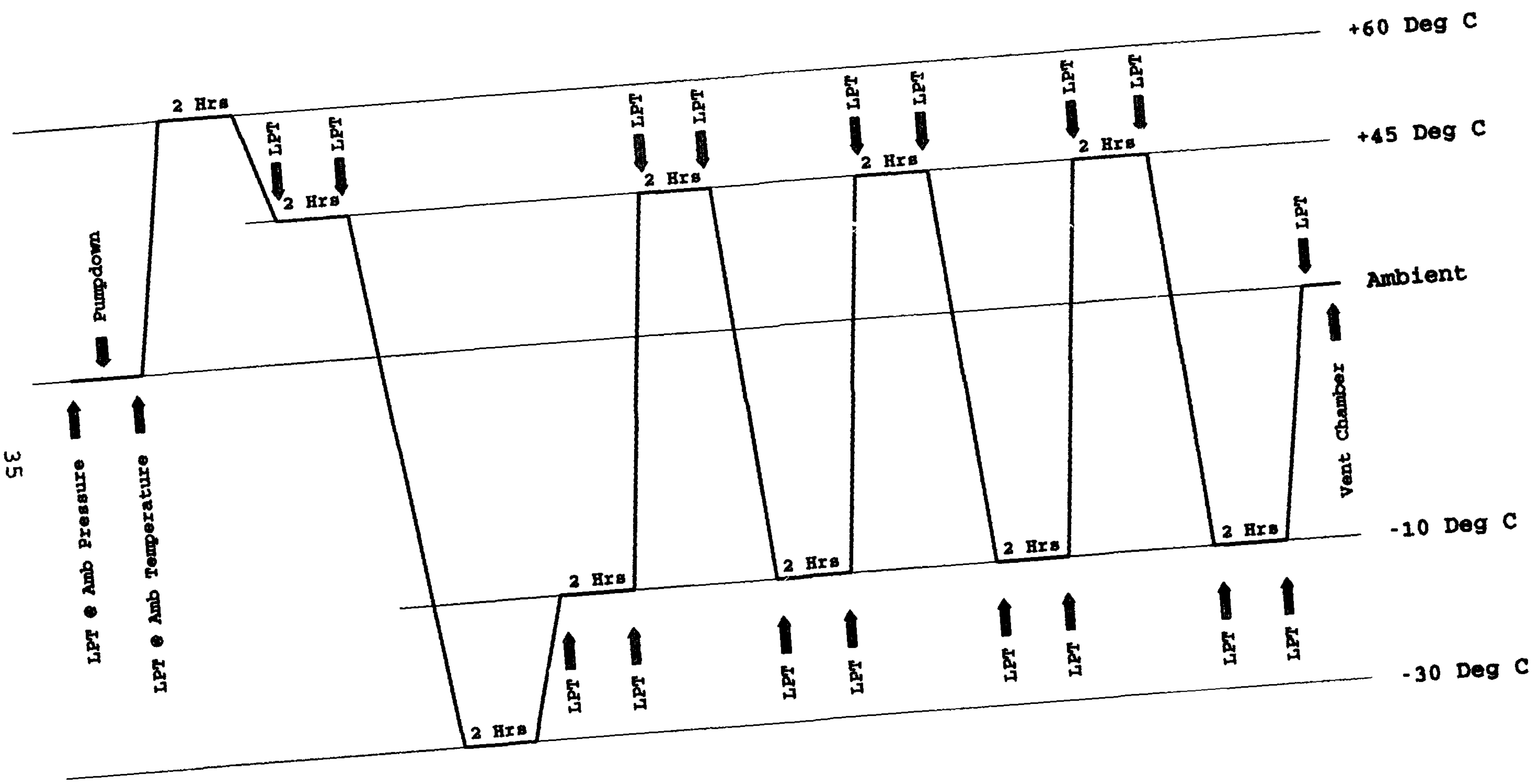

Figure 18. PROTOFLIGHT DOSIMETER THERMAL VACUUM TEST PROFILE

Table 10. Backup Dosimeter Printed Circuit Board Status		
Printed Circuit Board	Number Required	Status
Charge Sensitive Preamplifier	1	Fabrication and Testing Completed
Analog Signal Processor	6	Fabrication and Testing of 5 Completed
Data Processor	1	Fabrication and Testing Completed
DC to DC Converter	1	Fabrication and Testing Completed
Miscellaneous Circuitry	1	Fabrication and Testing Completed
Motherboard	1	Fabrication Completed Testing in Process

Table 11.
SUMMARY OF DOSIMETER CHARACTERISTICS

Sensors	6 planar silicon solid-state detectors (SSD's) under 4 aluminum shields
Field of View	2π steradians
Data Fields	For each channel (SSD) counts in 6 deposited energy ranges, and the dose for 2 deposited energy ranges. LOLET counts (0.050 - 1 MeV) HILETA counts (1 - 3 MeV) HILETB counts (3 - 10 MeV) OVERFLOW counts (> 10 MeV) VHILET counts (> 40 or 75 MeV) TOTAL counts (> 0.050 MeV) LOLET dose (0.050 - 1 MeV) HILET dose (1 - 10 MeV)
Output Data Format	272 bits serial, read out as 34 bytes, once per second. A total of 6 readouts is required to obtain all 6 channels. A total of 24 readouts is required to sample all Housekeeping data.
Command Requirements	2-byte commands initiate telemetry packet transmission, reset dose counters, determine PROM/RAM configuration, and upload data to RAM.
Size	5.5" H x 8" W x 9" D plus maximum 3.5" extension in D for Domes, excluding connectors and mounting tabs.
Mass	13.0 lbs
Power	5.5 W Nominal, 8.5 W Maximum
Temperature Range	0°C to +35°C Nominal Operating -10°C to +45°C Maximum Operating -30°C to +60°C Non-Operating

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1. B. Sellers, R. Kelliher, F.A. Hanser, and P.R. Morel, "Design, Fabrication, Calibration, Testing and Satellite Integration of a Space-Radiation Dosimeter," report AFGL-TR-81-0354, AD A113085 (December 1981). Final Report for Contract No. F19628-78-C-0247.

2. P.R. Morel, F.A. Hanser, B. Sellers, J. L. Hunerwadel, R. Cohen, B. Kane and B. Dichter, "Fabricate, Calibrate and Test a Dosimeter for Integration into the CRRES Satellite," Report GL-TR-89-0152, ADA213812 (April 1989). Final Report for Contract No. F19628-82-C-0090.