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DESCRIPTION OF THE SPACE TEST PROGRAM P78-2 SPACECRAFT AND PAYL--ETC(U)
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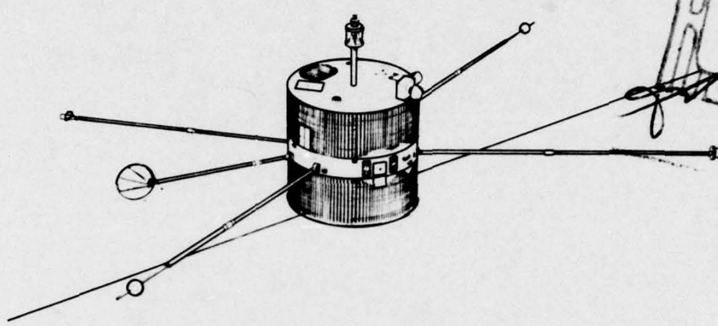

31 October 1978

SPACE AND MISSILE SYSTEMS ORGANIZATION

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The SAMSO Space Test Program is acquiring the P78-2 spacecraft from the Martin Marietta Company. Data from the payloads on board the P78-2 spacecraft will be used to help understand the phenomena of spacecraft charging. The payloads include particle and electromagnetic field monitors as well as contamination monitors and transient detectors. The report describes the general spacecraft charging program and how the P78-2 spacecraft contributes to the general program. An overview of the spacecraft and payloads is presented.

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Description of the Space Test Program P78-2 Spacecraft and Payloads

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31 October 1978

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1. INTRODUCTION

1.1 BACKGROUND

During the early 1970s evidence was obtained relating anomalous space vehicle behavior to the effects of spacecraft charging by the magnetospheric plasmas. Malfunctions and system interruptions have been attributed to noise pulses generated by arcing between differentially charged members on the spacecraft. The effects are most predominant near geosynchronous altitude during periods of enhanced geomagnetic substorm activity. Measurements onboard ATS-5 have indicated that the satellite occasionally became charged to negative potentials in the multikilovolt range. Through a statistical study of spacecraft anomalies and ground observatory data, a link was established between magnetic substorm conditions and space vehicle anomalies. Laboratory tests demonstrated that the electromagnetic pulse from an electrical discharge on an insulator could be coupled into a spacecraft telemetry harness. Additional studies have concluded that differential charging of satellite surfaces occurs, have demonstrated that discharges between differentially charged marterials results in degradation of thermal control material and properties, and have suggested that electrostatic forces may produce enhanced contamination.

In order to solve this spacecraft charging problem, a cooperative NASA/AF program was initiated in 1975. Since spacecraft charging has influenced the performance of military, commercial, and NASA satellites, it was a logical candidate for a joint program. Figure 1.1 presents the key elements in the program. The figure reflects true interdependency; each activity has been assigned to either NASA or USAF, and program success requires extensive efforts from both organizations

The objective of the spacecraft charging investigation is to provide the design criteria, materials, techniques, test and analytical methods to ensure control of the absolute and differential charging of spacecraft surfaces. This objective is being met by conducting a combined flight test and ground technology program. There has been considerable interaction among the various elements of this program. The Space Test Program P78-2 spaceflight program is shown in Figure 1.1 to be central to this interaction and vital to support the achievement of program goals, these include:

- Updates of Military Standards for EMI susceptibility
- The Design Guidelines Monograph (catalogues, criteria, and procedures for minimizing charging effects)
- Validated Analytical Models (tools to analyze space vehicle design susceptibilities)

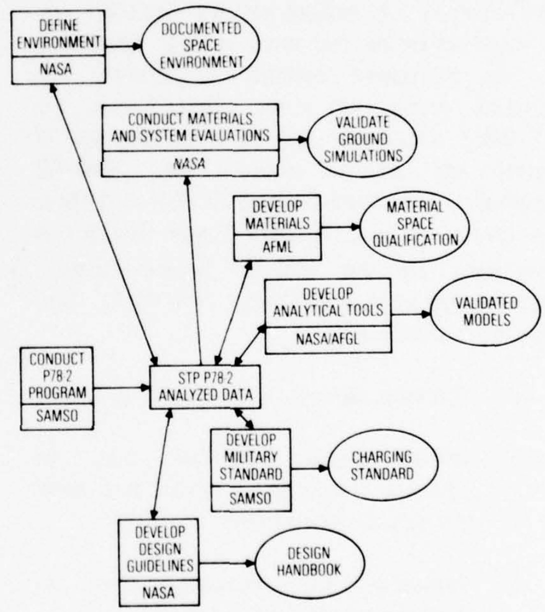


Figure 1.1. Cooperative NASA/AF Spacecraft Charging Investigation

A baseline document for the Design Guidelines Monograph has been produced during the past year and will soon be available for review by the community. The document presently uses information obtained in all the elements of this investigation. It will be upgraded and made final

AFTER THE INCORPORATION OF DATA FROM THE P78-2 SPACEFLIGHT.

1.2 P78-2 SPACEFLIGHT MISSION OBJECTIVES

THE PRIMARY P78-2 MISSION OBJECTIVE IS TO OBTAIN INFORMATION FOR A MILITARY STANDARD CONCERNING SPACECRAFT CHARGING. THE DATA OBTAINED FROM THIS SATELLITE IS KEY TO DEFINING THE EMI/RFI THAT IS ENCOUNTERED AT SYNCHRONOUS ALTITUDE. IN ORDER TO DESIGN SPACECRAFT THAT ARE IMMUNE TO THE VARIOUS EFFECTS CAUSED BY DIFFERENTIAL CHARGING, ONE MUST NOT ONLY UNDERSTAND THE PHENOMENA, BUT ALSO BE ABLE TO TEST NEW SPACE VEHICLES TO ENSURE THAT THEY ARE NOT SUSCEPTIBLE TO THE EFFECTS OF THE PHENOMENA. THE VALIDATION OF PROPOSED SYSTEM TESTS WILL BE BASED UPON THE RESULTS OBTAINED FROM THIS FLIGHT. THUS, THE P78-2 MISSION IS CENTRAL TO THE ACHIEVEMENT OF DESIRED END PRODUCTS IN THE NASA/AF PROGRAM. THE INFORMATION GENERATED CAN BE USED DIRECTLY BY PROGRAM OFFICES (MILITARY AND CIVILIAN) TO ENSURE THAT SPACE SYSTEMS, SURVIVABLE IN THE SPACECRAFT CHARGING ENVIRONMENT, ARE DESIGNED, TESTED, AND FLOWN. SPECIFICALLY, THE STP P78-2 SPACEFLIGHT MISSION OBJECTIVES ARE TO LAUNCH AND OPERATE ON-ORBIT THE SAMSO-402 EXPERIMENT, SPACECRAFT CHARGING AT HIGH ALTITUDES, THE OFFICE OF NAVAL RESEARCH PLASMA INTERACTION EXPERIMENT, AND THE AFML-902 THERMAL CONTROL/ CONTAMINATION AT HIGH ALTITUTDES EXPERIMENT. THIS INVOLVES RESPONSIBILITY TO:

o DETERMINE AND ANALYZE PAYLOAD REQUIREMENTS

o DESIGN, DEVELOP, FABARICATE, TEST, AND LAUNCH A SPACE VEHICLE SYSTEM THAT MEETS THE PAYLOAD REQUIREMENTS

o INTEGRATE THE PAYLOADS INTO AN OPERATIONAL SPACE VEHICLE SYSTEM

o OPERATE THE SPACE VEHICLE SYSTEM ON-ORBIT FOR AT LEAST ONE YEAR

o COLLECT AND DISTRIBUTE REQUIRED PAYLOAD DATA.

A PRIME OBJECTIVE OF THE ENGINEERING ANALYSES EFFORTS IS THE CHARACTERIZATION OF THE EMI ENVIRONMENT INTERNAL AND EXTERNAL TO THE SPACE VEHICLE. ELECTRICAL TRANSIENTS AND SPACECRAFT UPSETS WILL BE CAREFULLY STUDIED. THESE DATA WILL BE CORRELATED WITH SPACE PLASMA ENVIRONMENTAL CONDITIONS, SPACECRAFT LOCATION AND LOCAL TIME, AND GEOMAGNETIC INDICES. IN ADDITION, INVESTIGATIONS WILL BE PERFORMED RELATING THESE DATA TO THE ELECTRICAL POTENTIAL OF THE SPACECRAFT AND MATERIAL MONITORS. DIRECT MEASURMENTS OF SPACECRAFT AND SAMPLE MATERIAL POTENTIALS WILL BE MADE (INCLUDING THE POTENTIAL OF A SPACECRAFT "REFERENCE" BAND). CERTAIN EXPERIMENTS WILL ALSO BE CAPABLE OF INFERRING POTENTIAL MEASUREMENTS FROM SPECIFIC DATA. DISCHARGES MAY BE INDICATED THROUGH CAREFUL ANALYSIS OF THE POTENTIAL MEASUREMENTS. THE OBSERVATION OF DISCHARGES IN COINCIDENCE WITH ELECTRICAL UPSETS IS ESPECIALLY IMPORTANT. FOR THIS REASON, THE EXPOSED SPACE VEHICLE CONDUCTING AND NONCONDUCTING SURFACES HAVE BEEN CAREFULLY MAPPED TO PROVIDE INDICATIONS TO WHERE EXTERNAL DISCHARGES MAY OCCUR. A RELIABLE QUANTITATIVE MEASUREMENT OF THE ELECTRICAL TRANSIENTS AND SPACECRAFT POTENTIALS IS IMPORTANT TO PROVIDE STATISTICAL INPUTS INTO THE "MILITARY STANDARD" AND "DESIGN GUIDELINES" DOCUMENTS. CORRELATION OF THE DATA TO THE ENVIRONMENT WILL PROVIDE THE KEY TO PREDICTING ON-ORBIT BEHAVIOR FOR FUTURE SPACE SYSTEMS.

AS THE EXPECTED LIFETIME OF OPERATIONAL SPACECRAFT INCREASE (7 TO 10 YEARS IS NOT UNUSUAL), THE CONCERNS OVER THE LONG TERM DEGRADATIONS OF MATERIALS BECOME PRONOUNCED. IT HAS BEEN STATED THAT THE SPACECRAFT CHARGING PHENOMENON CAN DAMAGE EXPOSED SURFACE MATERIALS AND PROMOTE ENHANCED CONTAMINATION. EXPERIMENTS (SC1 AND ML12) ON THE P878-2 SPACECRAFT WILL PROVIDE QUALITATIVE DATA REGARDING THESE EFFECTS. RELATING THESE RESULTS TO SPACECRAFT DESIGN IS A CRUCIAL OUTPUT EXPECTED FROM THE ENGINEERING ANALYSES.

THE SATELLITE ELECTRON AND POSITIVE ION BEAM SYSTEMS ON THE P78-2 SPACECRAFT WILL PROVIDE EXPERIMENTAL TESTS OF ACTIVE CHARGE CONTROL OF THE SPACECRAFT POTENTIAL. THE PARTICLE BEAM SYSTEM DATA WILL BE CORRELATED TO ALL OF THE SPACECRAFT

POTENTIAL MEASUREMENTS AND TO THE MONITORED ELECTRICAL RESPONSES. THE SYSTEM WILL TEST THE POSSIBLE UTILITY OF CHARGE CONTROL DEVICES FOR OPERATIONAL SPACECRAFT.

DATA FROM THE P78-2 SPACECRAFT WILL BE APPLICABLE TO THE VALIDATIONS OF THE ANALYTICAL MODELS BEING DEVELOPED. THESE INCLUDE AN ENVIRONMENTAL MODEL, SHEATH/CHARGING MODELS, A DISCHARGE MODEL, AND EMI/COUPLING MODELS. THE ENVIRONMENTAL MODEL WILL DRAW UPON THE DATA OUTPUT FROM THE ASSORTMENT OF ELECTRON AND ION PARTICLE COUNTERS ON THE SPACECRAFT. THESE COVER AN ENERGY RANGE FROM ONE eV TO SEVERAL MILLION eV AS SHOWN IN TABLE 1.1. PARTICLES IN THE KILOELECTRON VOLT REGIME SEEM TO BE MOST IMPORTANT TO THE CHARGING PROBLEMS. THE REMAINING MODELS WILL BE VALIDATED USING CORRELATIONS OF DATA FROM SEVERAL EXPERIMENTS. THE PAYLOADS INVOLVED INCLUDE PARTICLE COUNTERS, ELECTRICAL POTENTIAL MONITORS, ELECTRICAL ANALYZERS, AND TRANSIENT DETECTORS. THE VALIDATED MODELS ARE AN IMPORTANT GOAL OF THE CHARGING INVESTIGATIONS AND THE P78-2 SPACECRAFT DATA ARE CRUCIAL TO ACHIEVING THAT GOAL. THE RESULTS CAN AGAIN BE DIRECTLY APPLIED AS INPUTS TO THE "EMC STANDARD" AND "DESIGN GUIDELINES MONOGRAPH."

Table 1.1. Particle Detector Characteristics

Species/ Number	Energy Min-Max	ΔE/E	Δt (sec)	Geometrical Factors (cm^2-sr)	Comments
Electrons					
SC6	1-100 eV		0.1	~0.4	
SC9	0.2 eV-1.55 keV	0.2	0.25, 0.04, or 0.0005	1.6×10^{-4}	Programmable Resolution
SC5	0.05-1.7 keV	0.8	0.2	10^{-4}	
SC2	6 eV-18 keV	0 07	0.1	1.7×10^{-4}	
SC9	1 eV-81 keV	0.2	0.25, 0.04, or 0.0005	1.6×10^{-4}	Programmable Resolution
SC5	1.7-60 keV	0.8	0.2	10^{-4}	
SC5	30-550 keV	0.4 to 1.3	0.1 or 0.2	3.5×10^{-3}	
SC3	0.05-5.1 MeV	0.1 to 1	0.5	3×10^{-3}	Programmable Resolution
SC3	5.1-10.0 MeV	Integral	0.5	3×10^{-3}	Programmable Resolution
Protons					
SC9	0.2 eV-1.55 keV	0.2	0.25, 0.04, or 0.0005	3.2×10^{-4}	Programmable Resolution
SC5	0.05-1.7 keV	0.8	0.2	10^{-2}	
SC2	5 eV-14 keV	0.1	0.1	6.7×10^{-4}	
SC9	1 eV-81 keV	0.2	0.25, 0.04, or 0.0005	3.2×10^{-4}	Programmable Resolution
SC5	1.7-60 keV	0.8	0.2	10^{-2}	
SC5	70-725 keV	0.5	0.1 or 0.2	2×10^{-2}	
SC2	17->3300 keV		1.0	2×10^{-3}	
SC5	0.725-35 MeV	0.5 to 0.9	0.1 or 0.2	2×10^{-2}	
SC3	1-200 MeV	0.003 to 0.3	0.5	3×10^{-3}	Programmable Resolution
Ions					
SC6	1-100 eV		0.1	~0.4	
SC7	1-100 eV	0.2	0.06	2×10^{-3}	H^+, $^4He^+$, $^{16}O^+$
SC8	0.1-32 keV	0.05	32	10^{-3}	Δm/m is mass dependent 1 - 160 AMU
SC2	≥90 keV/Nucleon	Integral	1.0 or 0.25	3.6×10^{-4}	
SC3	6-60 MeV	0.01 to 0.2	0.5	3×10^{-3}	Programmable Resolution

IN ADDITION, PARTICULAR PAYLOADS HAVE OBJECTIVES THAT EXTEND BEYOND THE SCOPE OF THE SPACECRAFT CHARGING INVESTIGATIONS. SPECIFICALLY, INVESTIGATIONS OF PLASMA INTERACTION PHENOMENA IS A GOAL OF THE ONR SPONSORED PAYLOADS. THE U. S. NAVY SUPPORTS SEVERAL PAYLOADS INCLUDING THE SC9 UCSD CHARGED PARTICLE EXPERIMENTS, THE SC8 ENERGETIC ION COMPOSITION EXPERIMENT, THE SC7 LIGHT ION MASS SPECTROMETER, AND THE SC3 HIGH ENERGY PARTICLE SPECTROMETER.

THESE OBJECTIVES INVOLVE THE COLLECTION OF SCIENTIFIC DATA OF PARTICULAR INTEREST TO EACH EXPERIMENT SPONSOR AND THE SCIENTIFIC COMMUNITY. KEY AREAS OF SCIENTIFIC INVESTIGATION INCLUDE MONITORING THE ENVIRONMENT, UNDERSTANDING PLASMA WAVES INTERACTIONS, AND DETERMINING HOW SPACECRAFT MATERIALS BEHAVE IN THE SPACE ENVIRONMENT. SPECIFIC OBJECTIVES OF EACH PAYLOAD ARE DISCUSSED FURTHER IN SECTIONS 3 THROUGH 19.

IN ORDER TO SUPPORT THESE VARIOUS OBJECTIVES, A TEAM OF HIGHLY QUALIFIED SCIENTISTS AND ENGINEERS HAS BEEN ASSEMBLED TO PROVIDE PAYLOADS FOR THE P78-2 SPACECRAFT. THE PRINCIPAL INVESTIGATORS ALONG WITH THEIR SPONSORS ARE IDENTIFIED IN TABLE 1.2. BECAUSE OF THE MULTITUDE OF POSSIBLE INTERACTIONS BETWEEN OTHERS IN THE SCIENTIFIC COMMUNITY AND THE PRINCIPAL INVESTIGATORS ON THE P78-2 SPACECRAFTS, THE SPACE TEST PROGRAM OFFICE ENCOURAGES INTERESTED INDIVIDUALS TO CONTACT KEY PAYLOAD PERSONNEL DIRECTLY. THE SPACE TEST PROGRAM INTENDS TO MAKE USE OF THE IMS NEWSLETTER AND MAILINGS TO THE GEOS CONSORTIUM TO FORMALLY ENCOURAGE COOPERATIVE EXPERIMENTATION.

Table 1.2. Principal Investigators/Sponsors

Experiment Number	Title	Principal Investigator/ Sponsor	Address
SC1	Engineering Experiments	Dr. H. C. Koons/ USAF/AFSC/SAMSO	The Aerospace Corporation P.O. Box 92957 Los Angeles, CA 90009
SC2	Spacecraft Sheath Electric Fields	Dr. J. F. Fennell/ USAF/AFSC/SAMSO	The Aerospace Corporation P.O. Box 92957 Los Angeles, CA 90009
SC3	High Energy Particle Spectrometer	Dr. J. B. Reagan Office of Naval Research	Lockheed Palo Alto Research Lab, 3251 Hanover Street Palo Alto, CA 94304
SC4	Satellite Electron and Positive Ion Beam System	Dr. H. A. Cohen/ USAF/AFSC	Hanscom AFB/LKB Bedford, MA 01731
SC5	Rapid Scan Particle Detector	Lt. D. Hardy/ USAF/AFSC	Hanscom AFB/PHE Bedford, MA 01731
SC6	Thermal Plasma Analyzer	Dr. R. C. Sagalyn/ USAF/AFSC	Hanscom AFB/PHR Bedford, MA 01731
SC7	Light Ion Mass Spectrometer	Dr. D. L. Reasoner/ Office of Naval Research	NASA Marshall Space Flight Center, Code BS-23 Huntsville, AL 35815
SC8	Energetic Ion Composition Experiment	Dr. R. G. Johnson/ Office of Naval Research	Lockheed Palo Alto Research Lab, 3251 Hanover Street Palo Alto, CA 94304
SC9	UCSD Charged Particle Experiment	Dr. S. E. Deforest/ Office of Naval Research/USAF/AFSC/ SAMSO	University of California B019 Dept. of Physics La Jolla, CA 92093
SC10	Electric Field Detector	Dr. T. L. Aggson/ Office of Naval Research	NASA Goddard Space Flight Center, Code 625 Greenbelt, MD 20771
SC11	Magnetic Field Monitor	Dr. B. G. Ledley/ Office of Naval Research	NASA Goddard Space Flight Center, Code 625 Greenbelt, MD 20771
ML12	Spacecraft Contamination	Dr. D. F. Hall/ USAF/AFSC/AFML	The Aerospace Corporation P.O. Box 92957 Los Angeles, CA 90009

2. P78-2 SPACECRAFT DESCRIPTION

2.1 INTRODUCTION

THE P78-2 SPACECRAFT IS SPIN-STABILIZED AND WILL BE PLACED IN A NEAR SYNCHRONOUS, NEAR EQUATORIAL EARTH ORBIT FROM THE EASTERN TEST RANGE BY A DELTA 2914 IN JANUARY 1979. THE SPACECRAFT HOUSES, PROTECTS, AND SUPPORTS SEVERAL SCIENTIFIC AND ENGINEERING PAYLOADS. IT SPINS ABOUT AN AXIS IN THE ORBIT PLANE AND NORMAL TO THE EARTH-SUN LINE. ON-ORBIT, THE SATELLITE WILL BE CONTROLLED BY THE AIR FORCE SATELLITE CONTROL FACILITY (AFSCF) AND WILL COMMUNICATE DIRECTLY WITH REMOTE TRACKING STATIONS IN NEW HAMPSHIRE, THE INDIAN OCEAN, GUAM, HAWAII, AND AT VANDENBERG AFB. THE MISSION IS PLANNED FOR A ONE-YEAR DURATION BUT THE SPACECRAFT IS PROVIDED WITH SUFFICIENT EXPENDABLES FOR TWO YEARS. ACTUAL LIFETIME OF THE SATELLITE WILL PROBABLY BE LIMITED BY SURVIVAL OF ELECTRONIC EQUIPMENT IN THE IONIZING RADIATION ENVIRONMENT.

2.2 SPACECRAFT CONFIGURATION

THE BODY OF THE SPACECRAFT HAS A CYLINDRICAL SHAPE APPROXIMATELY 1.75 M IN BOTH LENGTH AND DIAMETER. ON-ORBIT, SEVEN EXPERIMENT BOOMS ARE DEPLOYED. THE FINAL ON-ORBIT CONFIGURATION OF THE SPACECRAFT IS SHOWN IN FIGURE 2.1. BOOMS, ANTENNA HARDWARE, AND SOME INSTRUMENT PROTRUSIONS ALTER THE BASIC CYLINDRICAL GEOMETRY.

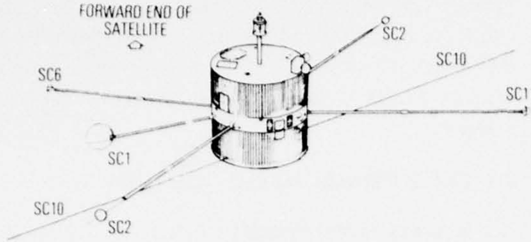


Figure 2.1. P78-2 Space Vehicle

MOST OF THE SPACECRAFT AND PAYLOAD EQUIPMENT IS MOUNTED IN THE CENTRAL (BELLYBAND) PORTION OF THE CYLINDER. FIGURE 2.2 SHOWS THE LOCATION OF INSTRUMENT APERTURES, TEST SURFACES, AND EXPERIMENT BOOMS IN THIS REGION. THE BOOM ARRANGEMENT ISOLATES SENSITIVE INSTRUMENTS FROM SPACE VEHICLE INFLUENCES AND PROVIDES CLEAR FIELDS OF VIEW (FOV) FOR EXPERIMENTS SENSITIVE TO LOW ENERGY PARTICLES OR CON- TAMINATION. THE BELLYBAND IS COVERED WITH ACCESS PANELS COATED TO MEET REQUIREMENTS OF THE EXPERIMENTS AND THERMAL CONTROL SUBSYSTEM. TWO SOLAR ARRAYS ENCIRCLE THE CYLINDER, ONE FORWARD AND ONE AFT OF THE BELLYBAND. THE APOGEE INSERTION MOTOR IS HOUSED IN A CENTRAL TUBE. A TRIPOD MOUNTED ON THE CENTRAL TUBE SUPPORTS THE

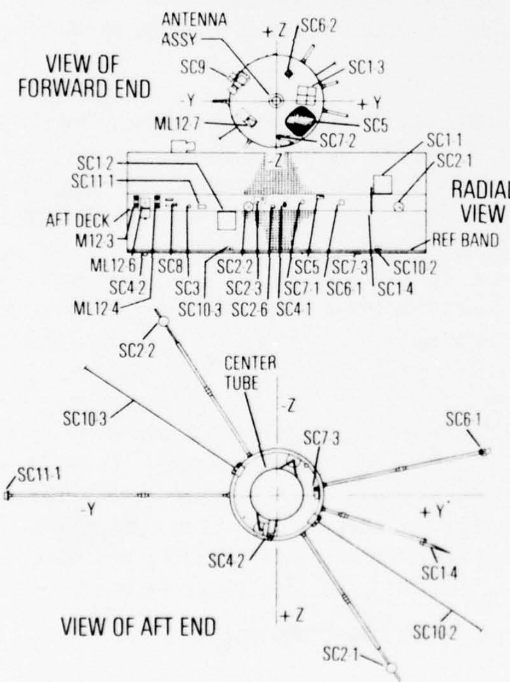


Figure 2.2. Payload Locations

FORWARD COMMUNICATIONS ANTENNA MAST AND A SPIDER STRUCTURE, WHICH IN TURN SUPPORTS EQUIPMENT LOCATED AT THE FORWARD END.

2.3 MATERIALS

SPECIAL LIGHTWEIGHT MATERIALS ARE USED IN THE SPACECRAFT STRUCTURE BECAUSE THE SPACECRAFT ORBIT AND PAYLOAD ARE NEAR THE MAXIMUM CAPABILITY OF THE DELTA 2914 LAUNCH VEHICLE. THE CENTER TUBE IS MADE OF MAGNESIUM. THE AFT EQUIPMENT DECK IS ALUMINUM HONEYCOMB. THE FORWARD DECK IS AN ALUMINUM BEAM STRUCTURE. THE SOLAR ARRAY SUBSTRATES ARE ALUMINUM CORE HONEYCOMB WITH A FIBER GLASS OUTER FACE AND AN ALUMINUM INNER FACE. THE SPIDER, ITS SUPPORT TRIPOD, AND THE ANTENNA MAST ARE MADE OF GRAPHITE-EPOXY.

BECAUSE SURFACE MATERIALS PLAY AN IMPORTANT ROLE IN SPACECRAFT CHARGING, THE P78-2 SPACECRAFT HAS MANY SURFACE FEATURES CHOSEN SPECIFICALLY TO SUPPORT MEASUREMENT OF THE CHARGING PHENOMENON. THESE ARE ILLUSTRATED IN FIGURE 2.3. THE FORWARD END IS COVERED WITH GOLD-PLATED STAINLESS STEEL FOIL TO PROVIDE A FLAT EQUIPOTENTIAL SURFACE. THE FOIL IS PAINTED WITH A PATTERN OF CIRCLES OF CONDUCTIVE BLACK PAINT TO PREVENT EXCESSIVE HEATING DURING THE TRANSFER ORBIT PERIOD WHEN THE FORWARD END IS EXPOSED TO THE SUN. TO PRESERVE A FLAT EQUIPOTENTIAL SURFACE AT THE FORWARD END OF THE SPACECRAFT, THE FIELD OF VIEW CAVITY FOR THE SC5 RAPID SCAN PARTICLE DETECTOR IS COVERED WITH A 1.00-IN. WOVEN AND WELDED MESH OF 0.010 IN. GOLD-PLATED STAINLESS STEEL WIRE.

THE SC9 UCSD CHARGED PARTICLE EXPERIMENT MEASURES FLUXES OF LOW-ENERGY CHARGED PARTICLES. THESE FLUXES WOULD BE ALTERED SIGNIFICANTLY BY FIELDS DUE TO CHARGED SURFACES NEAR THE INSTRUMENT APERTURES. FOR THIS REASON, THE INSTRUMENT IS SURROUNDED BY CONDUCTING SURFACES AT SPACECRAFT GROUND POTENTIAL. IN ADDITION TO THE CONDUCTING FOIL AT THE FORWARD END OF THE SPACECRAFT, THE SC9 SURROUNDINGS INCLUDE SOLAR CELL COVER GLASSES COATED WITH CONDUCTING INDIUM OXIDE. THE COVER GLASSES ARE REDUNDANTLY INTERCONNECTED AND COLLECTIVELY TIED TO THE SPACE VEHICLE FRAME.

THE BELLYBAND ACCESS PANELS MUST SATISFY BOTH THERMAL CONTROL AND EXPERIMENT REQUIREMENTS. IN

THE VICINITY OF INSTRUMENT APERTURES REQUIRING CONDUCTIVE SURROUNDINGS, THE PANELS ARE COATED WITH A CONDUCTIVE PAINT DEVELOPED AT GODDARD SPACE FLIGHT CENTER. THIS CONDUCTING PAINT COVERS METALLIC SURFACES TO LIMIT TEMPERATURES OF THE ACCESS PANELS. THE PAINT WILL SUPPORT NO MORE THAN A ONE-V POTENTIAL DIFFERENCE WHEN EXPOSED TO A ONE-nA cm^2 PLASMA CURRENT. WHERE NONCONDUCTIVE SURFACES ARE REQUIRED, THE ACCESS PANELS ARE COVERED WITH TEFLON MIRRORS SILVERED ON THE SECOND SURFACE.

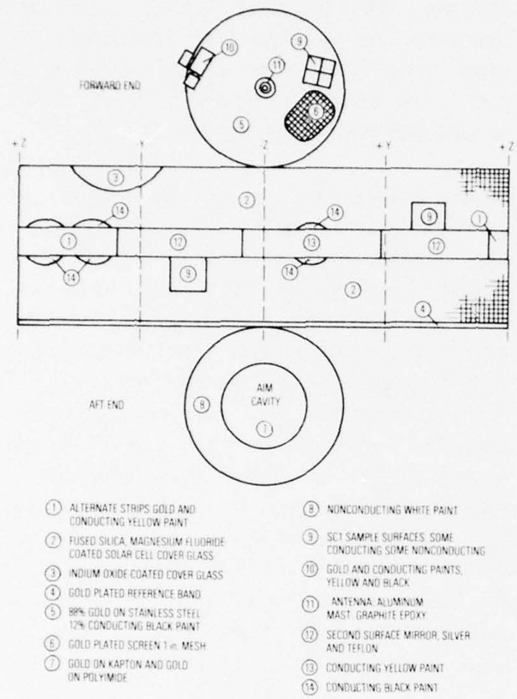


Figure 2.3. Spacecraft External Surface Materials

THE BOOMS USED TO SEPARATE SENSORS MEASURING AMBIENT ENVIRONMENTS FROM SPACECRAFT EFFECTS PERTURB THE SPACECRAFT SHEATH. CONDUCTING BOOMS WOULD SHORT-CIRCUIT THE PLASMA WHILE DIELECTRIC BOOMS WOULD CHARGE UP AND DISTORT THE SPACECRAFT ELECTRIC FIELDS. THE FIVE SHORT BOOMS SHOWN IN FIGURE 2.1 ARE FABRICATED WITH PLATINUM RINGS ON THE FIBER GLASS EPOXY BASE TO ALLOW SURFACE POTENTIALS TO APPROXIMATE THE LOCAL PLASMA POTENTIAL AND MINIMIZE DISTURBANCE OF THE SHEATH.

AT THE AFT END OF THE SPACECRAFT THERE IS AN ELECTRICAL POTENTIAL REFERENCE BAND. THE SURFACE OF THIS BAND IS GOLD TO ENSURE CONDUCTIVITY AND STABLE PHOTOELECTRIC PROPERTIES. THE BAND PRESENTS A CONSTANT PROJECTED AREA TO THE SUN AS THE SATELLITE SPINS. THE SC1 PAYLOAD DESCRIBED IN SECTION 3 USES THIS BAND AS A POTENTIAL REFERENCE SURFACE.

2.4 ELECTROMAGNETIC CONTROL

SC1 MEASURES RADIO FREQUENCY FIELDS AT THE SIGNAL LEVEL OF GALACTIC NOISE. TO AVOID SWAMPING THIS EXPERIMENT WITH SPACECRAFT NOISE, A NUMBER OF SPECIAL FEATURES ARE INCLUDED IN THE SPACECRAFT DESIGN. THE REGION BETWEEN AND AFT OF THE DECKS, WHERE MOST OF THE SPACECRAFT AND PAYLOAD EQUIPMENT IS MOUNTED, HAS BEEN DESIGNED AS A FARADAY CAGE. EQUIPMENT LOCATED OUTSIDE THIS REGION IS EITHER INDIVIDUALLY HOUSED IN SHIELDED ENCLOSURES AT SPACECRAFT GROUND POTENTIAL OR IS SUBJECT TO STRINGENT ELECTROMAGNETIC CONTROL REQUIREMENTS. CABLES OUTSIDE THE FARADAY CAGE ARE DOUBLY SHIELDED. POWER AND SIGNAL LINES CARRYING CURRENTS GREATER THAN 10 mA ARE ROUTED WITH THEIR RETURN LINES IMPLEMENTING A ZERO-NET-CURRENT CABLING APPROACH. THE SOLAR ARRAYS ARE BACK-WIRED TO CANCEL FIELDS GENERATED BY THE ARRAY CURRENTS. THE ELECTRICAL POWER SYSTEM SOURCE IMPEDANCE HAS BEEN HELD TO LESS THAN 20 MILLIOHMS FROM DC TO 10 MHz IN ORDER TO REDUCE COUPLING BETWEEN POWER USERS.

SPACECRAFT MAGNETIC FIELDS DIRECTLY AFFECT THE SC11 MAGNETIC FIELD DETECTOR AND THE SC6 THERMAL PLASMA ANALYZER. FURTHERMORE, THE MAGNETOMETER MEASUREMENTS ARE USED TO CORRELATE RESULTS FROM ALL THE CHARGED PARTICLE DETECTION PAYLOADS WITH THE EARTH'S MAGNETIC FIELD. COMMENSURATE WITH THESE REQUIREMENTS, THE SPACECRAFT IS MODERATELY CLEAN MAGNETICALLY WITH A TOTAL DIPOLE MOMENT OF APPROXIMATELY 500 GAUSS cm^3 (POLE-CM). THE MAGNETIC FIELDS, DUE TO THE SPACECRAFT AT THE LOCATION OF THE BOOM-MOUNTED MAGNETOMETER AND ALSO THE UNCERTAINTY IN THE MEASUREMENT OF THE EARTH'S FIELD BY THE MAGNETOMETER, ARE A FEW TENTHS OF A NANOTESLA (GAMMA). THIS ALLOWS DETERMINATION OF THE DIRECTION OF THE EARTH'S FIELD TO A FEW TENTHS OF A DEGREE IN THE P78-2 SPACECRAFT ORBIT.

2.5 THERMAL CONTROL

SPACECRAFT THERMAL CONTROL IS ACCOMPLISHED PRIMARILY BY PASSIVE MEANS WITH HEATERS USED TO maintain minimum temperatures for critical equipment.

The major features of the thermal control system are shown in Figure 2.4. The largest source of heat is joule heat from spacecraft and payload equipment. Most of this equipment is mounted to the aft deck in the central structure. Solar energy incident on the solar arrays is reradiated primarily to space, since the emissivity of the outer surface of the arrays is much higher than that of the inner face. The bellyband access panels, covered with second surface mirrors and thermal control paints, remain cool in the sunlight and function as effective radiators of waste energy from the deck-mounted equipment. Equipment at the ends of the spacecraft is kept warm by radiation from the deck-mounted equipment. To make this approach effective, rejection of heat by the end surface has been minimized. The thermal design contains special features to accommodate the following aspects of the mission and payloads:

1. The solar arrays are isolated from the equipment sections to prevent excessive radiative cooling during eclipse periods.

2. Some payloads and electric heaters are turned on in the transfer orbit to limit cooling of the spacecraft during this period.

3. A few components with low operating temperatures are isolated from spacecraft heat sources and radiatively coupled to the external environment.

4. Critical components such as batteries, the apogee insertion motor, and hydrazine rocket subsystem tanks, lines, and valves are electrically heated.

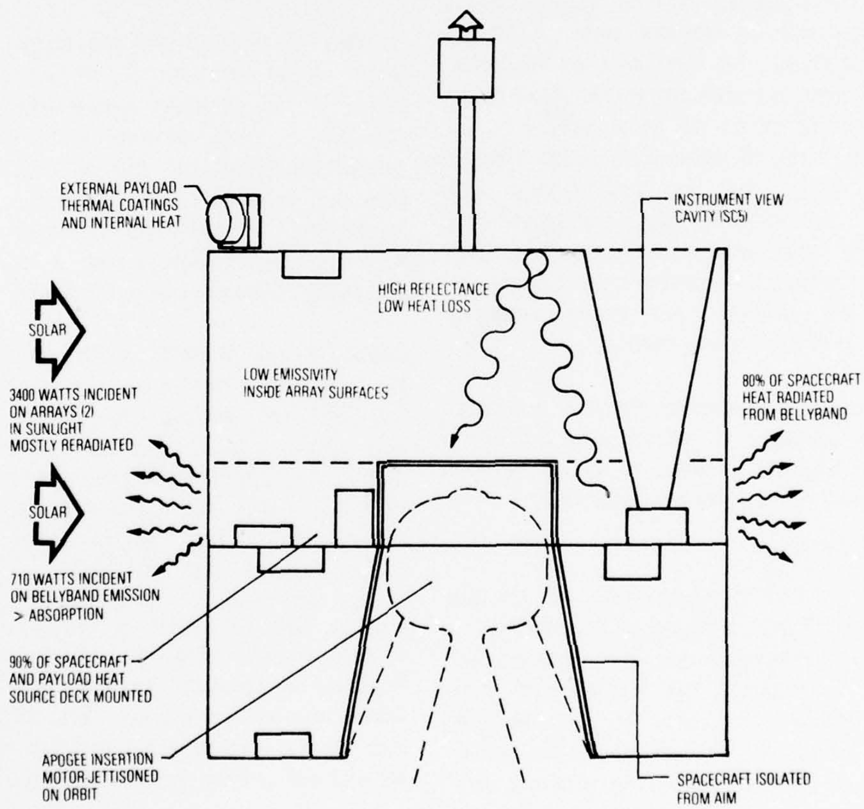


Figure 2.4. P78-2 Thermal Balance

5. The apogee insertion motor is a large heat source during its burn and until it is jettisoned. The insulation that protects the satellite from this heat source also prevents significant heat rejection through the aft central cavity during the mission operations period.

6. The SC5 Rapid Scan Particle Detector view cavity is pointed normal to the sunline. The walls of the cavity are radiatively isolated from the equipment compartments to prevent excess heat loss through this cavity.

2.6 ELECTRICAL POWER

The solar arrays provide 290 W of power for spacecraft and payload functions. The arrays are basically cylindrical with some irregularities in configuration to provide special surfaces surrounding instrument apertures and test samples. The projected area of each array is approximately 0.9 m^2 averaged over a complete satellite rotation. The spacecraft and experiment electrical loads are supplied by the array except when those loads exceed the array capability. At such times, three 8-ampere-hour nickel cadmium batteries supply the additional power. In particular, the batteries supply the entire load during boost phase and eclipse operation. When the array capability exceeds the loads, the batteries are charged. Any excess power is dissipated in resistive radiators.

The high sensitivity spectrum analyzer in payload SC1 can be commanded to operate from a separate battery, if required, in order to achieve suitable isolation from electromagnetic interference.

2.7 DATA SYSTEM

The basic data rate from spacecraft and payloads is 8192 bps. These data can be transmitted in realtime or tape-recorded for later transmission. Data transmission in the tape playback mode takes place at 65,536 bps. Each of the two tape recorders has a 12-hr capacity. The normal procedure is to record on one tape recorder until it is full. The other recorder, previously filled, is played back during periodic ground contacts.

In addition to the 8192 bps data stream, there is a 512 bps channel and a direct FM (broadband) channel. The 512 bps channel contains critical spacecraft and payload information that also appears in the 8192 bps data. The 512 bps and 8192 bps channels are not used simultaneously.

The direct FM channel provides frequency response up to 5 kHz and can be used in a number of different modes to handle analog data from one or more experiments.

At any time, the use of a particular data mode depends on the capability of a tracking station to close the appropriate telemetry link and the availability of that station to support the mission. The spacecraft has the capability at all times in the final orbit to close some telemetry link with the system of ground stations.

2.8 DATA TRANSMISSION

Realtime or recorded data are transmitted to the AFSCF ground stations by an S-band downlink. Either of two redundant transmitters may be used with any of three antennas in this link. The transmitter output is 10.5 W. The carrier is modulated with a 1.024-MHz phase shift-keyed subcarrier. The 1.024-MHz subcarrier can be used alone or summed with either a 1.7-MHz phase shift-keyed subcarrier or a 1.7-MHz FM subcarrier.

Omnidirectional antennas, mounted at both ends of the spacecraft, provide full spherical coverage. Each of these antennas consists of two crossed flat dipoles over a truncated, slotted cone. The dipoles are fed in quadrature. The third antenna is a radial array mounted on the same mast as the forward omni. This antenna consists of two crossed dipoles over truncated, slotted cones, placed back-to-back. These dipoles are fed in parallel and in phase to radiate a torodial pattern coaxial with the vehicle spin axis. Annular ring resonant cavity chokes are used to narrow this antenna pattern. The radial array is used for data transmission only, while the omnis are used for command reception as well.

2.9 COMMANDING

The command system is fully redundant. Two

OMNIANTENNAS, ONE AT EACH END OF THE SPACECRAFT, FEED EITHER OF TWO STRINGS OF RECEIVER-DEMODULATOR, DECODER, AND COMMAND DISTRIBUTION UNITS. THE SYSTEM ACCEPTS COMMANDS FROM THE AFSCF SPACE-GROUND LINK SUBSYSTEM. THE MAXIMUM COMMAND RATE IS ONE PER SEC. LATCHING, MOMENTARY, AND SERIAL DIGITAL COMMANDS ARE PROVIDED TO PAYLOADS AND SPACECRAFT SUBSYSTEMS. TIMING SIGNALS RANGING IN FREQUENCY FROM 2^{-8} HZ TO 2^{18} HZ ARE DISTRIBUTED TO THE PAYLOADS. THESE SIGNALS ARE GENERATED FROM A BASIC OSCILLATOR OUTPUT THAT IS INITIALLY ACCURATE TO 1 PPM AND DRIFTS LESS THAN 0.01 PPM/DAY.

2.10 ATTITUDE CONTROL AND DETERMINATION

SPACECRAFT ATTITUDE IS DETERMINED FROM THE OUTPUTS OF FOUR DIGITAL SUN SENSORS AND TWO STEERABLE HORIZON CROSSING INDICATORS. THESE DATA ARE PROCESSED ON THE GROUND AND CONTROL ACTIONS ARE DIRECTED BY UPLINK COMMAND. TWO ROCKET ENGINE MODULES PROVIDE THRUST FOR PRECESSING THE SPIN AXIS, CONTROLLING THE SPIN RATE, AND IMPARTING VELOCITY INCREMENTS FOR ORBIT ADJUSTMENT. EACH MODULE CONSISTS OF ONE 3.0 KG THRUST AND THREE 0.11 KG THRUST HYDRAZINE ROCKET ENGINES. TWO OIL-FILLED NUTATION DAMPERS PROVIDE ANGLE DAMPING. IN THE FINAL SPACECRAFT CONFIGURATION, WITH ALL BOOMS DEPLOYED AND THE SATELLITE SPINNING AT ONE RPM, THE DAMPING TIME CONSTANT IS 8 HR.

2.11 ORBIT

THE FINAL ORBIT IS ADJUSTED TO PROVIDE A SLOW EASTERLY DRIFT OF THE SATELLITE GROUND TRACK, TYPICALLY 6 DEG/DAY WITH APOGEE AND PERIGEE 27500 KM AND 42250 KM, RESPECTIVELY. FIGURE 2.5 ILLUSTRATES THE GROUND TRACE OF THE SUBSATELLITE POINT. THE SPATIAL RELATIONSHIPS BETWEEN THE EARTH, ITS MAGNETOSPHERE, AND THE SATELLITE ORBIT ARE SHOWN QUALITATIVELY IN FIGURE 2.6. ON MARCH 20, THE FIFTY-FIFTH DAY OF THE MISSION, THE SATELLITE ORBIT BEGINS TO INTERSECT THE EARTH'S SHADOW AS ILLUSTRATED IN FIGURE 2.7. THIS SPRING ECLIPSE SEASON LASTS 44 DAYS WITH A MAXIMUM ECLIPSE DURATION OF 71 MIN. A SECOND ECLIPSE SEASON IS ENCOUNTERED IN THE FALL.

2.12 OPERATIONS

DATA ACQUISITION ON THE P78-2 SPACECRAFT IS USUALLY LIMITED BY GROUND DATA HANDLING CAPACITY.

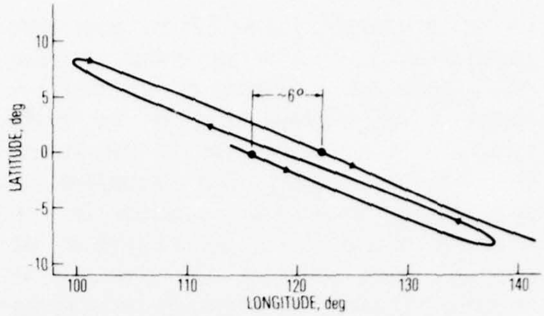


Figure 2.5. Typical Ground Track During Final Orbit

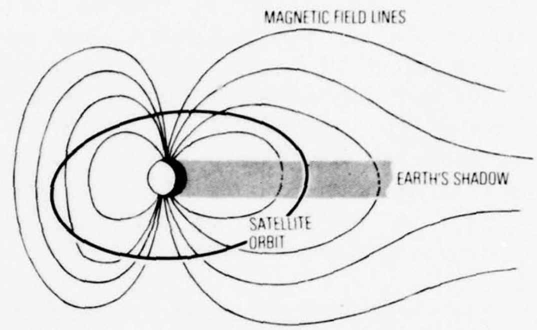


Figure 2.6. P78-2 Orbit Reference to the Magnetosphere

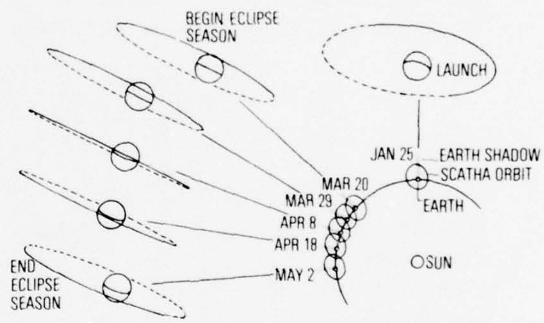


Figure 2.7. P78-2 Orbit and Earth Viewed From Sun

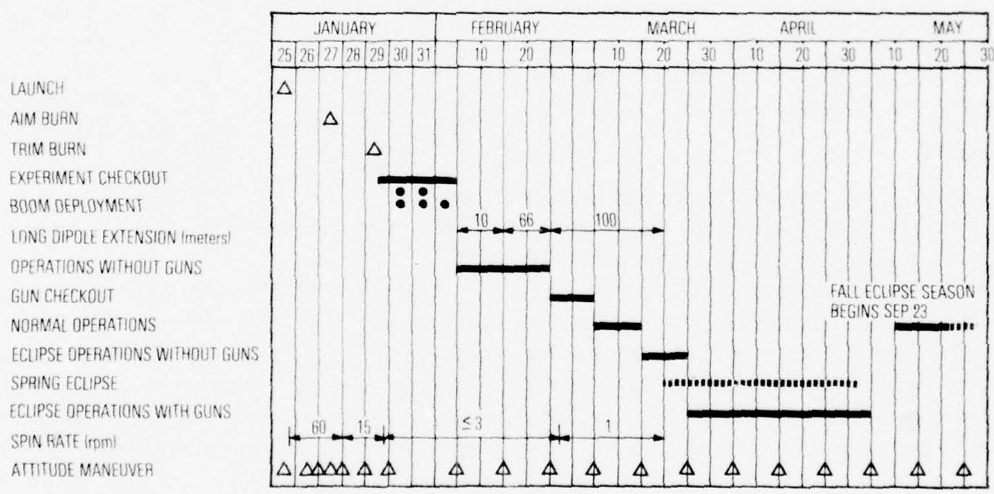
IN PRINCIPLE THE SATELLITE COULD SUPPORT 24 HR EACH DAY OF DIGITAL ACTIVITY AND UP TO 10 HR OF BROADBAND ACTIVITY. THE TOTAL TAPE RECORDER CAPACITY IS 24 HR OF DATA. THUS, TO SUPPORT FULL TIME ACTIVITY, THE TAPE RECORDERS WOULD NEED TO BE COMPLETELY PLAYED BACK ONCE A DAY. WHEN CONTINUOUS GROUND SUPPORT IS AVAILABLE, EXPERIMENT OPERATION IS NOT LIMITED BY SPACECRAFT POWER HANDLING CAPABILITIES. AN EXCEPTION TO THIS OCCURS ON THE DAYS OF THE LONGEST ECLIPSES. AT THOSE TIMES, BROADBAND DATA TRANSMISSION AND OPERATION OF THE ELECTRON AND ION GUNS IS RESTRICTED TO AVOID EXCEEDING AN 80% DEPTH OF DISCHARGE OF THE BATTERIES.

THE MISSION SEQUENCE, FIGURE 2.8, FOLLOWING ORBIT INSERTION AND EJECTION OF THE APOGEE INSERTION MOTOR, CALLS FOR ADJUSTMENT OF THE ORBIT TO ACHIEVE A SLOW EASTWARD DRIFT OF THE GROUND TRACK. THE SATELLITE SPIN AXIS IS THEN ORIENTED NORMAL TO THE SUNLINE. THIS ORIENTATION IS ESSENTIAL TO SATISFACTORY OPERATION OF THE SCIENTIFIC PAYLOAD AS WELL AS OPERATION OF THE SPACECRAFT POWER SUBSYSTEM. THE SPIN AXIS IS PRECESSED THROUGHOUT THE MISSION AT APPROXIMATELY ONE-WEEK INTERVALS TO MAINTAIN A 90-DEG ANGLE BETWEEN THE SPIN AXIS AND THE EARTH-SUN LINE. ONCE THE SATELLITE IS PROPERLY ORIENTED, BOOMS ARE DEPLOYED FOR THE SC6 THERMAL PLASMA ANALYZER, THE SC2 SPACECRAFT SHEATH POTENTIAL MONITOR, THE SC11 MAGNETIC FIELD MONITOR, AND THE SC1 RF ELECTROMAGNETIC WAVE ANALYZER. THE PAYLOADS, WHICH ARE DISCUSSED IN DETAIL IN THE FOLLOWING SECTIONS, ARE CHECKED OUT INDIVIDUALLY AND IN COMBINATION DURING THE NEXT FEW DAYS.

THE TWO 50-M ANTENNAS DEPLOYED FOR THE SC10 ELECTRIC FIELD DETECTOR WILL SIGNIFICANTLY CHANGE THE ELECTRICAL CONFIGURATION OF THE SATELLITE. TO PERMIT BASELINE DATA TO BE TAKEN BY EXPERIMENTS SENSITIVE TO THE SATELLITE ELECTRICAL CONFIGURATION, THE LONG ANTENNAS WILL BE DEPLOYED IN STEPS OVER A PERIOD OF WEEKS BEGINNING SEVERAL WEEKS INTO THE MISSION. AT THE END OF THE ECLIPSE SEASON, 90 DAYS INTO THE MISSION, THE P78-2 SPACECRAFT AND ITS' VARIED AND INTERACTIVE PAYLOAD BEGIN WHAT CAN BE CALLED NORMAL OPERATIONS.

2.13 TRANSIENT PULSE MONITOR

IN ORDER TO OBTAIN A QUANTITATIVE DESCRIPTION OF THE ELECTROMAGNETIC PULSE ENVIRONMENT ON THE SPACECRAFT, A TRANSIENT PULSE MONITOR WAS INCLUDED AS A SPACECRAFT COMPONENT. RELATIVE FREQUENCY OF OCCURANCE OF PULSES AS A FUNCTION OF AMPLITUDE AND DURATION PERMIT DESIGN OF COMMAND/CONTROL LOGIC THAT IS RELATIVELY IMMUNE TO SPURIOUS SIGNALS ON TYPICAL SPACECRAFT. CHARACTERISTICS OF SIGNALS PRODUCED BY ARCING BETWEEN DIFFERENTIALLY CHARGED ELEMENTS ON THE SPACECRAFT WILL BE MEASURED. ADDITIONALLY, DATA FROM KNOWN DISCHARGE EVENTS, IDENTIFIED BY DATA FROM THE SPACERAFT SURFACE POTENTIAL MONITOR, CAN BE USED QUANTITATIVELY AND QUALITATIVELY IN THE VALIDATION OF ELECTROMAGNETIC PULSE COUPLING MODELS.



	TRANSFER ORBIT	FINAL ORBIT
APOGEE	23100 nmi	23100 nmi
PERIGEE	100 nmi	15038 nmi
INCLINATION	27.4 deg	8.3 deg
PERIOD	12.86 hr	23.54 hr
DRIFT RATE	--	6 deg DAY EASTWARD

KEY PARAMETERS

Figure 2.8. Mission Operations Through Spring Eclipse Season

The Transient Pulse Monitor consists of an electronic processor and four electrical transient sensors. As shown in Figure 2.9, two of the sensors are current probes and two are long wire antennas. One current probe is located on one of the wires that connect the solar array to the Power Conditioning Unit. The other current sensor is located on one of seven ground wires between the Power Conditioning Unit and the vehicle frame. Both current sensors have sensitivities of 1 mV/mA. The long wire antennas each consist of insulated wires tied to the outside of the foil wrap of the main vehicle wiring harness. The two wires run parallel to each other and extend half way around the inside of the vehicle center tube. These antennas differ only in the magnitudes of their termination impedances. As shown in Figure 2.9, the low-impedance antenna is connected directly to the vehicle frame at the far end and is terminated in 50Ω within the instrument processor housing. The high-impedance antenna is connected to the vehicle frame through a 100-KΩ resistor at the far end. At the Transient Pulse Monitor end of the high-impedance antenna there is a 10-KΩ resistor in series with the 50-Ω input impedance.

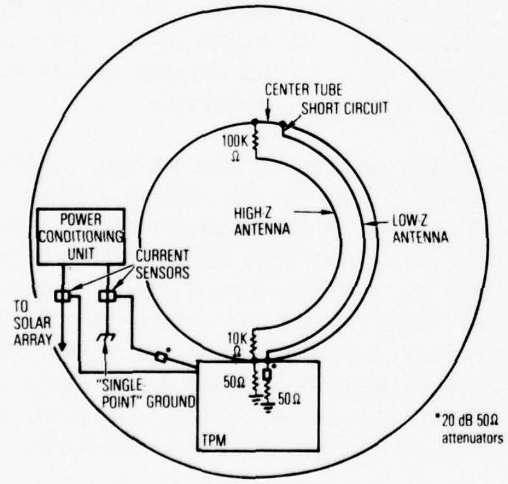


Figure 2.9. Layout of Transient Pulse Monitor Sensors

The Transient Pulse Monitor electronic processor continuously monitors electrical signals from each of the four sensors simultaneously and provides the following information for each sensor once per sec:

- o Total pulse count
- o Positive integral
- o Negative integral
- o Positive peak amplitude
- o Negative peak amplitude

Figure 2.10 is a functional block diagram of the electronics associated with each sensor.

2.14 PULSE COUNT CHANNELS

The pulse count channel associated with each sensor indicates the total number of times that the magnitude of the input signal exceeds a set threshold during each one-sec telemetry window. However, if the input signal exceeds the set threshold more than once during any 1-msec period, it is counted only once. The pulse counters acquire data throughout each one-sec telemetry frame regardless of the mode setting.

The Pulse Counter thresholds are as follows:

Threshold Setting	Threshold (V)
0	0.35
1	0.064
2	0.012
3	0.002

2.15 PULSE INTEGRAL CHANNELS

The two pulse integral channels associated with each sensor indicate the total positive and negative integral of the input signals during each timing window. However, the portions of the input signal that do not exceed the lower amplitude thresholds shown in the table are not included in the integral measurement. In the continuous mode (mode 0), the timing window is the entire one-sec telemetry frame. In the single-pulse mode (mode 1), the inputs to the pulse integral channels from any sensor are disabled approximately 10 msec after the occurence of any transient that exceeds the threshold of the pulse counter channel associated with that sensor.

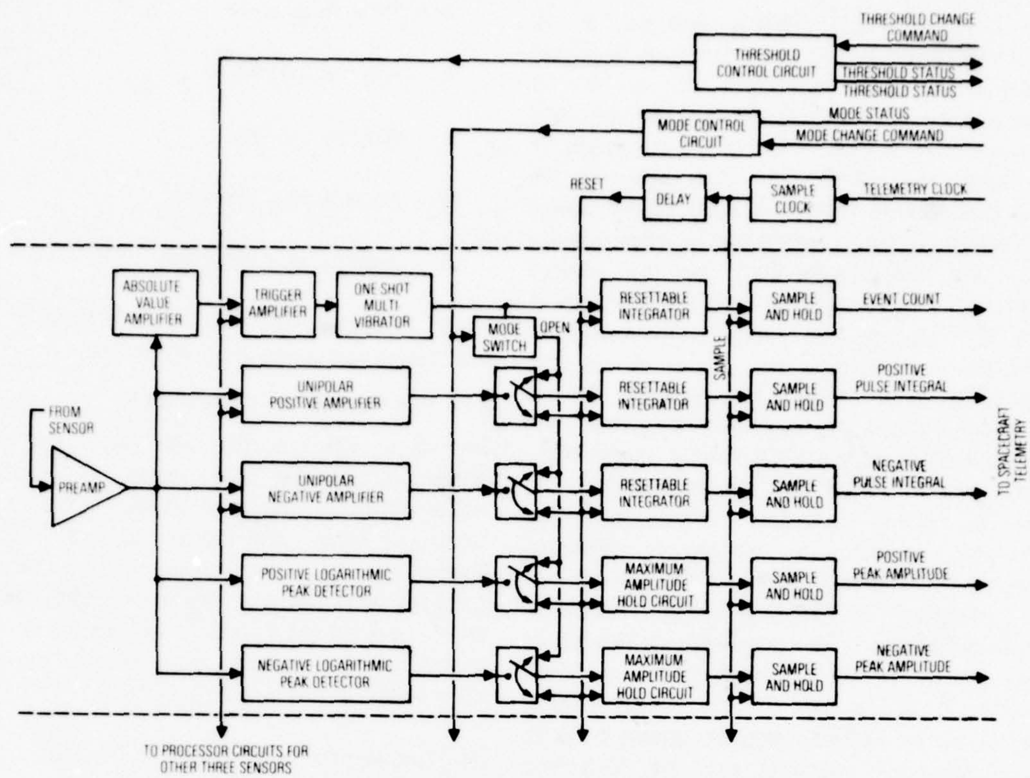


Figure 2.10. Transient Pulse Monitor System Block Diagram

The relationship between the input pulse integral as defined above and the output of the pulse integral channel is determined by the overall threshold setting and by the input pulse amplitude as measured by the associated peak amplitude channel. The dynamic range is 2×10^{-8} to 1.6×10^{-4} V-sec.

The Transient Pulse Monitor can be commanded to operate in one of two modes (continuous or single pulse) and the detector threshold can be commanded to one of four levels.

2.16 PEAK AMPLITUDE CHANNELS

The two peak amplitude channels associated with each sensor indicate the maximum positive and negative excursions of the input signals during each timing window. In the continuous mode (mode 0), the timing window is the entire one-sec frame. In the single-pulse mode (mode 1), the inputs to the peak amplitude channels from any sensor are disabled approximately 10 msec after the occurance of any transient that exceeds the threshold of the pulse counter channel associated with that sensor. The peak amplitude channels are not affected by changes in threshold.

The dynamic range of the peak amplitude channels is 2 mV to 24 V for the high impedance antenna, 20 mV to 240 V for the low impedance antenna, 2 mA to 24 A for the solar array sensor, and 140 mA to 1700 A for the power distribution unit sensor. These ranges include the effects of 20 dB attenuators in the inputs to the low impedance and Power Conditioning Unit sensors and also the fact that only one of seven identical power leads is monitored by the Power Conditioning Unit sensor.

3. SC1 SATELLITE SURFACE POTENTIAL MONITOR

3.1 SCIENTIFIC OBJECTIVES

THE SATELLITE SURFACE POTENTIAL MONITOR (SSPM) CONSISTS OF THE SC1-1, SC1-2, AND THE SC1-3 INSTRUMENTS. THESE INSTRUMENTS MEASURE THE CHARGING POTENTIALS AND CURRENTS ASSOCIATED WITH PLASMA INTERACTIONS WITH TYPICAL SPACECRAFT MATERIALS AT NEAR-SYNCHRONOUS-ORBIT ALTITUDES OF THE P78-2 SPACECRAFT. SPECIFICALLY, THE TIME PROFILE OF CHARGING EVENTS ON INSULATORS, GROUNDED INSULATORS, AND AN ISOLATED CONDUCTOR IN CONJUCTION WITH VARIOUS ENVIRONMENTAL PARAMETERS MEASURED ON THE SAME SATELLITE, WILL BE COMPARED WITH ANALYTICAL RESULTS OF VARIOUS SPACECRAFT CHARGING MODELS.

3.2 MEASURING TECHNIQUE

TWO PARAMETERS SOUGHT BY THE SSPM EXPERIMENT ARE SURFACE POTENTIALS ON AND BULK CURRENT FLOWS IN TYPICAL SPACECRAFT MATERIALS DURING ALL PHASES OF THE P78-2 SPACEFLIGHT. A TECHNIQUE DEVELOPED TO PROVIDE THE FRONT SURFACE POTENTIAL IS TO MEASURE DIRECTLY THE BACK SURFACE VOLTAGE USING AN ELECTROSTATIC DEVICE AND THEN TO CALCULATE THE FRONT SURFACE POTENTIAL BY MEANS OF LABORATORY CALIBRATIONS.

TO INFER THE CHARGING PROFILE OF A TYPICAL SPACECRAFT MATERIAL, ONE MUST MAKE A SERIES OF MEASUREMENTS AND ASSUMPTIONS. REDUNDANT MEASUREMENTS OF ALUMINIZED KAPTON ARE MADE ON EACH OF THREE INSTRUMENTS (SC1-1, SC1-2, AND SC1-3) FOR THE FOLLOWING REASONS: DURING HIGH TEMPORAL CHARGING EVENTS, THE PHYSICAL LOCATION OF THE SAMPLE MATERIAL ON THE SATELLITE MAY BE IMPORTANT; WHETHER OR NOT THE DIELECTRIC MATERIAL IS IN SUN OR SHADOW MAY ALSO AFFECT THE FINAL RESULT; AND THE BOUNDARY CONDITIONS (I.E., PROXIMITY OF OTHER SAMPLES AND GROUNDING PLANES) WILL PROBABLY AFFECT THE CHARGING PROFILE. IN ADDITION TO THE ALUMINIZED KAPTON, OTHER SAMPLES TO BE FLOWN ON THE P78-2 SPACECRAFT ARE SILVERED TEFLON, QUARTZ FABRIC MOUNTED ON SILVERED TEFLON, GOLD-FLASHED ALUMINIZED KAPTON, TWO SETS OF OPTICAL SOLAR REFLECTING (OSR) MIRRORS, AND A GOLD-PLATED MAGNESIUM PLATE.

TWO OF THE NINE SAMPLES ARE NOT EXPECTED TO CHARGE IN SPACE, AT LEAST DURING THE INITIAL OPERATION OF THE SPACECRAFT. SAMPLE #2 ON SC1-1 HAS A GROUNDED THIN CONDUCTING SURFACE MATERIAL OVER A MOSAIC OF MIRRORS. SAMPLE #4 ON SC1-3 HAS A GROUNDED THIN COATING OF GOLD FLASHING OVER ALUMINIZED KAPTON.

TABLE 3.1 SHOWS THE COMPLETE LIST OF SSPM SAMPLES AND DESIGNATED MEASUREMENT NUMBERS. SC1-1 AND SC1-2 ARE LOCATED NEAR THE EQUATORIAL PLANE OF THE SPACECRAFT APPROXIMATED 180 DEG FROM EACH OTHER. THE FOUR SAMPLES OF SC1-1 AND THE LARGE SAMPLE OF SC1-2 WILL ROTATE IN AND OUT OF SHADOW EVERY 60 SEC. SAMPLES ON SC1-3 ARE ALWAYS IN SHADOW ON TOP OF THE VEHICLE.

Table 3.1. Location and Identification of Samples

Sample Position	SC1-1	SC1-2	SC1-3[a]
1	Aluminized Kapton	Aluminized[c] Kapton	Aluminized Kapton
2	OSR[b]	Aluminized Kapton	Silvered Teflon
3	OSR	Reference Band	Quartz Fabric
4	Gold/	Reference[d] Band	Gold/ Aluminized Kapton

[a]Shadowed

[b]Grounded to chassis of spacecraft

[c]125 mil hole through sample

[d]High gain of redundant measurement

SINCE THE CHASSIS OF THE THE P78-2 WILL CHANGE POTENTIAL DURING EITHER NATURAL OR ARTIFICIAL CHARGING EVENTS, TWO OF THE SC1-2 POTENTIAL MEASUREMENTS ARE OF A CONDUCTING REFERENCE BAND THAT IS ALWAYS PARTIALLY SOLAR ILLUMINATED (EXCEPT DURING ECLIPSE). THIS REFERENCE BAND IS DESIGNED TO MAINTAIN A CONSTANT AND LOW REFERENCE POTENTIAL.

ONCE THE BACK SURFACE POTENTIALS AND BULK CURRENT FLOWS ARE DETERMINED, THE FRONT SURFACE POTENTIALS OF THE DIELECTRICS ARE INFERRED BY MEANS OF CALIBRATION TESTS PERFORMED AT THE NASA LEWIS RESEARCH SUBSTORM FACILITY. DURING THESE CHARGING TESTS WITH ELECTRON BEAMS, A FRONT SURFACE PROBE RECORDED POTENTIALS SIMULTANEOUSLY WITH A RECORDING OF THE BACK SURFACE POTENTIALS.

ALL MEASUREMENTS ARE DERIVED FROM AN ASSEMBLY CONSISTING OF A SAMPLE, SAMPLE HOLDER,

DIRECT-MOUNTED ELECTROSTATIC SENSOR FROM MONROE ELECTRONICS, AND A BIPOLAR ELECTROMETER CIRCUIT CAPABLE OF DIGITIZING CURRENTS FROM 10^{-10} TO 10^{-6} AMPS. FIGURE 3.1 SHOWS A SCHEMATIC REPRESENTATION OF A TYPICAL SAMPLE ASSEMBLY. IN ADDITION TO THE VOLTAGE AND CURRENT MEASUREMENTS, THE TEMPERATURE FROM EACH MONITOR BOARD ASSEMBLY IS ALSO RECORDED.

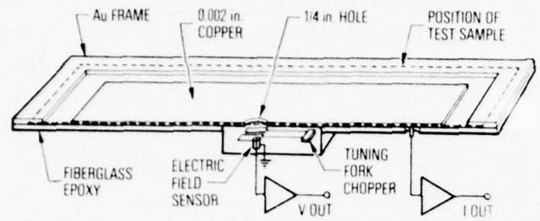


Figure 3.1. Cutaway of Typical SSPM Sample Board

A TYPICAL DIELECTRIC SAMPLE HAS A METALLIZED BACKING THAT IS GROUNDED THROUGH THE CURRENT MEASURING CIRCUIT. A 250 MIL DIAMETER AREA, ETCHED FREE OF THE METALIZATION, IS ALIGNED DIRECTLY OVER THE MONROE ELECTROSTATIC SENSOR AND A HOLE OF THE SAME DIAMETER, WHICH IS DRILLED THROUGH THE SAMPLE BOARD. THIS SAMPLE BOARD POSITIONS THE MONROE ASSEMBLY AS WELL AS THE SAMPLE MATERIAL.

BY MEANS OF A DIRECT MEASUREMENT OF THE ELECTRIC FIELD TO THE SENSITIVE ELECTRODE OF THE SENSOR, THE BACK SURFACE POTENTIAL IS DERIVED. EACH DEVICE IS CALIBRATED BY PLACING A VOLTAGE ELECTRODE AT THE SAME DISTANCE FROM THE SENSOR AS THE SAMPLE. ALTHOUGH THE ELECTRIC FIELD IS THE MEASURED PARAMETER, THE BACK SURFACE POTENTIAL IS THE RECORDED QUANTITY. THE CURRENT CIRCUIT IS CALIBRATED BY MEANS OF DIRECT SIMULATION OF A KNOWN CURRENT SOURCE FROM 10^{-9} TO 10^{-6} AMPS.

THE FINAL DERIVED QUANTITY IS THE FRONT SURFACE POTENTIAL. EACH SAMPLE AND ASSEMBLY HAS UNDERGONE CALIBRATION IN THE NASA LEWIS RESEARCH CENTER SUBSTORM FACILITY IN CLEVELAND, OHIO. FOR ELECTRON BEAMS WITH ENERGIES FROM 2 KEV TO 20 KEV THE FRONT VERSUS BACK SURFACE POTENTIAL WAS RECORDED DURING CHARGING OF EACH SAMPLE. THEREFORE THE FRONT SURFACE POTENTIAL IS DERIVED BY MEANS OF A SIMPLE ANALYTICAL FUNCTION. IN ADDITION, CHARGING PROFILES AND HISTORIES WERE ALSO RECORDED ON MAGNETIC TAPE DURING THESE CALIBRATION RUNS.

3.3 DESCRIPTION AND BLOCK DIAGRAM

ELECTRIC FIELDS BETWEEN THE BACK SURFACE OF EACH SAMPLE AND THE ELECTROSTATIC SENSOR ARE MODULATED BY TINES OSCILLATING AT 700 HZ. THIS SIGNAL IS FED TO THE INPUT OF A HIGH IMPEDANCE AMPLIFIER THAT CONTAINS A PHASE-SENSITIVE DEMODULATOR. THE AMPLITUDE OF THE SIGNAL IS PROPORTIONAL TO THE INPUT ELECTRIC FIELD AND THE PHASE OF THE AC SIGNAL IS RELATED TO THE POLARITY OF THE ELECTRIC FIELD.

ELECTRIC CURRENTS PASSING THROUGH EACH SAMPLE ARE COLLECTED ON A BACK SURFACE ELECTRODE OF KNOWN AREA AND ROUTED TO THE HIGH IMPEDANCE ELECTROMETER CIRCUIT. THE SIGNAL IS AMPLIFIED AND DIGITIZED BY MEANS OF A CHARGING CAPACITOR AND SWITCHING DEVICE. THE RANGE OF FREQUENCY FROM ZERO TO 10^4 HZ CORRESPONDS TO CURRENTS OF 10^{-10} TO 10^{-6} AMPS COLLECTED ON A SENSITIVE AREA OF APPROXIMATELY 160 CM^2. CURRENT POLARITY IS DETERMINED BY A PHASE SENSITIVE DEMODULATOR, AND IS MAINTAINED BY MEANS OF TWO IDENTICAL CIRCUITS, ONE FOR POSITIVE, THE OTHER FOR NEGATIVE CURRENT.

FIGURE 3.2 SHOWS A BLOCK DIAGRAM OF ONE SENSOR AND ASSOCIATED ELECTRONICS. THE DATA ARE OBTAINED WITH CIRCUITRY ON THE MONITOR BOARD. THE SIGNALS FROM SUBASSEMBLIES ARE ROUTED TO THE INTERFACE BOARD FOR DIGITIZING AND CONDITIONING. DIGITAL PULSES ARE FED TO THE SC2 DATA SYSTEM FOR ACCUMULATION AND ROUTING TO THE MAIN TELEMETRY SYSTEM.

3.4 OPERATIONAL ASPECTS

TWELVE VOLTAGE AND 18 CURRENT CHANNELS ARE DIGITIZED, SENT TO THE SC2-4 DATA BOX, AND COMPRESSED INTO 12 BIT SCALERS. EACH OF THE THREE INSTRUMENTS HAVE SERIAL READOUTS FOR FOUR VOLTAGE CHANNELS AND PARALLEL READOUTS FOR FOUR POSITIVE AND NEGATIVE CURRENTS. EACH OF THE FOUR VOLTAGE SIGNALS FROM EACH UNIT IS ACCUMULATED FOR 0.25 SEC. THE POLARITY OF EACH VOLTAGE SIGNAL IS RETAINED IN THE LEAST SIGNIFICANT BIT OF THE 12-BIT SCALER.

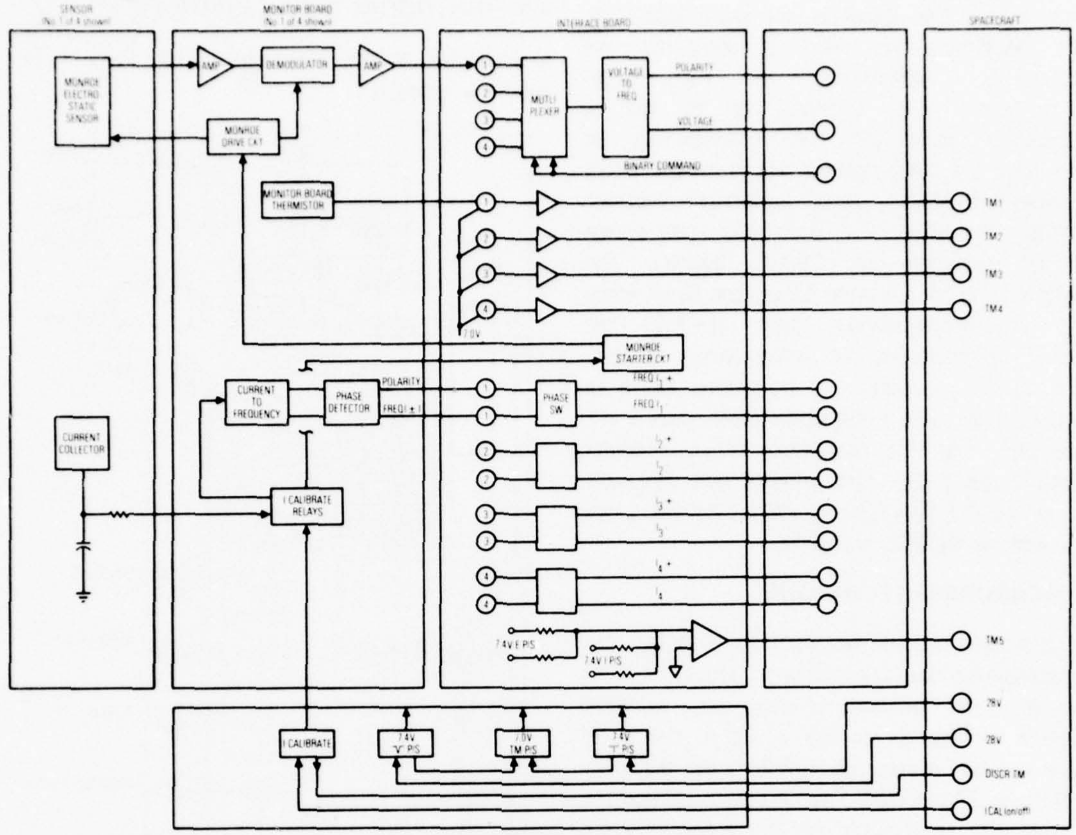


Figure 3.2. SSPM Block Diagram

In addition to these primary digital channels for each SSPM, four analog temperatures and one analog voltage monitor are sent directly to the satellite analog telemetry system. Each primary voltage or current circuit can be commanded separately. A current calibrate command is also available and upon receipt, approximately -7×10^{-8} amps is cycled into each electrometer input with a 10-sec period. This results in a cyclic pattern of approximately 700 Hz on each negative current output line. A discrete telemetry output level indicates that the instrument is in the calibrate mode.

4. SC1 VERY LOW FREQUENCY WAVE ANALYZER

4.1 SCIENTIFIC OBJECTIVES

The VLF Analyzer measures electromagnetic emissions in the ELF, VLF, and LF ranges.

The primary engineering objective of this experiment is to verify that electrical discharges are occurring when other experiments measure large differential potentials between spacecraft materials and between the vehicle and the space plasma. The secondary engineering objectives are to measure the intensity of the fields to determine the rate at which discharges occur and to determine the normal EMI characterisitics of a spacecraft in the plasma environment at synchronous orbit.

The primary scientific objective of this experiment is to measure the intensity and spectra of electromagnetic and electrostatic emissions by the energetic particles in the magnetosphere outside of the plasma sphere. These data will be used to model the dynamics of the radiation belt particles in this region of the magnetosphere. The secondary scientific objective is to investigate wave-particle interaction and whistler-mode propagation in the outer magnetosphere. The approach is to use a high-power, ground-based, VLF transmitter to couple into the magnetosphere whistler-mode waves of known frequency, pulse duration, radiated amplitude, and phase. The TVLF Transmitter system will be installed near Strand, Norway. The antenna will be an existing 30-km long 60-kV power line. At geosynchronous orbit (L≈ 6.6) the electron gyrofrequency is approximately 3 kHz. The transmitter is capable of delivering 100 kW to a matched load over a frequency range from 1 kHz to 30 kHz. For this experiment it will operate between 1 and 5 kHz. The primary wave receivers will be the VLF Analyzer on P78-2 and the S-300 experiment on the GEOS satellite.

4.2 MEASURING TECHNIQUE

The experiment employs two antennas to detect the electromagnetic and electrostatic emissions. An air-core loop antenna detects the magnetic component of the waves and a 100-m tip-to-tip dipole antenna, designated SC10-2, 3 and described in Section 17, detects the electric component. The over-all sensitivity of the electric field receiver is 5×10^{-7} V/m$\sqrt{Hz}$ at 1.3 kHz and 10^{-7} V/m$\sqrt{Hz}$ at 10.5 kHz.

The air-core loop is electrostatically -shielded and has an effective area of 575 sqm at 1.3 kHz. It is constructed of 1530 turns of 36 AWG copper wire on a form 50 cm in diameter. The antenna is a boom mounted loop 2 m from the spacecraft. The frequency response of the loop antenna and low pass filter is shown in Figure 4.1. The overall sensitivity of the receiver is $3 \times 10^{-6} \gamma/\sqrt{Hz}$ at 1.3 kHz. The dynamic range is 60 dB.

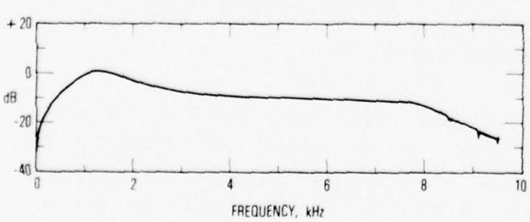


Figure 4.1. Frequency Response of the Loop Antenna and Low Pass Filter

4.3 FUNCTIONAL BLOCK DIAGRAM

A schematic of the Functional Block Diagram is shown in Figure 4.2.

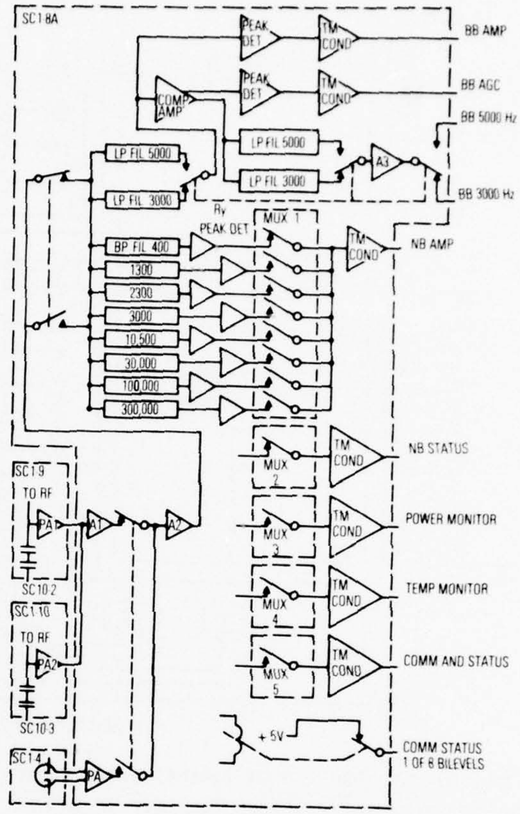


Figure 4.2. VLF Frequency Wave Analyzer Block Diagram

4.4 OPERATIONAL ASPECTS

The VLF Analyzer has eight pulsed commands to control the operation of the experiment as follows:

1) Selection of the broadband output mode-OFF/3kHz/5kHz

2) Selection of the antenna signal to be analyzed-ELECTRIC/MAGNETIC/ AUTOMATIC SWITCHING AT 16 INTERVALS

3) Selection of the Calibrate mode-ON/OFF

4) Selection of the narrowband filter mode-ON/OFF

The primary on-orbit operation will be the narrowband filter mode providing tape recorded data with the antennas switching. Broadband data can be obtained at four periods approximately centered at midnight, dawn, noon, and dusk. These data can only be collected in realtime. One hour per day is allocated to this experiment with a minimum broadband acquisition time of 20 min/orbit.

5. SC1 RADIO FREQUENCY ELECTROMAGNETIC WAVE ANALYZER

5.1 SCIENTIFIC OBJECTIVES

The RF Analyzer measures electromagnetic emissions in the frequency range from 2 MHz to 30 MHz.

The primary objective of this payload is to verify that electrical discharges are occurring when other instruments measure large differential charging levels on the the space vehicle surfaces. For this purpose it will measure the number of pulses and the spectral envelope in the RF frequency (integrated over many pulses). The secondary objective is to measure the normal EMI environment of the space vehicle in the plasma environment at synchronous orbit.

5.2 MEASURING TECHNIQUE

The RF analyzer employs two antennas for the measurements: an extendible 100-m tip-to-tip dipole provided by the Goddard Space Flight Center for the DC field experiment and a 1.5-m monopole along a boom that is deployed perpendicular to the spin axis of the vehicle.

The analyzer can be operated in both a swept or a fixed frequency mode. The design includes five frequency bands, two sweep rates for each band, and two detection bandwidths. The details are specified in Table 5.1. The amplitude (peak detection) is sampled 400 times per second, converted to an 8-bitdigital format (one bit is a sync bit) and telemetered on a special purpose 3 kHz broadband data channel. During tape recorder only operations, the amplitude is sampled eight times per second. Only fixed frequency operation will take place in this mode.

5.3 FUNCTIONAL BLOCK DIAGRAM

A schematic of the RF Analyzer is shown in Figure 5.1.

Table 5.1. RF Analyzer Specifications

Frequency Coverage (MHz)	1.94-3.5, 3.37-6.5, 5.75-10.0, 9.5-18.0, 17.5-30.0
Sensitivity	Less than -110 dBm for 10 dB S + N/N for a CW signal
Overall Audio Response	Wide; 4.4 kHz at 6 dB down, 11.0 kHz at 30 dB down Narrow; 860 Hz at 6 dB down, 2.6 kHz at 30 dB down
Overall Gain	Less than 1 μV input for 1 V output
Harmonic Distortion	2nd harmonic intercept + 10 dBm 3rd harmonic intercept + 13 dBm
Intermodulation Distortion	2nd order intercept + 8 dBm 3rd order intercept 0 dBm
Image Rejection	60 dB
IF Rejection	60 dB
Internally Generated Spurious Signals	There are 49 spurious signals above 1 μV
Frequency Tolerance	±25 ppm -55 to + 105°C
Tuning Rate	Slow / Fast Band 1: 16 sec / 3.5 sec Band 2: 32 / 6.5 Band 3: 46 / 9.0 Band 4: 90 / 19.0 Band 5: 118 / 23.5
Sweep Accuracy	Within 10 kHz after calibration at nearest 1 MHz marker
IF Frequencies	1.252, 3.005, 8.0 MHz
Antenna Input Impedance	50 k ohms
Temperature Range	-20°C to +50°C
Power Requirement	28 VDC at 0.58 amp max
	20 VDC at 0.65 amp max
Dimensions	9 in. W × 5 in. H × 10.2 in. D
Net Weight	8.4 lb

5.4 OPERATIONAL ASPECTS

The RF analyzer is commanded by a 22-bit serial digital command and 10 pulsed commands. The digital command selects the bands to be swept, the sweep rate, or the fixed frequency for that mode of operation. The pulsed commands select the antenna, bandwidth, gain, calibration signal, and broadband operational mode.

The on-orbit operation will be based on scheduled commands (to be determined after the times for satellite data acquisition for a week are scheduled).

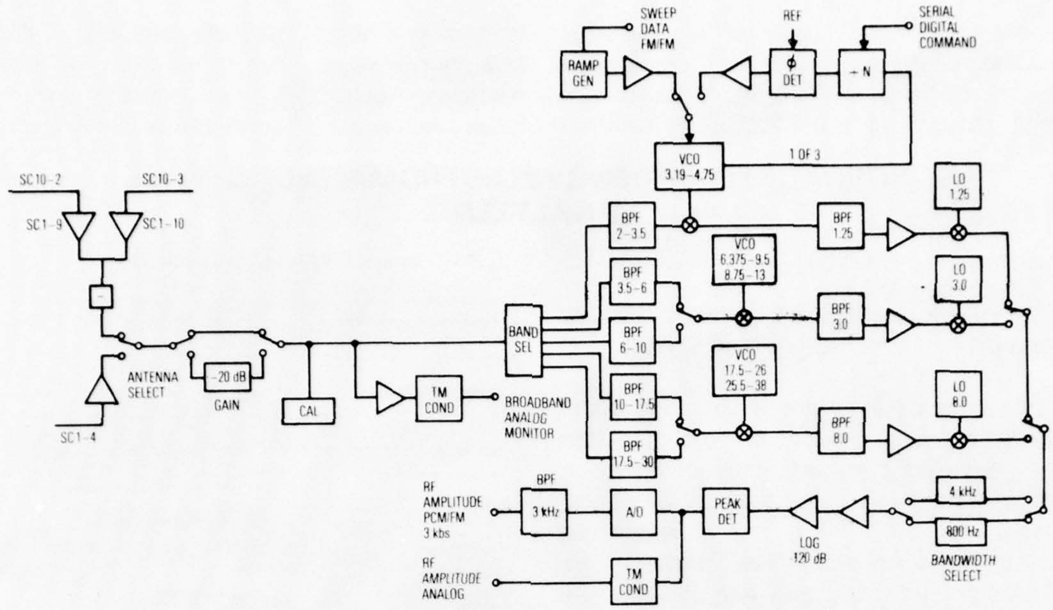


Figure 5.1. RF Analyzer Block Diagram

6. SC1 TRANSIENT PULSE SHAPE ANALYZER

6.1 SCIENTIFIC OBJECTIVES

THE PULSE SHAPE ANALYZER MEASURES THE SHAPE OF ELECTROMAGNETIC PULSES IN THE TIME DOMAIN FROM 7 NSEC TO 3.7 MSEC.

THE PRIMARY OBJECTIVE OF THIS EXPERIMENT IS TO VERIFY THAT ELECTRICAL DISCHARGES ARE OCCURRING WHEN OTHER INSTRUMENTS MEASURE LARGE DIFFERENTIAL CHARGING LEVELS ON SPACE VEHICLE SURFACES. THE PULSE AMPLITUDES AND SHAPES PRODUCED BY SUCH ELECTRICAL DISCHARGES WILL BE MEASURED ON FOUR SENSORS.

6.2 MEASURING TECHNIQUE

THE PULSE ANALYSES ARE MADE ON FOUR SENSORS: (1) A LOOP ANTENNA AROUND ONE OF THE TWO REDUNDANT SPACE VEHICLE COMMAND DISTRIBUTION UNITS, (2) A WIRE ALONG THE OUTSIDE OF A "TYPICAL" SPACE VEHICLE CABLE BUNDLE, (3) AN EXTERNAL SHORT DIPOLE ANTENNA AT THE END OF A 2-M BOOM, AND (4) A DIGITAL COMMAND LINE FROM THE COMMAND DISTRIBUTION UNIT TO THE PULSE SHAPE ANALYZER.

6.3 FUNCTIONAL BLOCK DIAGRAM

THE SIGNAL PROCESSOR MAY BE SWITCHED BY COMMAND TO ANY OF THE FOUR SENSORS. IT THEN STEPS AUTOMATICALLY THROUGH THE SELECTED SENSORS MONITORING EACH IN TURN FOR 16 SEC. THE FUNCTIONAL BLOCK DIAGRAM IS SHOWN IN FIGURE 6.1. WHEN A SIGNAL EXCEEDS A COMMANDABLE THRESHOLD ITS AMPLITUDE IS SAMPLED AT 16 POINTS TO MEASURE THE PULSE SHAPE. THE 16 SAMPLES MAY BE SPACED LOGARITHMICALLY OR LINEARLY IN TIME. THE LOGARITHMIC SPACING COVERS THE RANGE FROM 7 NSEC TO 492 μSEC. THE LINEAR SPACING IS COMMANDABLE WITH FOLLOWING OPTIONS: 0.15, 0.16, 0.24, 1.0, 3.8, 30, AND 250 μSEC. THE AMPLITUDE IS MEASURED BY A BANK OF 24 DISCRIMINATORS, 12 POSITIVE AND 12 NEGATIVE. THE TOTAL RANGE IS 3 MV TO 1.8 V. THE SIGNAL FROM EACH SENSOR CAN BE ATTENUATED BY COMMAND TO PLACE IT WITHIN RANGE. THERE ARE SIX ATTENUATION SETTINGS THAT SELECT MEASUREMENT RANGES FROM 3 MV TO 1.84 V AT MINIMUM ATTENUATION TO 3.46 V TO 1910 V AT MAXIMUM ATTENUATION. THE THRESHOLD IS COUPLED TO THE ATTENUATION SETTING. THE ATTENUATION, THRESHOLD, AND SAMPLING INTERVAL CAN BE INDEPENDENTLY COMMANDED FOR EACH SENSOR. THE NUMBER OF PULSES PER SECOND ABOVE FOUR SELECTABLE THRESHOLDS IS ALSO MEASURED. THREE OF THE THRESHOLDS ARE DETERMINED BY THE ATTENUATION SELECTION, THE FOURTH IS THE PULSE ANALYSIS THRESHOLD.

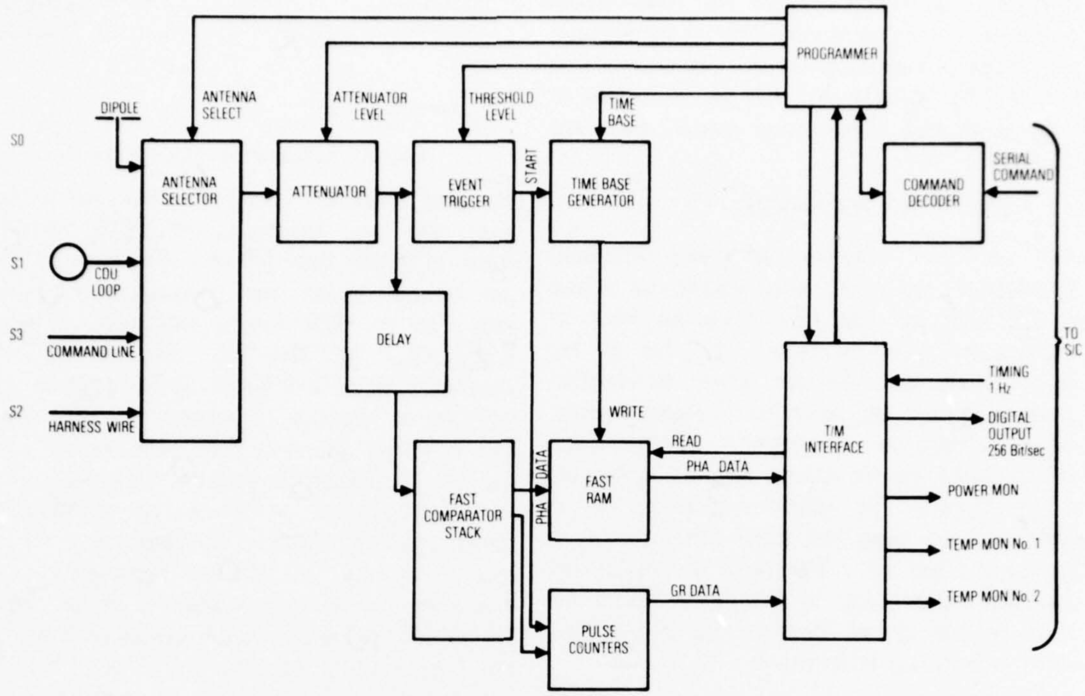


Figure 6.1. SC1-8B Pulse Analyzer Simplified Block Diagram

The instrument is commanded by a 22-bit serial magnitude command of which only the seven least significant bits are used.

6.4 OPERATIONAL ASPECTS

In its normal mode of operation the instrument steps through each of the four sensors monitoring each for 16 sec in sequence. The thresholds and attenuations for each sensor will be determined by experience on orbit.

Initial measurements will be made with the logarithmic sample spacing. Later linear spacing will be used if typical pulses prove to be very short (<100 nsec) or very long (>200 μsec).

Inflight verification of the calibration is accomplish by sending serial magnitude commands from the Command Distribution Unit to the serial magnitude command sensor.

7. SC2 SHEATH ELECTRIC FIELDS

7.1 SCIENTIFIC OBJECTIVES

This experiment is intended to provide the electron and ion distribution functions, over a limited energy range, at three positions in the spacecraft plasma sheath. The experiment also measures the floating potential of two Agua-Dag (colloidal graphite) coated spherical probes relative to the spacecraft ground over a large dynamic range. The spherical probes can be biased relative to the spacecraft upon ground command. The current to one of the biased probes is also measured. The biased probes modify the particle distribution measured at the probe and in their vicinity. The aims of the experiment are to obtain insight into the characteristics of spacecraft sheath fields, to observe the effects of particles that comprise the energetic plasma near a spacecraft, to observe the potential that a relatively simple geometrical shape (a sphere) attains in the plasma environment both in sunlight and in shadow, and to monitor the influence that the spacecraft itself has on the final potential that such simple objects attain. These observations will be compared with the results of

OTHER MORE COMPREHENSIVE PLASMA MEASUREMENTS ABOARD THE SPACECRAFT TO OBTAIN NEW INSIGHTS CONCERNING THE PLASMA SHEATHS THAT FORM AROUND OBJECTS IN HOT DILUTE PLASMAS BOTH IN THE PRESENCE AND ABSENCE OF PHOTOILLUMINATION. THE OBSERVATIONS WILL BE USED AS TEST DATA FOR THE VALIDATION OF SPACECRAFT-PLASMA INTERACTION MODELS THAT ARE BEING DEVELOPED.

7.2 MEASURING TECHNIQUE

THE EXPERIMENT CONSISTS OF THREE MINIATURE ELECTROSTATIC ANALYZERS, WHICH MEASURE THE FLUXES OF ELECTRONS AND IONS OVER A LIMITED RANGE OF ENERGIES AS SHOWN IN TABLE 7.1. TWO OF THE ANALYZERS ARE EACH ENCLOSED WITHIN BOOM-MOUNTED SPHERICAL PROBES AND THE THIRD IS MOUNTED BEHIND THE CENTER BAND ON THE SPACECRAFT. THE BOOMS ARE 180 DEG APART AND ARE MOUNTED NEAR THE CENTERLINE OF THE VEHICLE. THE RELATIVE GEOMETRIES OF THE SPACECRAFT AND BOOMS ARE SHOWN SCHEMATICALLY IN FIGURES 2.2 AND 7.1. THE FIELDS OF VIEW OF THE ANALYZERS ARE PARALLEL TO EACH OTHER AND TO THE FIELD OF VIEW OF THE ENERGETIC PROTON DETECTOR, WHICH IS DESCRIBED IN SECTION 8.

Table 7.1. SC2 Electrostatic Analyzer Energies

	Step	Approximate Energy (eV/charge)	
		Electrons	Ions
Program 1	0	190	150
	1	450	350
	2	1060	830
	3	2530	1980
	4	4480	3510
	5	10500	8200
	6	18600	14500
	7	Return to zero	Return to zero
Program 2	0	0.0 - 5	0.0 - 4
	1	90	70
	2	330	260
	3	800	630
	4	1890	1480
	5	5960	4660
	6	14000	11000
	7	Return to zero	Return to zero
Program 3	0	6 - 13	5 - 10
	1	20 - 24	15 - 20
	2	45	36
	3	600	470
	4	1410	1110
	5	3380	2650
	6	7850	6150
	7	Return to zero	Return to zero

EACH ELECTROSTATIC ANALYZER CONSISTS OF THREE CONCENTRIC CYLINDRICAL PLATES THAT DEFLECT THE PARTICLES OF PROPER ENERGY PER CHARGE THROUGH 127

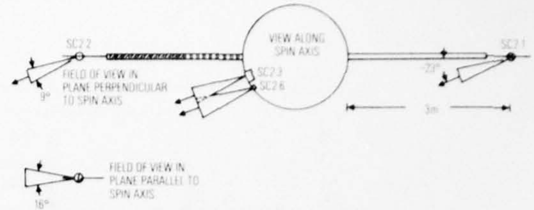


Figure 7.1. Spacecraft and Boom Geometry

DEG ONTO SPIRALTRON CHANNEL ELECTRON MULTIPLIERS WHERE THEY ARE DETECTED. THE CENTER ANALYZER PLATE IS BIASED FROM ~0.0 TO +1600 V, WHILE THE TWO OUTSIDE PLATES ARE SIMULTANEOUSLY BIASED FROM ~ 0.0 TO -1600 V BY A PROGRAMMER AS SHOWN SCHEMATICALLY IN FIGURE 7.2. THE IONS ARE POST ACCELERATED BY -1600 V BEFORE IMPINGING ON THE ION DETECTOR TO INCREASE THE DETECTION EFFICIENCY. THE ELECTRONS ARE NOT POST ACCELERATED. THE ANLAYZER COLLIMATER AND SERRATED PLATES ARE COATED WITH "GOLD BLACK" TO REDUCE THE ULTRAVIOLET RESPONSE OF THE SYSTEM. THE THREE UNITS ARE AS NEARLY IDENTICAL AS POSSIBLE MECHANICALLY AND ELECTRICALLY. THE ANGULAR RESPONSE OF THE UNITS (FW AT 10% MAXIMUM RESPONSE) ARE APPROXIMATELY 9 AND 7 DEG FOR THE ELECTRONS AND 16 AND 9 DEG FOR THE IONS IN PLANES PARALLEL AND PERPENDICULAR, RESPECTIVELY, TO THE SPACECRAFT SPIN AXIS. THEY HAVE GEOMETRIC FACTORS OF $\sim 1.7 \times 10^{-4}$ CM^2 STER FOR ELECTRONS AND $\sim 6.7 \times 10^{-4}$ CM^2 STER FOR *IONS. THE ENERGY RESOLUTIONS ARE* $\Delta E/E = \sim 0.09$ FOR ELECTRON AND $\Delta E/E = 0.14$ FOR IONS.

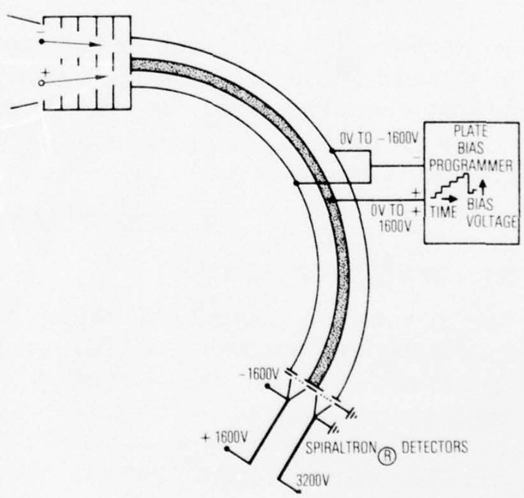


Figure 7.2. Schematic Diagram of ESA

THE SPHERICAL PROBES CONTAINING THE ELECTROSTATIC ANALYZERS ARE ~17.8 CM IN DIAMETER. THE BOOMS ON WHICH THEY ARE MOUNTED ON ARE 2.54 CM DIA FOR THE FIRST 38 CM AND HAVE A SHADOW STUB OF THE SAME DIA AND 25.4 CM LONG (SEE FIGURE 7.1). THE SPHERES, THE SHADOW STUB, AND THE 2.54 CM DIA BOOM SECTIONS ARE COATED WITH AQUA-DAG. THE SPHERICAL PROBES CONTAIN ALL ELECTRONICS NECESSARY TO SUPPORT THE ELECTROSTATIC ANALYZERS, PLUS THOSE NECESSARY TO PROVIDE BIAS VOLTAGES FOR THE PROBES AND TO MEASURE THE POTENTIAL BETWEEN THE PROBES AND THE SPACECRAFT FRAME. ONE PROBE, SC2-1, ALSO CONTAINS A DIGITAL ELECTROMETER FOR MEASURING THE CURRENT TO THE PROBE WHEN IT IS BIASED.

THE PROBE VOLTAGE MEASUREMENT IS A NULL MEASUREMENT. A SPHERICAL FARADAY CAGE, WHICH SURROUNDS ALL THE ELECTRONICS AND THE PARTICLE ANALYZER, IS BIASED RELATIVE TO THE SPACECRAFT FRAME. THE VOLTAGE DIFFERENCE BETWEEN THIS FARADAY CAGE AND THE PROBE SURFACE IS SENSED AND CONTROLLED IN A "FOLLOWER CIRCUIT" SO THAT IT IS LESS THAN ABOUT 0.01 PERCENT OF THE PROBE VOLTAGE RELATIVE TO THE SPACECRAFT. THE SMALLEST COMMON MODE VOLTAGE MEASURABLE IN THIS MANNER IS $\lesssim \pm 10^{-2}$ V AND THE LARGEST IS ~± 700 V. IF THE PROBE VOLTAGE SHOULD ATTEMPT TO EXCEED THIS MAXIMUM RANGE, THE CIRCUITRY CHANGES IMPEDANCE TO LIMIT THE VOLTAGE THE PROBES CAN ATTAIN. IN THE BIASED MODE THE PROBES CAN BE STEPPED THROUGH SEVERAL BIAS PROGRAMS WITH THE TWO MAJOR ONES COVERING THE APPROXIMATE RANGES 0 TO ±20 V AND 0 TO ± 450 V IN 32 QUASI-LOGARITHMICALLY SPACED STEPS AS SHOWN IN TABLE 7.2.

THE INTERIOR OF ONE OF THE SPHERICAL PROBES IS SHOWN SCHEMATICALLY IN FIGURE 7.3. THE CASE OF THE ELECTROSTATIC ANALYZER AND ALL ITS CIRCUITRY IS ELECTRICALLY REFERENCED TO THE FARADAY SHIELD, THUS THE PARTICLES ARE NOT PREACCELERATED BETWEEN THE PROBE SURFACE AND THE ANALYZER. TO OBTAIN THE ACTUAL PARTICLE ENERGY MEASURED, ONE MUST ACCOUNT FOR THE PROBE VOLTAGE.

Table 7.2. Probe Bias Programs*

Program 1		Program 2		Program 3		Program 4	
Step Seq.#	Voltage	Step Seq.	Voltage	Step Seq.	Voltage	Step Seq.	Voltage
7	0	7, 24	0	0	-449	0	-54.8
15	0.1	15	0.08	1	-159	1	55.4
8	0.2	8	0.12	2	-54.8		
25	0.31	25	0.21	3	55.4		
14	0.63	14	0.25	4	164		
31	1.27	31	0.38	5	452		
9	1.90	9	0.62				
26	3.96	26	0.78				
13	7.9	13	1.17				
30	11.9	30	1.95				
10	28.0	10	2.42				
27	55.4	27	3.65				
12	82.6	12	6.03				
29	164	29	8.24				
28	313	28	12.4				
11	452	11	20.5				
24	0	24	0				
16	-0.1	16	-0.08				
23	-0.2	23	-0.13				
6	-0.28	6	-0.21				
17	-0.63	17	-0.25				
0	-1.3	0	-0.39				
22	-1.91	22	-0.63				
5	-3.96	5	-0.78				
18	-7.9	18	-1.18				
1	-11.9	1	-1.96				
21	-27.3	21	-2.37				
4	-54.8	4	-3.6				
19	-82.2	19	-6.0				
2	-159	2	-8.03				
3	-309	3	-12.2				
20	-449	20	-20.4				

*Value of bias voltages are for SC2-1, SC2-2 similar.

#Step sequence indicates the order in which the biases are applied, there are 32 steps (0-31) in Programs 1 and 2, 6 steps (0-5) in Program 3 and 2 steps in Program 4.

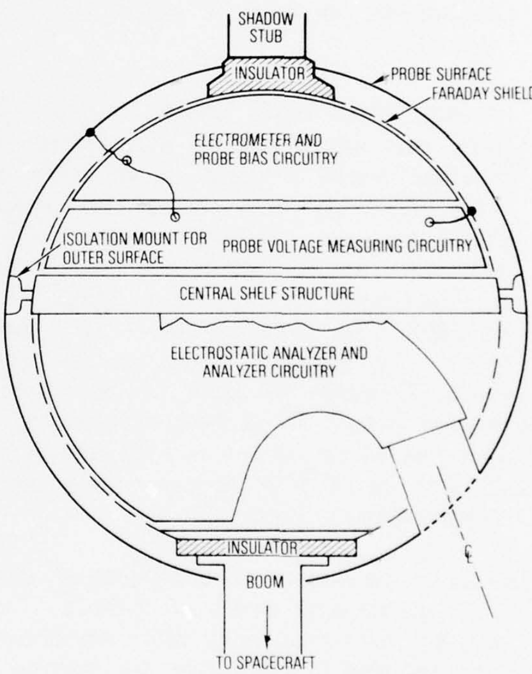
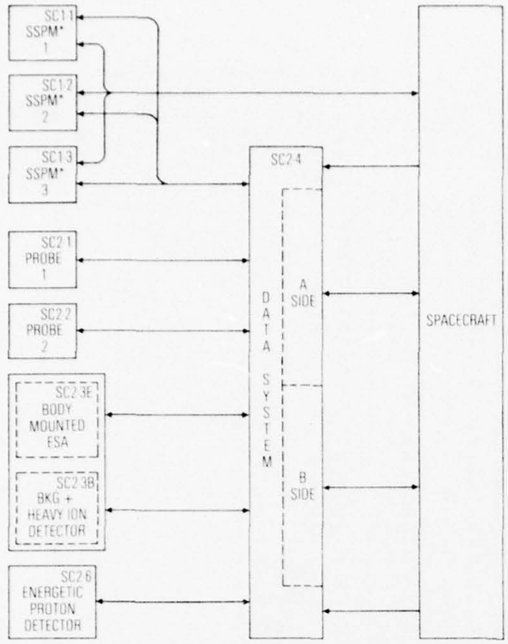


Figure 7.3. Spherical Probe Schematic

7.3 FUNCTIONAL BLOCK DIAGRAM

THE DATA FLOW THROUGH THE SHEATH ELECTRIC FIELD EXPERIMENT (SC2) IS COMPLICATED AND SEVERAL DIAGRAMS ARE REQUIRED TO REPRESENT IT. FIGURE 7.4 SHOWS THE RELATIONSHIP BETWEEN THE SC2 EXPERIMENTS, THE SSPM (REF. SECTION 3), AND THE SPACECRAFT. THE DATA SYSTEM THAT IS CONTAINED IN UNIT SC2-4 IS THE DIGITAL INTERFACE FOR ALL THE SSPM UNITS AND IS THE COMPLETE INTERFACE FOR ALL



*Satellite Surface Potential Monitor, Ref. Section 4.1

Figure 7.4. Relationship Between SC1 and SC2

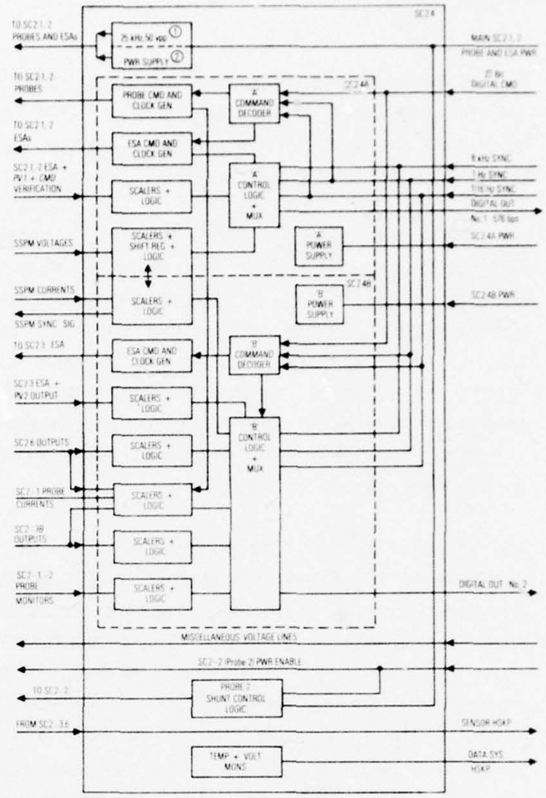


Figure 7.5. SC2 Data System Block Diagram

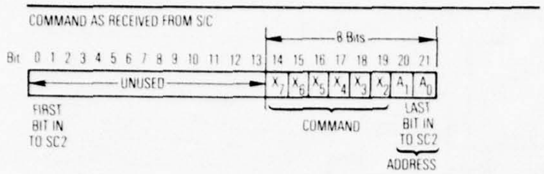
THE SC2 UNITS WITH THE SPACECRAFT. THE DETAILS OF THIS INTERFACE ARE SHOWN IN GREATER DETAIL IN FIGURE 7.5.

THE DATA SYSTEM SERVES SEVERAL PURPOSES. IT PASSES POWER THROUGH FROM THE SPACECRAFT TO THE INDIVIDUAL SENSORS AS SHOWN IN THE BOTTOM OF FIGURE 7.5 IT ALSO PASSES THE ANALOG HOUSEKEEPING DATA FROM THE SENSORS TO THE SPACECRAFT. THE DATA SYSTEM ALSO CONTAINS THE MAIN POWER SUPPLY FOR THE SPHERICAL PROBES SC2-1 AND SC2-2. THE REFERENCED SUPPLY IS A DUAL SUPPLY. THE SEPARATE INVERTER CIRCUITS EACH PROVIDE 25 KHZ-50 VPP POWER FOR ONE OF THE SPHERICAL PROBES. THE AC POWER IS ROUTED INSIDE THE PROBES VIA REED RELAYS THAT ARE ACTUATED BY THE SC2-1 AND SC2-2 28 VDC ENABLE POWER LINES, REFERENCE BOTTOM OF FIGURE 7.5.

THE LOGIC FUNCTIONS OF THE DATA SYSTEM ARE SPLIT INTO TWO INDEPENDENT SUBSYSTEMS, A AND B. EACH SUBSYSTEM HAS ITS OWN POWER SUPPLY AND RECEIVES POWER ON SEPARATE LINES FROM THE SPACECRAFT. WITHIN EACH SUBSYSTEM IS A COMMAND DECODER FOR PROCESSING THE 22-BIT DIGITAL COMMANDS FROM THE SPACECRAFT, A SYSTEM OF CONTROL LOGIC AND SYNC CIRCUITRY, AND A MULTIPLEXER FOR FEEDING THE SYNCHRONOUS SENSOR DATA, COMMAND VERIFICATION DATA, AND SYNC WORDS TO THE SPACECRAFT. THE SENSOR OUTPUTS ARE WIRED TO THE APPROPRIATE SUBSYSTEM CIRCUITS WITH THE RELATIONSHIPS SHOWN SCHEMATICALLY IN FIGURE 7.5. THE CONTENTS OF SEVERAL OF THE TELEMETRY BYTES ARE CONTROLLED BY THE DIGITAL COMMANDS FROM THE SPACECRAFT.

THE SPACECRAFT COMMAND IS EFFECTIVELY 8 BITS LONG WITH THE TWO LSB BEING THE SENSOR ADDRESS AND THE SIX MSB BEING THE COMMAND FOR THAT ADDRESS AS SHOWN IN FIGURE 7.6. THE RECEIVED COMMANDS ARE STORED, BY ADDRESS, IN REGISTERS IN THE APPROPRIATE SUBSYSTEM (A OR B). THE COMMANDS ARE DISPLAYED IN THE TELEMETRY OUTPUT FOR VERIFICATION WITHIN THREE SECONDS AFTER THEY ARE RECEIVED. THE DATA SYSTEM LOGIC SETS UP THE SENSOR PROGRAM AND SENDS COMMANDS TO THE SENSORS TO EXECUTE THE FIRST STEP OF THE PROGRAM IMMEDIATELY. THIS FIRST STEP IS CONTINUOUSLY EXECUTED UNTIL THE NEXT 1/16 HZ CLOCK PULSE IS RECEIVED, AT WHICH TIME THE PROGRAM

EXECUTION PROCEEDS IN SYNCHRONIZATION WITH THE SPACECRAFT. THE SYNCHRONIZATION IS EVIDENCED BY THE SYNC BYTES IN THE TM STREAM FOR EACH SENSOR.



SC2 ADDRESS STRUCTURE

COMMAND	ADDRESS		
XXXXXX	00	SC2 1, 2 PROBE LOGIC	VERIFICATION ON DIGITAL No 2
XXXXXX	10	SC2 1, 2 ESA LOGIC	VERIFICATION ON DIGITAL No 1
XXXXXX	01	SC2 3 ESA LOGIC	VERIFICATION ON DIGITAL No 2
XXXXXX	11	SC2 3 B LOGIC	VERIFICATION ON DIGITAL No 2
765432	10	SC2 BIT COUNT	

ESA COMMAND STRUCTURE (Addresses 01 and 10)*

6 Bits

765432 SC2	BIT COUNT
000000	STEP PROGRAMS 1, 2 AND 3 EXECUTED IN SEQUENCE, 8 STEPS/sec – DEFAULT MODE†
000001	STEP PROGRAM 1 ONLY, 8 STEPS/sec
000010	STEP PROGRAM 2 ONLY, 8 STEPS/sec
000100	STEP PROGRAM 3 ONLY, 8 STEPS/sec
000011	STEP PROGRAMS 1 AND 2 EXECUTED IN SEQUENCE, 8 STEPS/sec
000101	STEP PROGRAMS 1 AND 3 EXECUTED IN SEQUENCE, 8 STEPS/sec
000110	STEP PROGRAMS 2 AND 3 EXECUTED IN SEQUENCE, 8 STEPS/sec
001XXX	CHANGE ALL STEP RATES TO 64 sec/STEP
01XXXX	DETECTOR BIAS BOOST No 1 ON
10XXXX	DETECTOR BIAS BOOST No 2 ON

*The SC2 1, 2 and 3 ESAs have the same command structure

PROBE LOGIC COMMAND STRUCTURE (address 00)

6 BITS

765432	SC2 BIT COUNT
000000	FLOATING SC2 1, 2 PROBE VOLTAGE MEASUREMENT – DEFAULT MODE†
000001	ELECTROMETER CALIBRATION – REAL TIME COMMANDED
000010	PROBE BIAS PROGRAM 1 – HIGH RANGE, 8 STEPS/sec – REAL TIME INITIATION*
000100	PROBE BIAS PROGRAM 2 – LOW RANGE, 8 STEPS/sec – REAL TIME INITIATION
001010	PROBE BIAS PROGRAM 1 – HIGH RANGE, 64 sec/STEP – REAL TIME INITIATION
001100	PROBE BIAS PROGRAM 2 – LOW RANGE, 64 sec/STEP – REAL TIME INITIATION
010010	PROBE BIAS PROGRAM 3 – 6 STEPS, 512 sec/STEP – REAL TIME INITIATION
100010	PROBE BIAS PROGRAM 4 – 2 STEPS, 512 sec/STEP – REAL TIME INITIATION

*Can be initiated in real time with automatic shut off after ~1 hour

SC2 3 B SENSOR LOGIC

000000	NORMAL MODE – NO PRIORITY – DEFAULT MODE†
000001	PRIORITY 1
000010	PRIORITY 2
000100	PRIORITY 3
001000	UNUSED
010000	UNUSED
100000	UNUSED
765432 SC2 BIT COUNT	

† Default mode is the state logic will be in when power is applied to SC2 4A and SC2 4B, prior to commanding and after any power interruptions.

Figure 7.6. SC Magnitude Commands

THE FUNCTIONAL DIAGRAM FOR A REPRESENTATIVE ELECTROSTATIC ANALYZER IS SHOWN IN FIGURE 7.7. THIS DIAGRAM REPRESENTS THE SC2-1 AND SC2-2 ESAs IN THE SPHERICAL PROBES.

THE ION AND ELECTRON DETECTORS ARE FOLLOWED BY CHARGE-SENSITIVE PREAMPLIFIERS, PULSE AMPLIFIERS, DISCRIMINATORS, AND ONE-SHOTS. THE OUTPUTS OF THE ONE-SHOTS FOR SC2-1 AND SC2-2 ESAs ARE TRANSMITTED DOWN THE BOOM VIA 2 kV ISOLATION TRANSFORMERS. ALL COMMANDS, POWER (EXCEPT FOR RELAY POWER), AND DATA FOR THE SC2-1 AND SC2-2 ARE TRANSMITTED ACROSS HIGH VOLTAGE ISOLATION USING TRANSFORMERS. THE SC2-3 IS NOT ISOLATED.

THERE ARE FOUR INDEPENDENT HIGH VOLTAGE SUPPLIES AND ONE LOW VOLTAGE SUPPLY FOR EACH ESA. ANY SINGLE SUPPLY CAN FAIL WITHOUT DAMAGING ANY OF THE OTHERS OR BY "PULLING DOWN" THE 25 kHz POWER LINES. SINCE THE ESA IS ENABLED SEPARATELY, IF MULTIPLE FAILURES OCCUR THE ESA CAN BE ISOLATED SO THE PROBE VOLTAGE MEASUREMENTS CAN STILL BE OBTAINED. SIMILAR FLEXIBILITY IS AVAILABLE WITHIN THE PROBE VOLTAGE AND CURRENT MEASUREMENT SECTION OF THE PROBES. THUS, IF ONE DETECTOR OR PLATE BIAS SUPPLY FAILS, THE REMAINING SUPPLIES WILL FUNCTION AND STILL PROVIDE USEFUL DATA. THE VOLTAGE ON ALL SUPPLIES ARE MONITORED CONTINUOUSLY. THE DETECTOR SUPPLY VOLTAGES CAN BE CHANGED BY COMMAND TO ONE OF FOUR LEVELS. THESE WILL BE UTILIZED TO BOOST DETECTOR GAIN ON ORBIT AS THE NEED ARISES.

THE FUNCTIONAL DIAGRAM FOR THE VOLTAGE AND CURRENT SECTIONS OF SPHERICAL PROBES IS SHOWN IN FIGURE 7.8. THE FUNCTIONAL STATE OF EACH SECTION IS DETERMINED BY EITHER 28 V REED RELAY CLOSURES VIA THE DATA SYSTEM AND/OR SPACECRAFT (SWITCHES SW1 TO SW4 IN PROBE 1 OR SW1 TO SW3 IN PROBE 2) AND BY DIGITAL COMMANDS THE PROBES RECEIVE FROM THE DATA SYSTEM. THE POWER, COMMANDS AND DATA FOR THE SC2-1 AND SC2-2 PROBE VOLTAGE AND CURRENT MEASURING SYSTEMS ALL CROSS HIGH VOLTAGE ISOLATION VIA TRANSFORMERS.

THE POWER CONTROL UTILIZES REED RELAYS THAT PROVIDE ISOLATION BETWEEN THE + 28-VDC SPACECRAFT POWER AND THE SENSOR. THE PROBES HAVE SEVERAL INDEPENDENT POWER SUPPLIES. PROBE 1 HAS ONE HIGH VOLTAGE AND TWO LOW VOLTAGE SUPPLIES (ONE FOR THE ELECTROMETER) WHILE PROBE 2 HAS ONLY ONE HIGH VOLTAGE AND ONE LOW VOLTAGE SUPPLY. LIKE THE ESAs, A FAILURE IN A SUPPLY CANNOT DAMAGE THE MAIN 25 kHz - 50 VPP SUPPLY IN THE DATA SYSTEM AND THE PROBE CAN BE ISOLATED BY SPACECRAFT COMMAND. IF THE PROBE VOLTAGE SECTION IS OFF BUT THE ESA IS ON THEN THE PROBE SHUNT COMMAND MUST BE EXECUTED FOR PROBE 1. THE PROBE SHUNT COMMAND IS AUTOMATICALLY EXECUTED FOR SUCH A CONDITION IN PROBE 2. THE SHUNTS TIE THE OUTER SURFACE OF THE SPHERICAL

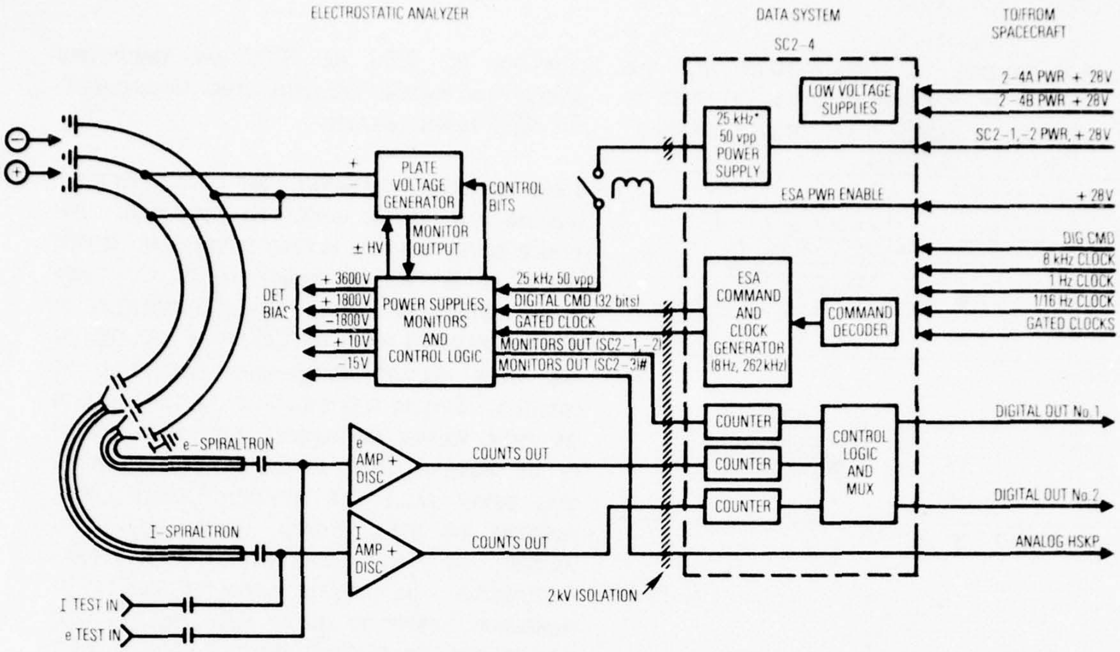


Figure 7.7. Sheath Electric Fields ESA Functional Block Diagram

PROBE TO SPACECRAFT STRUCTURE GROUND VIA A 100 ΩK RESISTOR. THIS QUARANTEES A REFERENCE FOR THE ESA PARTICLE MEASUREMENTS.

7.4 OPERATIONAL ASPECTS

THE ESAs ARE CONTROLLED BY THE DATA SYSTEM. WHEN THE ESA IS POWERED UP IT RESPONDS TO THE 32-BIT COMMAND THAT IS IN ITS STORAGE REGISTER AT THAT TIME. THE 32-BIT ESA COMMAND WORD IS SENT BY THE DATA SYSTEM TO THE ESAs EIGHT TIMES A SECOND IN BURSTS ~125 μSEC LONG (CLOCK RATE~260 KHZ). WHEN THE DATA SYSTEM IS FIRST TURNED ON IT IMMEDIATELY STARTS SENDING A PREDETERMINED PROGRAM TO THE ESAs. IF A DIFFERENT ESA COMMAND IS NOT TRANSMITTED TO THE DATA SYSTEM BY THE SPACECRAFT, THE ESAs CONTINUALLY EXECUTE THIS "DEFAULT" PROGRAM. TWENTY-TWO BITS CONTROL THE ESA PLATE BIASES, TWO CONTROL THE DETECTOR BIASES, AND EIGHT CONTROL THE HOUSEKEEPING DATA MULTIPLEXER IN EACH ESA. THERE ARE A TOTAL OF FOURTEEN ESA OPERATIONAL PROGRAMS THAT ARE USED TO INCREASE OR DECREASE THE NUMBER OF ENERGIES MEASURED AND THAT CHANGE THE TIME TAKEN TO OBTAIN A COMPLETE SPECTRUM. A CRUDE SPECTRUM CAN BE OTAINED IN ONE SEC. A COMPLETE SPECTRUM CAN BE OBTAINED IN AS LITTLE AS THREE SEC. IF GOOD ANGULAR RESOLUTION IS REQUIRED THE ENERGIES CAN BE SCANNED SLOWLY (64 SEC PER ENERGY) WITH VALUES OBTAINED AT EIGHT SAMPLES PER SEC. IN THIS MODE A COMPLETE SPECTRUM IS OBTAINED IN 512 SEC. THE SC2-1 AND SC2-2 ESAs ARE ALWAYS IN THE SAME PROGRAM SINCE THEY ARE DRIVEN BY THE SAME COMMAND GENERATOR IN THE DATA SYSTEM. THE SC2-3 ESA COMMANDS ARE GENERATED SEPARATELY. THE OUTPUTS FROM THE ESA DETECTORS ARE ACCUMULATED FOR 101.5 MSEC EACH 125 MSEC IN 12-BIT COMPRESSED SCALERS. THE SCALER CONTENTS ARE MULTIPLEXED INTO THE TM STREAM BY THE DATA SYSTEM. THE SCALERS ARE INHIBITED FOR ~23 MSEC AFTER EACH 32-BIT COMMAND IS SENT TO ALLOW THE ESA PLATE VOLTAGES TO STABILIZE BEFORE ACCUMULATING A NEW SAMPLE.

THE VOLTAGE AND CURRENT MEASUREMENT SECTION OF THE PROBES IS CONTROLLED BY BOTH THE SPACECRAFT AND DATA SYSTEM COMMANDS. THE DIGITAL DATA SYSTEM COMMANDS ARE 8-BIT BYTES THAT ARE TRANSMITTED TO THE PROBES EIGHT TIMES A SECOND IN BURSTS LASTING~ 30 μSEC (CLOCK RATE IS~260 KHZ). THE PROBE RESPONDS IMMEDIATELY TO EACH NEW COMMAND. WHEN THE DATA SYSTEM IS TURNED ON IT IMMEDIATELY STARTS SENDING COMMANDS THAT CONSIST OF ALL ZEROS. THIS PLACES THE PROBE INTO A FLOATING VOLTAGE

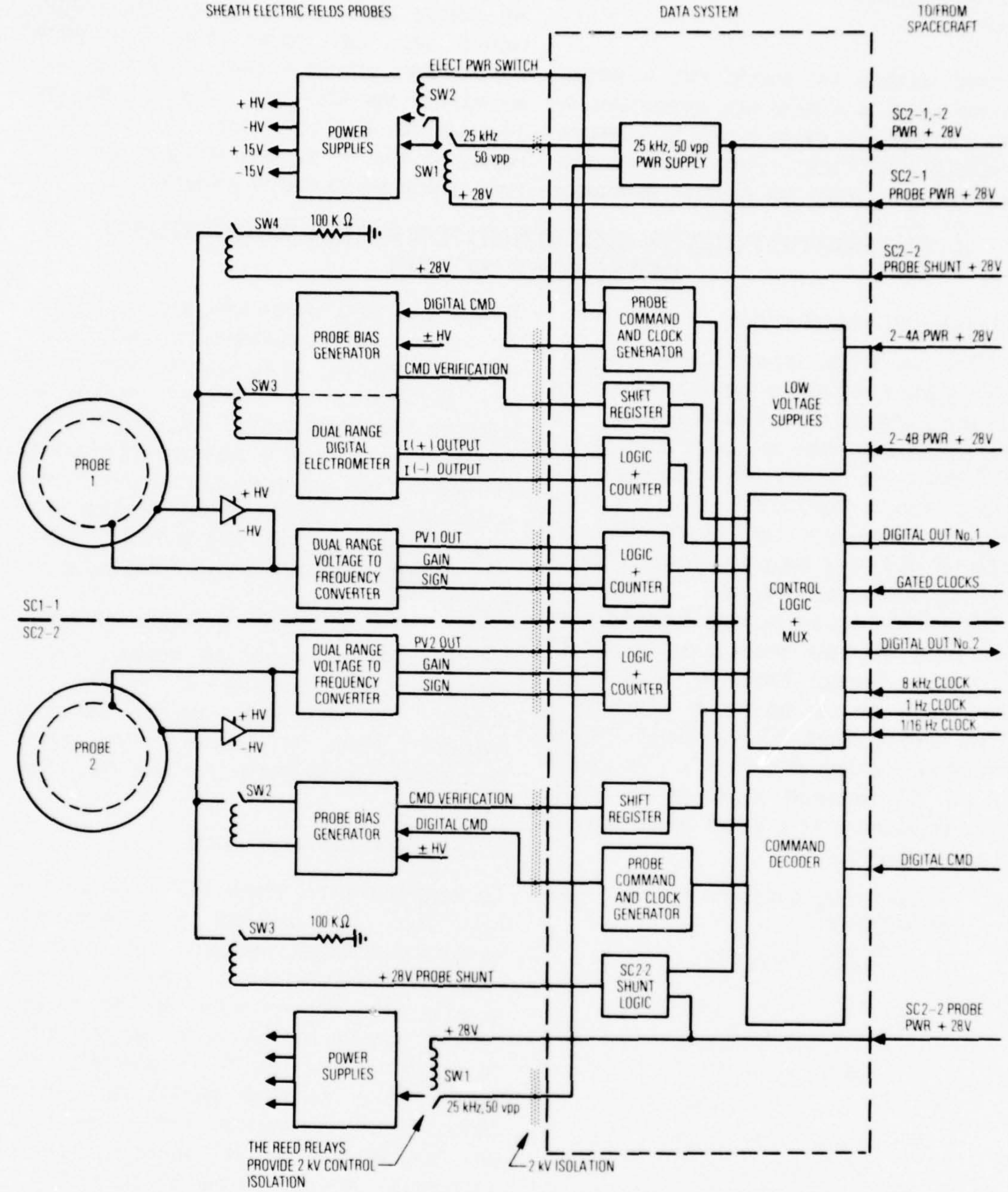


Figure 7.8. Functional Block Diagram for SC2-1 and SC2-2 Voltage and Current Measurements

MEASUREMENT MODE WHEN ITS POWER SUPPLIES ARE ENABLED. IF A NEW PROBE COMMAND IS NOT SENT BY THE SPACECRAFT TO THE DATA SYSTEM THE PROBE STAYS IN THE FLOATING VOLTAGE MEASUREMENT OR "DEFAULT" MODE. THE OTHER COMMANDS ALLOW THE PROBES TO CALIBRATE THE ELECTROMETER, AND TO PROVIDE SIX DIFFERENT BIAS PROGRAMS (SEE FIGURE 7.6). THE BIAS PROGRAMS HAVE DIFFERENT PERIODS AND CONTAIN DIFFERENT NUMBERS OF UNIQUE VOLTAGES. WHEN THE PROBES ARE BEING BIASED, THE ELECTROMETER IS ACTIVE IN PROBE 1 AND MEASURES THE CURRENT TO THAT PROBE. THE COMMANDS ARE MONITORED ONCE A SECOND and the bit patterns, as returned to the data system by the probes, are placed in the TM stream for reference.

The probe voltages are sampled once a second. Since the output is a pulse rate proportional to voltage, a compressed scaler is used to accumulate the pulses for 101.5 msec. These counts are then combined with the range and polarity information into a 12-bit byte and multiplexed into the telemetry stream. Similarly, the probe currents are sampled eight times a second. The current outputs are also pulses with each pulse representing a quantum of charge. The pulses are accumulated for ~62.5 msec. The scalers are inhibited for ~62.5 msec after each new probe command is sent by the data system to allow the probe current and voltage to stabilize.

8. ENERGETIC PROTON (SC2-6) AND ION PLUS BACKGROUND DETECTORS (SC2-3B)

8.1 SCIENTIFIC OBJECTIVES

The SC2-6 and SC2-3B measure protons, alphas, carbon, nitrogen, and oxygen ions with emphasis on pitch angle coverage with good resolution. The proton measurements cover the energy range 17 keV to 3.3 MeV. The heavier ion measurements are integral, covering energies ≥96 keV/nucleon. The background contribution for protons and ions penetrating >0.3 cm of brass and having >3 MeV of energy remaining is also measured. The details of the energies measured are shown in Table 8.1. The proton energy range was chosen to overlap the SC9 UCSD Charged Particle Experiment described in Section 16 on the low end and to extend up to energies covered by the SC3 High Energy Particle Spectrometer described in Section 9. The overlap with the SC9 instrument allows us to provide similar measurements at a higher sample rate and greater sensitivity.

Table 8.1. Energy Channels for Energetic Proton Detector

Protons Channel	Energy# (MeV)
A1*	0.017 - 0.29
A2	0.029 - 0.054
A3	0.054 - 0.104
A4	0.104 - 0.189
A5	0.189 - 0.363
A6	0.363 - 0.717
A7	>0.717
A8	>3.3

$G_p \sim 2 \times 10^{-3}\ cm^2\ ster$

#Defined at half response points for 20°C. Thresholds are temperature sensitive.

*The efficiency of this channel is ≤90%.

By combining these measurements with the results of other P78-2 measurements and other near-synchronous and ground-based measurements, it will be possible to investigate proton and energetic ion acceleration and precipitation processes, the dynamics of substorms as evidenced by energetic ions via their resultant pitch angle scattering, and acceleration and transport processes. The results will also be used to update the particle environments at the P78-2 spacecraft altitudes.

The experiment will measure the temporal, spatial and directional variations in positive ion fluxes. The solid-state particle detection technique makes it possible to obtain instantaneous energy spectra for each one second interval.

8.2 MEASURING TECHNIQUE

The proton detection system (SC2-6) is shown in Figure 8.1. The instrument is a two-element solid-state detector telescope. The particles entering the collimator pass through a uniform magnetic field and then those that pass through the last defining slit are energy analyzed based on the energy depositied in the detectors. The magnetic field separates protons and heavier particles from the electrons that are deflected away from the detector. The protons and heavier ion paths are unaffected by the magnetic field.

The proton telescope consists of a front and a rear solid-state detector behind a collimator-magnet assembly. The front detector is used for energy analysis while the rear detector eliminates penetrating particles from the analysis

AND PROVIDES NECESSARY BACKGROUND INFORMATION. THE PROTON ANALYSIS PRODUCES DIFFERENTIAL FLUX MEASUREMENTS IN SIX ENERGY WINDOWS AND TWO INTEGRAL FLUX MEASUREMENTS AS SHOWN IN TABLE 8.1. THE INSTRUMENT HAS A GEOMETRIC FACTOR OF 2×10^{-3} CM^2/STER.

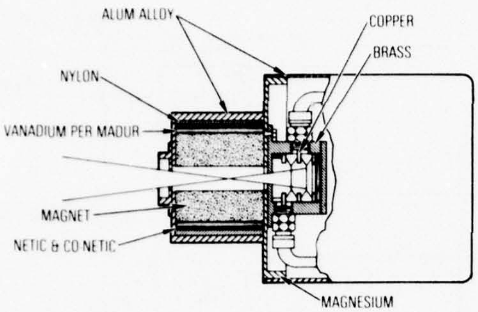


Figure 8.1. Energetic Proton Detector

THE HEAVIER ION DETECTION SYSTEM SC2-3B IS SIMILAR TO THE PROTON DETECTOR. THE ION DETECTOR IS SHOWN SCHEMATICALLY IN FIGURE 8.2. THE INSTRUMENT IS A TWO-ELEMENT SOLID-STATE TELESCOPE THAT IS HIGHLY COLLIMATED AND THE DETECTORS ARE HEAVILY SHIELDED IN ALL DIRECTIONS, EXCEPT THE SOLID ANGLE OF THE FIELD OF VIEW. THE ANALYZING MAGNET IS WELL SEPARATED FROM THE DETECTORS AND DEFLECTS ALL ELECTRONS WITH ENERGIES OF ≤ 1.7 MEV OUT OF THE BEAM. THE ENERGETIC IONS ARE NOT AFFECTED BY THE "BROOM MAGNET." THE TELESCOPE HAS A GEOMETRIC FACTOR OF 3.6×10^{-4} CM^2 STER.

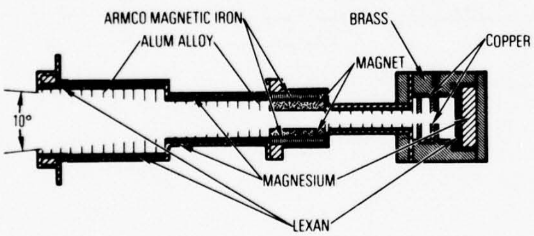


Figure 8.2. Energetic Ion Plus Background Detector

THE ION TELESCOPE CONSISTS OF A THIN FRONT DETECTOR AND A THICKER REAR DETECTOR. THE OUTPUT FROM THE FRONT DETECTOR IS ENERGY-ANALYZED WHILE THE REAR DETECTOR IS USED TO REJECT PENETRATING PARTICLES IN AND OUT OF THE FIELD OF VIEW. THE IONS ARE DIFFERENTIATED BY THE ENERGY REQUIRED TO PENETRATE THE FRONT DETECTOR. IONS WITH ENERGIES 90 KEV/NUCLEON ARE DETECTED. A HIGH THRESHOLD IS ALSO USED ON THE REAR DETECTOR TO MEASURE THOSE PARTICLES THAT PENETRATE THE BRASS SHIELD OR FRONT DETECTOR AND STILL DEPOSIT LARGE AMOUNTS OF ENERGY. THE SHIELDING SHOULD STOP <45 MEV PROTONS AND <5 MEV ELECTRONS.

8.3 FUNCTIONAL BLOCK DIAGRAMS

THE DATA FLOW THROUGH ENERGETIC PROTON DETECTOR IS ILLUSTRATED IN FIGURE 8.3. THE PARTICLE DETECTORS OF SC2-6 ARE FOLLOWED BY CHARGE SENSITIVE PREAMPLIFIERS, PULSE AMPLIFIERS, SHAPERS, AND DISCRIMINATORS. THE OUTPUTS OF MOST OF THE STACKED DISCRIMINATORS THAT FOLLOW THE FRONT DETECTOR ARE IN ANTICOINCIDENCE WITH THE REAR DETECTOR OUTPUT TO DELETE PENETRATING PARTICLES FROM THE ENERGY ANALYSIS. THE DISCRIMINATED OUPUT OF THE REAR DETECTOR IS ACCUMULATED SEPARATELY. A CHANNEL IS ALSO FORMED THAT REPRESENTS LARGE ENERGY DEPOSITS IN THE FRONT DETECTOR OR COINCIDENCE BETWEEN A LARGE ENERGY DEPOSIT IN THE FRONT AND AN OUTPUT FROM THE REAR DETECTOR. THIS LATTER CHANNEL IS AN INTEGRAL PROTON CHANNEL. THE RANDOM OUTPUT PULSES ARE CONTINUOUSLY TRANSMITTED TO THE DATA SYSTEM. THE FUNCTIONAL DIAGRAM FOR THE ION PLUS BACKGROUND DETECTOR IS SHOWN IN FIGURE 8.4. THE PARTICLE DETECTORS ARE FOLLOWED BY CHARGE SENSITIVE PREAMPLIFIERS, PULSE AMPLIFIERS, SHAPERS, AND DISCRIMINATORS. THE FRONT DETECTOR IS ENERGY-ANALYZED IN ANTICOINCIDENCE WITH THE REAR DETECTOR TO DELETE PENETRATING PARTICLES FROM THE ENERGY AND SPECIES ANALYSIS. TWO DISCRIMINATED OUTPUTS FROM THE REAR DETECTOR ARE ACCUMULATED SEPARATELY, ONE REPRESENTING ALL PARTICLES INCIDENT ON THE REAR DETECTOR AND ONE THAT CORRESPONDS TO LARGE ENERGY DEPOSITS IN THE REAR DETECTOR. THE FRONT DETECTOR OUTPUT IS ANALYZED TO GIVE SEVERAL INTEGRAL CHANNELS. THE OUTPUT DATA IS TRANSMITTED TO THE DATA SYSTEM AS RANDOM PULSES OR AS 8-BIT BYTES THAT ARE ACCUMULATED WITHIN THE EXPERIMENT ON SELECTED CHANNELS.

8.4 OPERATIONAL ASPECTS

THE FUNCTIONING OF THE SC2-6 IS INDEPENDENT OF THE DATA SYSTEM. THE DATA SYSTEM ACCUMULATES THE OUTPUT PULSES INTO 12-BIT COMPRESSED SCALERS AND MULTIPLEXES RESULTANT BYTES INTO THE TM STREAM AT THE PROPER TIMES. THE ACCUMULATION INTERVAL FOR ALL SC2-6 OUTPUTS IS ONE SECOND. SOME OF THE SC2-6 DATA CHANNELS ARE SHARED WITH OTHER SC2

MEASUREMENTS THIS IS DETERMINED BY THE COMMAND STATE OF THE EXPERIEMENT.

THE SC2-3B FUNCTIONS PARTIALLY INDEPENDENT OF THE DATA SYSTEM AND PARTIALLY UNDER THE CONTROL OF THE DATA SYSTEM. SOME OF THE OUTPUTS ARE ACCUMULATED IN 8-BIT SCALERS WITHIN THE DETECTOR AND SHIFTED OUT DIRECTLY INTO THE TM STREAM UNDER THE CONTROL OF THE DATA SYSTEM. THE REMAINING OUTPUTS ARE ACCUMULATED BY THE DATA SYSTEM INTO 8-BIT SCALERS OR 12-BIT COMPRESSED SCALERS AND THEN MULTIPLEXED INTO THE TM STREAM. THE SAMPLE RATES FOR THE SC2-3B OUTPUTS ARE 0.5, 1, AND 4 SAMPLES PER SECOND.

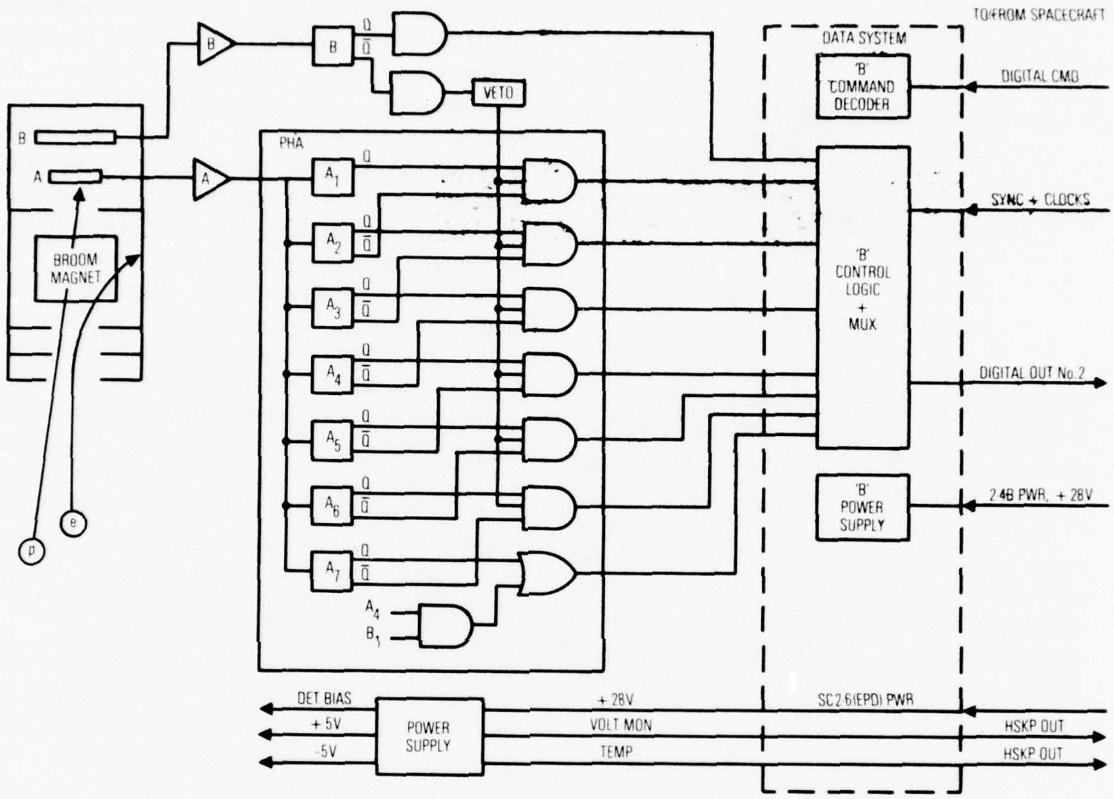


Figure 8.3. Energetic Proton Detector Schematic (SC2-6)

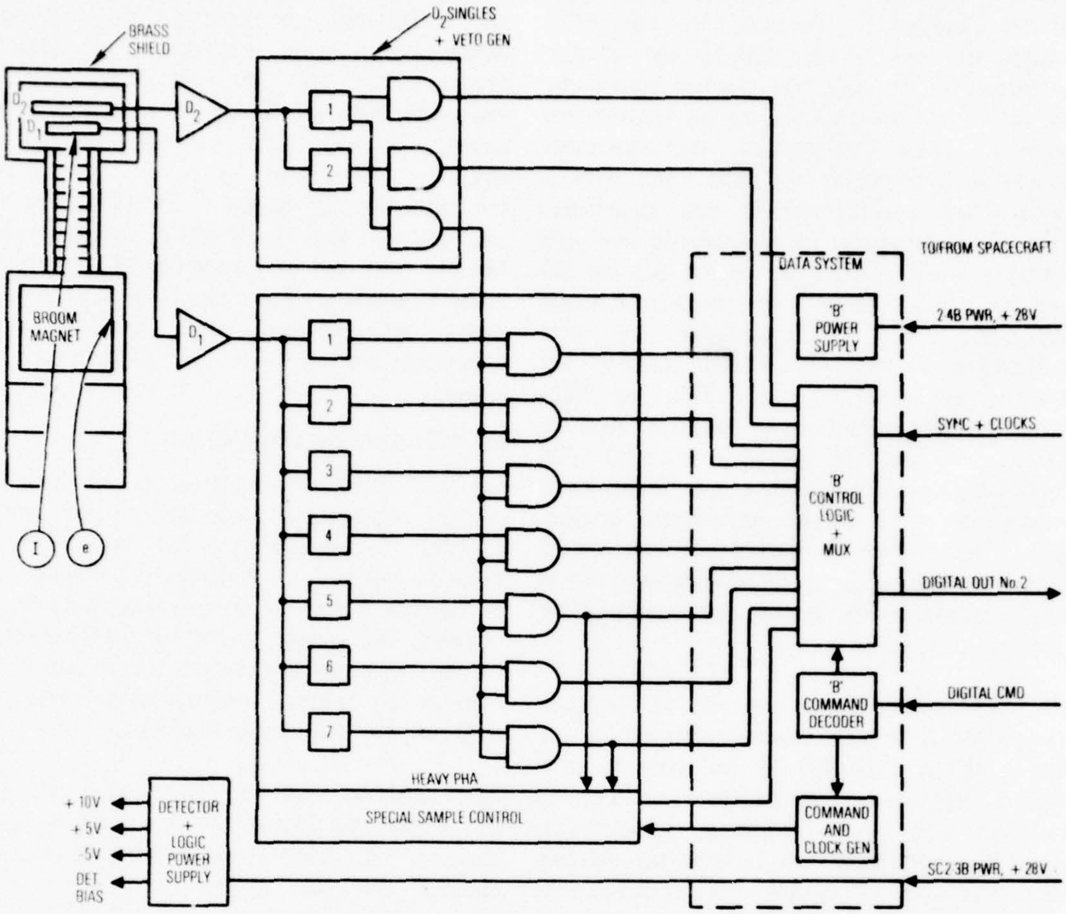


Figure 8.4. Background and Heavy Ion Sensor Schematic (SC2-3B)

9. SC3 HIGH ENERGY PARTICLE SPECTROMETER

9.1 SCIENTIFIC OBJECTIVES

THE PRIMARY GOALS OF THE SC3 PAYLOAD ARE TO MAKE ENERGETIC ELECTRON AND PROTON MEASUREMENTS THAT ARE NEEDED TO MEET THE OBJECTIVES OF THE SPACECRAFT CHARGING PROGRAM. THE ENERGETIC ELECTRON FLUX AT NEAR-SYNCHRONOUS ALTITUDES EXHIBITS PRONOUNCED PITCH-ANGLE, DIURNAL AND SOLAR ROTATION DEPENDENCES, AND IS HIGHLY DYNAMIC IN TIME. THE ENERGETIC ELECTRONS BEHAVE DIFFERENTLY IN MANY WAYS FROM THE LOW-ENERGY ELECTRONS AND, THEREFORE, MEASUREMENTS OBTAINED WITH THE SC3 SPECTROMETER WILL COMPLEMENT THE MEASUREMENTS MADE AT LOWER ENERGIES BY OTHER EXPERIMENTS ON THE P78-2 SPACEFLIGHT. ONE APPLICATION TO THE SPACECRAFT CHARGING MISSION IS THE MEASUREMENT OF FLUX INTENSITIES OF PENETRATING ENERGETIC ELECTRONS TO DETERMINE WHETHER ANOMALOUS CHARGING OF COAXIAL CABLES IN SPACECRAFT IS A SOURCE OF SYSTEM NOISE.

A KNOWLEDGE OF THE FLUXES, SPECTRA, AND PITCH-ANGLE DISTRIBUTIONS OF THE ENERGETIC ELECTRONS AT NEAR-EQUATORIAL ALTITUDES ON HIGH L-SHELLS IS ESSENTIAL TO AN UNDERSTANDING OF ENVIRONMENTAL EFFECTS ON ELF AND VLF COMMUNICATIONS. THESE COMMUNICATIONS ARE AFFECTED BY NATURALLY-OCCURRING AND ARTIFICIALLY-INDUCED WAVE-PARTICLE INTERACTIONS THROUGH TRANSFER OF WAVE ENERGY TO PARTICLE ENERGY. PERTURBATION OF THE PARTICLE ENERGY OR PITCH-ANGLE DISTRIBUTION AS A RESULT OF SUCH INTERACTIONS ENHANCES PARTICLE PRECIPITATION FROM THE RADIATION BELTS, WHICH

SUBSEQUENTLY AFFECTS LONG-WAVELENGTH COMMUNICATION SYSTEMS ADVERSELY. PAYLOADS ON THE P78-2 SPACEFLIGHT SIMULTANEOUSLY MEASURE THE DETAILED PARAMETERS OF THE ENERGETIC ELECTRON POPULATION, THE COLD PLASMA ENVIRONMENT, AND THE ELECTRIC AND MAGNETIC FIELD ENVIRONMENT NEAR-SYNCHRONOUS EQUATORIAL ALTITUDES AT ALL LOCAL TIMES UNDER A VARIETY OF NATURALLY-OCURRING WAVE CONDITIONS. THE SC3 SPECTROMETER, IN CONJUNCTION WITH LOW ENERGY ELECTRON MEASUREMENTS IN THE SC5 AND SC9 PAYLOADS, WILL DEFINE THE TRAPPED ELECTRON ENVIRONMENT THAT INTERACTS WITH THE WAVE ENVIRONMENT AS MEASURED BY THE ELECTRIC AND MAGNETIC FIELD PAYLOADS, SC1, SC10, AND SC11, UNDER WELL-DEFINED COLD PLASMA CONDITIONS THAT ARE MEASURED BY THE SC6 AND SC7 PAYLOADS. THE KNOWLEDGE OBTAINED FROM SUCH A SIMULTANEOUS STUDY SHOULD LEAD TO A BETTER UNDERSTANDING OF BOTH NATURAL AND MAN-MADE ELF AND VLF WAVE INTERACTIONS WITH TRAPPED PARTICLES IN THE MAGNETOSPHERE AND TO THE SUBSEQUENT EFFECTS OF SUCH INTERACTIONS ON THE IONOSPHERE.

THE SC3 PAYLOAD WILL MEASURE THE ELECTRON ENVIRONMENT WITH GOOD ENERGY RESOLUTION IN THE ENERGY REGION (1.5 MeV) AT THE TIME OF SOLAR MAXIMUM CONDITIONS. THE ENERGETIC ELECTRONS IN THIS ORBIT CONSTITUTE A POTENTIAL HAZARD TO THE ELECTRONIC COMPONENTS USED IN BOTH THE PAYLOADS AND THE SPACECRAFT. OUTPUTS FROM THE SC3 PAYLOAD WILL BE USED TO DETERMINE IN NEAR REALTIME THE ENVIRONMENT AND RADIATION DOSE ACQUIRED BY THE SPACECRAFT BEHIND VARIOUS SHIELDING THICKNESS. THESE DATA WILL BE USED FOR THE P78-2 SPACEFLIGHT DEGRADATION CALCULATIONS AND TO IMPROVE THE RADIATION MODELS FOR SUBSEQUENT MISSIONS.

AT THE TIMES OF SOLAR PARTICLE EVENTS THAT REACH THE EARTH, ENERGETIC SOLAR PROTONS, ELECTRONS, AND ALPHA PARTICLES TYPICALLY HAVE HIGHLY EFFICIENT ACCESS TO THE NEAR-GEOSYNCHRONOUS ORBIT. THEY MAY SIGNIFICANTLY ALTER THE ENERGETIC PLASMA COMPOSITION. THE SC3 SPECTROMETER WILL MEASURE THESE ENERGETIC SOLAR PARTICLES AND THEIR CONTRIBUTIONS TO THE BACKGROUNDS AND RADIATION DOSE IN THE OTHER ELEMENTS OF THE P78-2 SPACEFLIGHT. THE SC3 INSTRUMENT MEASURES THE FLUXES, SPECTRA, AND PITCH-ANGLE DISTRIBUTION OF THE ENERGETIC PLASMA IN THE ENERGY RANGE 50 KeV TO 5100 KeV AND THE INTEGRAL FLUX BETWEEN 5100 KeV AND 10,000 KeV. IN ADDITION, THE INSTRUMENT MEASURES THE PROTON ENVIRONMENT AT ENERGIES BETWEEN 1-200 MeV AND THE ALPHA PARTICLE ENVIRONMENT BETWEEN 6-60 MeV DURING SOLAR PARTICLE EVENTS. THE MEASUREMENTS ARE MADE WITH A PITCH ANGLE RESOLUTION OF 3 DEG (FULL-WIDTH-AT-HALF-MAXIMUM). THE ENERGY SPECTRA ARE OBTAINED WITH A 12-CHANNEL PULSE HEIGHT ANALYZER THAT CAN BE PROGRAMMED BY COMMAND TO COVER A NARROW OR WIDE ENERGY RANGE. IN THIS MANNER, BOTH COMPLETE SURVEY DATA AND HIGH RESOLUTION SPECTRAL DATA CAN BE OBTAINED ON COMMAND.

9.2 MEASURING TECHNIQUE

THE BASIC MEASUREMENT TECHNIQUE IS A SOLID-STATE PARTICLE SPECTROMETER CONSISTING OF FOUR SENSOR ELEMENTS. A LINE DRAWING OF THE SPECTROMETER IS SHOWN IN FIGURE 9.1. VARIOUS LOGIC COMBINATIONS OF THE FOUR SENSORS IN THE INSTRUMENT ARE USED TO DETERMINE THE PARTICLE TYPES AND ENERGY RANGES. THE VARIOUS PARTICLE TYPES AND ENERGY RANGES ARE MEASURED IN SEVERAL TIME-MULTIPLEXED MODES OF OPERATION THAT ARE COMMAND-SELECTABLE.

THE D-DETECTOR, WHICH IS 200μM THICK INTRINSIC SI, IS USED TO MEASURE BOTH THE RATE OF ENERGY LOSS OF THE HIGHER ENERGY PARTICLES AND TO DIRECTLY STOP AND MEASURE THE LOWER ENERGY PARTICLES. THE E-DETECTOR, WHICH CONSISTS OF FIVE 2 MM THICK DETECTORS IN PARALLEL, IS LOCATED BEHIND THE D-DETECTOR TO STOP THE HIGHER ENERGY PARTICLES AND TO MEASURE THEIR TOTAL ENERGY LOSS. THE E'-DETECTOR, WHICH IS 1000 MICRONS THICK, IS LOCATED BEHIND THE E-DETECTOR AND IS USED AS AN ACTIVE COLLIMATOR. BEHIND THE E'-DETECTOR IS A TUNGSTEN ABSORBER THAT SETS THE UPPER ENERGY LIMIT FOR ANALYSIS. ALL OF THESE DETECTORS ARE FABRICATED OF SURFACE-BARRIER SILICON AND ARE STACKED TOGETHER IN A TELESCOPE CONFIGURATION. THE ENTIRE STACK IS SURROUNDED BY THE A-DETECTOR, WHICH CONSISTS OF PLASTIC SCINTILLATOR VIEWED BY A PHOTOMULTIPLIER TUBE. THE PURPOSE OF THE A-ANTICOINCIDENCE DETECTOR IS TO SENSE AND REJECT ENERGETIC PARTICLES AND BREMSSTRAHLUNG THAT PENETRATE EITHER THE OUTER SHIELDING WALLS OF ALUMINUM AND TUNGSTEN OR THE SILICON DETECTOR STACK AND ABSORBER. THE SENSOR STACK IS LOCATED

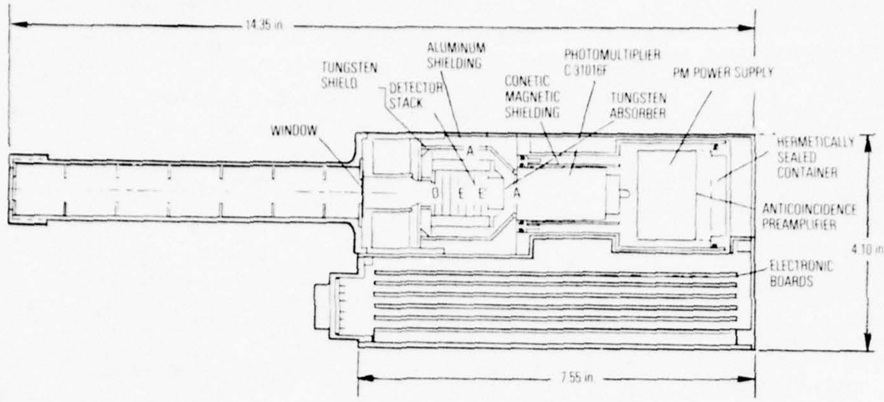


Figure 9.1. SC3 High Energy Particle Spectrometer

behind a long, narrow collimator that defines the 3 deg field of view.

9.3 FUNCTIONAL BLOCK DIAGRAM

A functional block diagram of the SC3 instrument is shown in Figure 9.2. The instrument operates from a 2048-bit semiconductor memory (CMOS) that is structured into 256 8-bit words that are individually addressable and loadable via 9-bit serial-digital commands (magnitude commands). Four of these words (32-bit control register) completely define one operating MODE of the instrument. A MODE is defined by specifying the logic conditions (coincidence/anticoincidece), gain, and energy thresholds required between the four sensor elements (D, E, E', A) to uniquely establish a particle type and energy range for analysis. A choice of two amplifier gain settings for the D- and E-detectors is available. The lower and upper energy thresholds selected for analysis by the 12-channel pulse-height-analyzer (PHA) are determined to 8-bit and 6-bit resolution, respectively. Either the D- or E-detector is selectable at any time for analysis by the PHA through the multiplexer. The energy threshold of the sensor not selected for analysis can be set to 8-bit resolution.

Eight of these modes comprise one PAGE of memory and eight PAGES constitute the complete memory. To load the complete memory requires 512 commands (address + data) and 512 seconds at a commanding rate of one per second. Each PAGE of memory can be structured to emphasize one particle type (i.e., electrons) or all particle types; to concentrate on special events, such as solar particle events; or to dwell on a narrow energy region of interest with any particle type. The commandable options are extensive but an optimum operating congfiguration will be loaded initially and adjusted as conditions dictate.

Once the instrument memory is loaded, operation from any PAGE is selectable by a subsequent instruction magnitude command (INST). Each 9-bit INST command also selects the dwell time that the instrument will remain in each MODE as it cycles through the memory PAGE. Times of 8, 16, 32, and 64 sec are possible. Since the satellite spin rate is 1 rpm, the longest dwell time corresponds approximately to one spin period. Dwell times as short as one-eighth of a spin period are, therefore, also possible. The ability to calibrate the instrument with an internal pulse generator system is selectable by one bit of the INST command. The order of the digital data output from the spectrometer is also selectable. A primary format is used unless some failure occurs in the readout circuitry at which time a secondary format is available. The ability to select a hardwired backup MODE is also available should a major failure occur in the memory operation. The hardwired backup MODE measures the higher energy electrons (300-5100 keV) and is independent of the memory. The instrument operates in this condition automatically whenever the memory is being loaded or disabled. Digital signals from the four sensors are applied to a coincidence logic unit where they are tested against the conditions specified in the command to

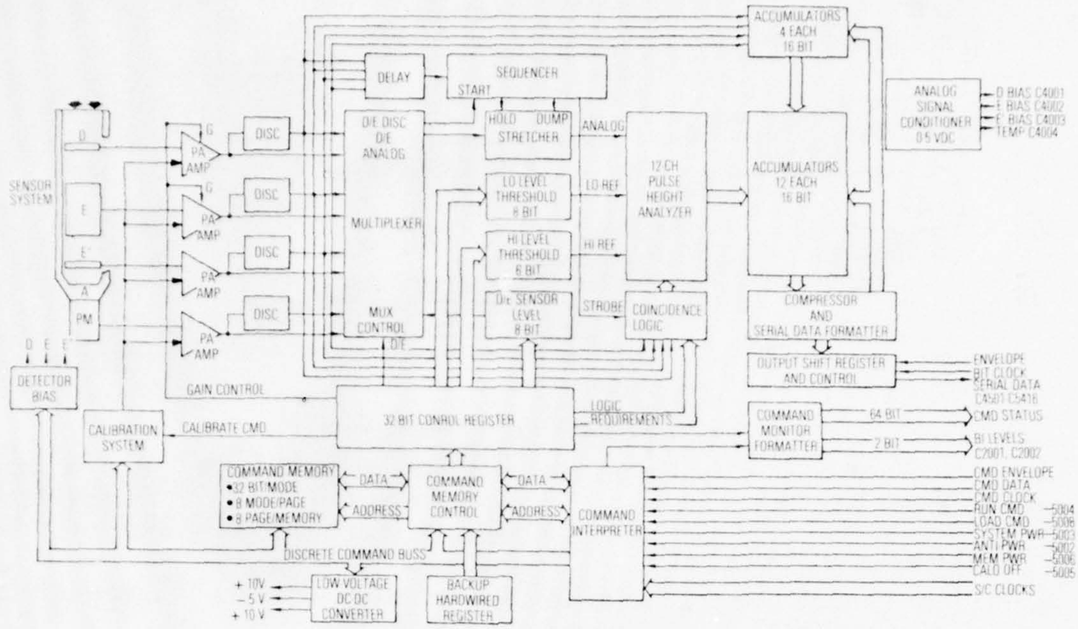


Figure 9.2. Functional Block Diagram

UNIQUELY MEASURE A CERTAIN PARTICLE TYPE AND ENERGY RANGE. THE LOGIC CONDITIONS REQUIRED TO MEASURE THE VARIOUS PARTICLES AND ENERGIES OF INTEREST ARE SHOWN IN TABLE 9.1. THE SUBSCRIPTS ON THE SENSOR NOTATION REFER TO THE LOWER ENERGY THRESHOLDS REQUIRED TO ESTABLISH THE CORRECT ENERGY RANGE. HIGH AMPLIFIER GAIN IS REQUIRED IN THE ELECTRON MODES OF OPERATIONS SINCE THE ENERGIES INVOLVED ARE CONSIDERABLY BELOW THOSE OF THE PROTONS AND ALPHA PARTICLES MEASURED. BARS OVER A SENSOR NOTATION INDICATE AN ANTICOINCIDENCE CONDITION (NO SIGNAL) MUST BE PRESENT FROM THAT SENSOR TO SATISFY THE LOGIC. THE PLASTIC SCINTILLATOR, A, IS ALWAYS USED IN AN ANTI-COINCIDENCE MODE. THE E'-DETECTOR IS USED TO DETECT AND MEASURE THE ENERGETIC ELECTRONS BETWEEN 5100 AND 10,000 KEV, WHERE THE UPPER ENERGY IS DETERMINED BY THE TUNGSTEN ABSORBER BEHIND THE SENSOR AND IN FRONT OF THE ANTICOINCIDENCE SCINTILLATOR (FIGURE 9.1). THE E'-DETECTOR IS ALSO USED TO DETECT AND COLLIMATE THE HIGHEST ENERGY PROTONS BUT ANALYSIS IS PERFORMED IN THE NONLINEAR PORTION OF THE E-DETECTOR.

SIGNALS FROM THE SENSOR SELECTED FOR ANALYSIS THAT SATISFY ALL THE LOGIC CONDITIONS ARE ROUTED TO THE 12-CHANNEL DIFFERENTIAL PHA AFTER BEING STRETCHED IN TIME. THE PHA IS A 13-LEVEL COMPARATOR STACK WITH THE LOWER AND UPPER LEVEL REFERENCES DETERMINED BY COMMAND. THE LOWER LEVEL REFERENCE CAN BE SET TO 1-PART-IN-256 (8-BIT) OF THE AMPLIFIER RANGE WHILE THE UPPER LEVEL CAN BE SET AND RESOLVED TO 1-PART-IN-64 (6-BIT) OF THE RANGE. ALL AMPLIFIER PULSES BETWEEN THE LOWER AND UPPER REFERENCE LEVELS ARE ANALYZED INTO 12 EQUAL-WIDTH VOLTAGE BINS. BASIC ANALYSIS TIME IS 496 MSEC. THE REFERENCE LEVELS CAN BE SET AS CLOSE AS THE BASIC RESOLUTION AND STABILITY OF THE PHA SYSTEM (1-PART-IN-256) IN ORDER TO ACHIEVE HIGH ENERGY RESOLUTION OVER A LIMITED ENERGY RANGE. ALTERNATELY, THE LEVELS CAN BE SET OVER A WIDER RANGE WITH BROADER ENERGY RESOLUTION IN ORDER TO OBTAIN BETTER STATISTICS.

Table 9.1. Detector Logic

Mnemonic	Particle Measured	Energy Range	Sensor Logic	Detector Analyzed	Comments
Elec 1	Electrons	50-300 keV	$D_1 \cdot \bar{E}_1 \cdot \bar{E}' \cdot \bar{A}$	D_1*	*Hi Amplifier Gain $D_1 \approx 30$ keV
Elec 2	Electrons	300-5100 keV	$\bar{D}_3 \cdot E_1 \cdot \bar{E}' \cdot \bar{A}$	E_1*	*Hi Amplifier Gain $E_1 \approx 200$ keV
Elec 3	Electrons	5100-10000 keV	$\bar{D}_3 \cdot \bar{E}_1 \cdot E' \cdot \bar{A}$	E'	Differential Channel $E' \approx 100$ keV
Prot 1	Protons	1.0-5.3 MeV	$D_2 \cdot \bar{E}_2 \cdot \bar{E}' \cdot \bar{A}$	D_2	$D_2 \approx 800$ keV $E_2 \approx 176$ keV
Prot 2	Protons	5.3-20 MeV	$D_2 \cdot E_3 \cdot \bar{E}' \cdot \bar{A}$	E_3	$E_3 \approx 1.5$ MeV
Prot 3	Protons	20-44 MeV	$\bar{D}_2 \cdot E_4 \cdot \bar{E}' \cdot \bar{A}$	E_4	$E_4 \approx 18$ MeV
Prot 4	Protons	44-200 MeV	$\bar{D}_2 \cdot E_5 \cdot E' \cdot \bar{A}$	E_4	$E_5 \approx 8.5$ MeV
Alpha 1	Alphas	6.0-20 MeV	$D_4 \cdot \bar{E}_1 \cdot \bar{E}' \cdot \bar{A}$	D_4	$D_4 \approx 5.5$ MeV

Each of the 12 channels of the PHA are connected to 16-bit binary accumulator shift registers that are readout every 0.5 sec to the telemetry. The 0.5-sec accumulation time corresponds to a 3-deg rotation of the satellite. In addition, there are 16-bit accumulators connected to each of the four sensors to measure the integral counting rates above the lowest threshold.

Upon serial readout, each 16-bit accumulator is compressed into an 8-bit output word in a pseudo-logarithmic manner. The 8-bit output word consists of 4 bits that define the location of the most-significant-one bit in the accumulator (a fifth bit is implied) and the 4 bits of binary data that follow. The data contents of the accumulator up to a value of 31 are not compressed and, hence, are not effected in accuracy. At higher accumulator values the maximum error associated with the truncation never exceeds a few percent.

A 64-bit status block describing the complete configuration logic of the instrument is readout every 8 sec and, therefore, the minimum dwell time (8 sec) of a MODE can be defined. This status block reflects the control logic of the instrument as acquired from the memory for each MODE and also the conditions specified by the instruction and the discrete commands. Four analog outputs measure the bias on the D-, E-, and E'-detectors and the temperature of these detectors. A summary of the key features of the spectrometer is given in Table 9.2.

Table 9.2. Summary of the Key Features of the SC3 Spectrometer

Number of sensors	4	
Particles and energy range measured	e p α	50-5100 keV; 5.1-10.0 MeV 1-200 MeV 6-60 MeV
Number of differential energy channels	12	
Energy resolution	Programmable	
Number of integral energy channels	4	
Time required to obtain an integral or a differential spectra	500 ms	
Pitch angle resolution	3° (FWHM)	
Geometric factor	$\sim 3 \times 10^{-3}$ cm^2-sr	
Number of MODES of operation to measure all particles and energies	8	
Dwell time in each MODE	8, 16, 32, 64 sec (programmable)	

9.4 OPERATIONAL ASPECTS

The SC3 instrument utilizes three discrete commands to power (1) the instrument (5003), (2) the anticoincidence system (5002), and (3) the memory system (5006). A LOAD command (5008) must precede each memory loading operation and a RUN command (5004) must precede the sending of an instruction (INST) command. There are 256 INST commands available for use (5101 through 5356). The calibration system can be disabled in the event of a failure via a discrete command (5005). The SC3 memeory will be loaded at the earliest opportunity after launch and remain active for the duration of the mission. This is accomplished by sending 256 combinations of data and address words at a rate of 1 word/sec. Changes to the memory will be accomplished by automatic blocks of serial binary commands (9 bit) or by individual serial commands (9 bit). Threshold changes to select different energy ranges are expected to be the most frequently sent command after payload initialization.

It is planned that the SC3 instrument be operational at all times during the P78-2 spaceflight. The primary mode of operation will be measuring electrons and the instrument will operate alternately between the mid- and high-energy electron ranges from a PAGE of memory. These data will be used in near-realtime analysis to determine the primary energy spectrum and radiation dose acquired behind various shielding thicknesses. At the times of solar particle events, operation will be by command from a preselected PAGE in memory to obtain the proton spectrum and its constribution to the dose.

Since a knowledge of the SC3 orientation with respect to the magnetic field orientation is essential to all measurements, the SC3 instrument will be operated with the SC11 instrument. Special alignment calibrations between the two instruments will be performed on-orbit.

10. SC4-1 SATELLITE ELECTRON BEAM SYSTEM

10.1 SCIENTIFIC OBJECTIVES

THE SATELLITE ELECTRON BEAM SYSTEM, PAYLOAD SC4-1, IS TO BE USED FOR THE EJECTION OF ELECTRONS FROM THE P78-2 SPACECRAFT. THE SC4-1 GROUND IS CONNECTED BY A LOW IMPEDEANCE PATH TO THE SPACECRAFT GROUND, AND THUS THE CHARGE EJECTION FROM SC4-1 WILL EFFECT THE DIFFERENCE IN POTENTIAL BETWEEN THE SPACECRAFT GROUND AND THE AMBIENT PLASMA. THE PAYLOAD WILL BE USED FOR THREE DIFFERENT INVESTIGATIONS: (A) WHEN ENERGETIC ELECTRONS IMPART A LARGE NEGATIVE POTENTIAL TO THE SPACECRAFT, SC4-1 WILL BE USED TO DETERMINE THE CURRENT AND ENERGY OF BEAM ELECTRONS REQUIRED TO RESTORE SPACECRAFT GROUND TO THE AMBIENT PLASMA POTENTIAL. (B) SC4-1 WILL BE USED TO DETERMINE THE EJECTION CURRENT REQUIRED TO PREVENT CHARGING OF THE SPACECRAFT GROUND DURING SUBSTORM PERIODS. (C) SC4-1 WILL BE USED TO SWING THE VEHICLE TO A POSITIVE POTENTIAL RELATIVE TO THE AMBIENT PLASMA AT PREDETERMINED TIMES AND FOR PREDETERMINED PERIODS.

10.2 MEASURING TECHNIQUE

THE SC4-1 PACKAGE CONTAINS THE ELECTRON SOURCE, ELECTRON GUN, AND THE ELECTRONICS FOR CONTROLLING AND MEASURING THE EMITTED CURRENT. THE ELECTRON GUN, SHOWN SCHEMATICALLY IN FIGURE 10.1, IS ESSENTIALLY A POWER TRIODE CONSISTING OF AN INDIRECTLY HEATED OXIDE-COATED CATHODE, A CONTROL GRID, A FOCUSSING ASSEMBLY, AND AN EXIT ANODE KEPT AT SPACECRAFT GROUND POTENTIAL. THE ENERGY OF THE EMITTED ELECTRONS IS DETERMINED BY THE CONTROLLED NEGATIVE POTENTIAL BETWEEN THE CATHODE AND THE ANODE.

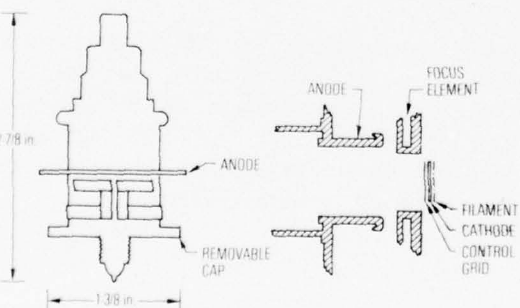


Figure 10.1. Electron Gun

THE CONTROL GRID POTENTIAL, REFERENCED WITH RESPECT TO THE CATHODE, CAN VARY FROM MINUS 30 V TO PLUS 30 V. THIS GRID CONTROLS THE CURRENT EMITTED FROM THE GUN. THIS CONTROL GRID VOLTAGE CAN BE PULSED, OR MAINTAINED AT A CONSTANT VALUE, THEREBY PERMITTING THE EJECTION OF EITHER A PULSED OR A CONTINUOUS STREAM OF ELECTRONS. THE FOCUSSING ASSEMBLY VOLTAGE DETERMINES THE BEAM SHAPE. ALL THE VOLTAGES REQUIRED TO SET THE AMOUNT OF CURRENT EMITTED, THE ENERGY OF THE EMITTED ELECTRONS, DUTY CYCLE, AND THE BEAM SHAPE ARE SENSED AND CONTROLLED BY FEEDBACK CIRCUITRY THAT CAN BE SET BY GROUND COMMAND-CONTROLLED RELAYS. THE STATE OF THE CONTROL RELAYS CAN BE VERIFIED BY TELEMETERED FLAG SIGNALS. ANALOG MEASUREMENTS ARE MADE OF THE ACTUAL EMITTED BEAM CURRENT, CATHODE VOLTAGE, AS WELL AS PARAMETERS INDICATING THE CONDITION OF THE ELECTRONIC ASSEMBLY.

AS SHOWN SCHEMATICALLY IN FIGURE 10.1, THE GUN STRUCTURES ARE HOUSED IN AN EVACUATED CERAMIC TUBE SEALED WITH A METAL CAP. THIS ALLOWS FOR COMPLETE TESTING OF SC4-1 DURING ALL PHASES OF SPACECRAFT INTEGRATION, AND PREVENTS POISONING OF THE OXIDE-COATED CATHODE DURING LAUNCH AND ORBIT INJECTION OPERATIONS. DURING INTEGRATION TESTING, THE BEAM CURRENT INCIDENT ON THE METAL CAP IS MEASURED AND USED AS ONE OF THE MONITORS OF THE STATE OF SC4-1. WHEN THE SPACECRAFT IS IN ORBIT, A GROUND- COMMANDED SQUIB MECHANISM WILL BE USED TO OPEN THE GUN BY PEELING AND SWINGING THE METALLIC CAP AWAY FROM THE CERAMIC TUBE.

10.3 FUNCTIONAL BLOCK DIAGRAM

A FUNCTIONAL BLOCK DIAGRAM OF THE SC4-1 POWER SUPPLY IS SHOWN IN FIGURE 10.2. THE INPUT POWER LINES CONTAIN AN LC FILTER TO REDUCE CONDUCTED EMISSIONS FROM THE POWER SUPPLY SWITCHING REGULATORS AND INVERTERS. THE OUTPUT OF THE FILTER POWERS TWO SWITCHING REGULATORS; ONE FOR THE HIGH VOLTAGE INVERTER AND THE OTHER FOR THE LOW VOLTAGE INVERTER. THE OUTPUT OF SWITCHING REGULATOR NO. 1 IS 20 V REFERENCED TO INPUT POWER RETURN. THIS REGULATED POWER FEEDS THE MASTER OSCILLATOR AS WELL AS THE LOW VOLTAGE INVERTER.

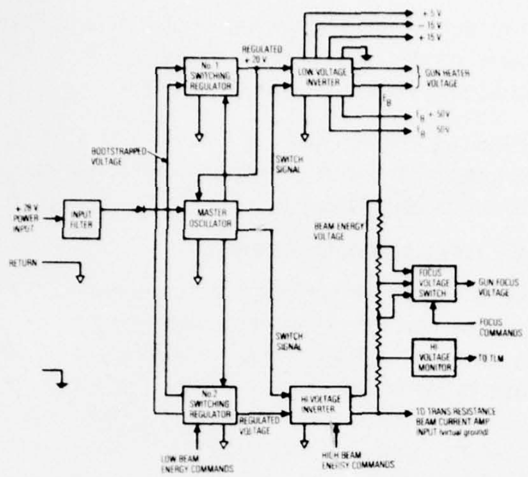


Figure 10.2. Power Supply

THE MASTER OSCILLATOR PROVIDES A BOOTSTRAPPED SUPPLY ON TOP OF THE INPUT + 28 V SO THAT BOTH SWITCHING REGULATOR PASS TRANSISTORS MAY BE BOTTOMED AT LOW INPUT LINE VOLTAGE AND, THEREFORE, MAINTAIN HIGH EFFICIENCY. THE OSCILLATOR ALSO PROVIDES DITHER SIGNALS FOR THE SWITCHING REGULATORS, AND SWITCH SIGNALS FOR BOTH INVERTERS. THUS THE SWITCHING REGULATORS AND THE INVERTERS ARE ALL SYNCHRONIZED TO THE MASTER OSCILLATOR.

THE MASTER OSCILLATOR IS LOW POWER FERRITE CORE TRANSFORMER TYPE DESIGNED TO FREE-RUN IN THE SATURATING MODE AT 20 KHZ.

THE SWITCHING REGULATORS ARE NONSATURATING. THE SWITCHING TRANSISTOR BASE DRIVES ARE SUPPLIED BY SECONDARY WINDINGS ON THE MASTER OSCILLATOR TRANSFORMER.

SWITCHING REGULATOR NO. 1 PROVIDES +5 V REFERENCE TO SIGNAL FOR THE TTL LOGIC CIRCUITS, ±15 V REFERENCE TO SIGNAL GROUND FOR THE ANALOG CIRCUITS, AN AC WINDING FOR THE ELECTRON GUN HEATER REFERRED TO NEGATIVE HIGH VOLTAGE, AND A FLOATING ±35 V REFERENCE TO NEGATIVE HIGH VOLTAGE FOR THE ELECTRON GUN CONTROL GRID AMPLIFIER. SECONDARY SERIES REGULATORS, ALTHOUGH NOT SHOWN ON THE BLOCK DIAGRAM, ARE USED FOR THE ±15V ANALOG CIRCUIT SUPPLY

SWITCHING REGULATOR NO. 2 POWERS THE HIGH VOLTAGE INVERTER. THE INVERTER HAS ONE PAIR OF SWITCHING TRANSISTORS AND FIVE TRANSFORMERS WITH PRIMARY WINDINGS THAT ARE OPERATED IN PARALLEL, AND WITH SECONDARY RECTIFIED SUPPLIES WIRED IN SERIES TO DEVELOP THE HIGH VOLTAGE. THE FIRST THREE SECONDARY SUPPLIES PRODUCE 500 V EACH AND THE LAST TWO PRODUCE 750 V EACH. AS A FUNCTION OF THE HIGH BEAM ENERGY COMMANDS, 1, 3, OR 5 TRANSFORMER PRIMARIES ARE SWITCHED INTO THE INVERTER COLLECTOR CIRCUITS PRODUCING 500 V, 1500 V, AND 3000 V AT THE OUTPUT OF THE STACK OF SECONDARY SUPPLIES.

THOSE SECONDARY SUPPLIES THAT ARE IN THE OFF STATE IN OTHER THAN THE 3000 V MODE ESSENTIALLY LOOK LIKE SHORT CIRCUITS DUE TO THE FORWARD BIASING OF THE RECTIFIER DIODES. THE INPUT VOLTAGE FROM THE SWITCHING REGULATOR IN THE HIGH BEAM ENERGY MODE IS + 20 V, REFERRED TO POWER RETURN.

IN THE THREE LOW BEAM ENERGY MODES OF 300 V, 150 V, AND 50 V A SINGLE 500 V SECONDARY TRANSFORMER IS PLACED IN THE HIGH VOLTAGE STRING, AND THE SWITCHING REGULATOR OUTPUT AS A FUNCTION OF COMMAND SIGNALS IS REDUCED TO APPROXIMATELY 12 V, 4 V, AND 2 V. THIS REDUCES THE SINGLE SECONDARY OUTPUT TO THE REQUIRED LEVELS FOR THE ENERGY MODES.

A HIGH IMPEDANCE DIVIDER IS PLACED ACROSS THE HIGH VOLTAGE TO DEVELOP VOLTAGES FOR THE FOCUS ANODE OF THE GUN AND FOR THE SLOW SPEED ANALOG MONITOR TO TELEMETRY (TLM). THE FOCUS SWITCHES ARE SMALL REED RELAYS CAPABLE OF 3000-V ISOLATION BETWEEN THEIR CONTACTS AND THEIR ENERGIZING COILS, WHICH ARE DRIVEN FROM COMMAND CIRCUITS. THE FOCUS LEVELS ARE 5, 10, AND 20% OF THE HIGH VOLTAGE TAPPED DOWN FROM THE NEGATIVE HIGH VOLTAGE.

THE POSITIVE END OF THE SUPPLY IS AT A 0-V POTENTIAL REFERRED TO SIGNAL GROUND BUT NOT CONNECTED TO GROUND. THIS POINT IS THE INPUT OF A TRANSRESISTANCE AMPLIFIER THAT MONITORS AND CONTROLS THE BEAM RETURN CURRENTS, EITHER FROM SPACECRAFT SKIN RETURN IN FLIGHT OR FROM THE GUN CAP IN TEST AND BEFORE CAP REMOVAL DURING FLIGHT. THE TLM MONITOR OF HIGH VOLTAGE IS A VERY HIGH INPUT IMPEDANCE AMPLIFIER. THUS, ALL BLEEDER CURRENT IS RETURNED TO THE POWER SUPPLY WITHOUT BEING A PART OF THE MEASURED AND CONTROLLED BEAM CURRENT.

A FUNCTIONAL BLOCK DIAGRAM OF THE ELECTRON GUN

Control Circuits is shown in Figure 10.3. The basic elements of the control circuits are: (1) a current-to-voltage amplifier A1, with command-switched gain, (2) a strobed comparator amplifier A2, to compare the output of A1 with a low temperature coefficient reference voltage, (3) an optical isolator to transform the beam control signal to the high voltage level of the gun control grid, and (4) a floating grid driver amplifier A3. In addition, there is a 4.5 decade logarithmic electrometer to monitor the gun cap current.

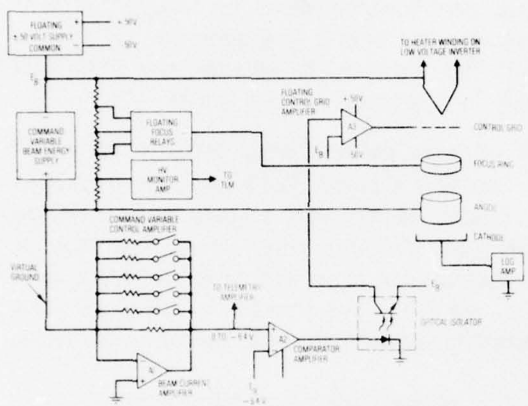


Figure 10.3. Control Circuits

When the beam is on, the control loop is such that the output of A1 is forced to the reference voltage of 6.4 V. Any error voltage between the output of A1 and the reference is amplified through A1, the optical isolator A3, and the gun. The gun beam current, either from the cap or from skin return current passes through the low voltage power supplies to the output of A1, and through the command- selectable feedback resistor to the positive return of the beam energy supply. The loop, therefore, holds the beam current to a value equal to the reference voltage divided by the feedback resistor. The beam may be pulsed by strobing the comparator amplifier off and, thus, forcing the gun control grid to maximum negative voltage. The control feedback resistors are selected to produce beam currents of 0.001, 0.01, 0.1, 1, 6, and 13 mA.

Note that the anode ring is returned to the virtual ground or the positive return of the beam energy supply. At low energies significant anode ring currents could be present, and if returned to signal ground could cause a substantial error in actual beam current leaving the gun.

Within the dynamic range of control grid voltage available (±30 V with respect to cathode) the beam current is controlled within 2 percent.

10.4 OPERATIONAL ASPECTS

During orbital operations, the parameters of the electron beam can be set by command before power is supplied to SC4-1. Flag outputs can then be used to verify the state of SC4-1. The following beam variables can be commanded energy level, current level, duty cycle, and focus characteristics. In addition, a separate verifiable command state is available to turn the beam on and off. A list of the command states for each of the variables is given below:

Beam Current level (mA)
13, 6, 1, 0.1, 0.01, 0.001

Beam Energy Levels (kV)
3, 1.5, 0.5, 0.3, 0.15, 0.05

Focus SHARP, MEDIUM, DIFFUSE

Beam Duty Cycle 100%, 6.25%*

* Beam pulse width 3.9 msec, 16 times per sec.

Although the beam energy and beam current command states can be independently set, not all the combinations derivable from these lists can be obtained. The restrictions are due either to spacecraft power limitations, or to the characteristics of the electron gun. Two specific examples are: (1) to avoid drawing excessive power from the spacecraft power supply, the 13 mA, 3 keV, 100% duty cycle mode has been locked out as an operational mode, (2) currents above 0.1 mA cannot be emitted by the electron gun for the electron energy of 0.05 keV.

Figure 10.4 gives an overall view of the command states available for electron energies and beam currents, and also shows the SC4-1 power requirements for the 100% duty cycle state.

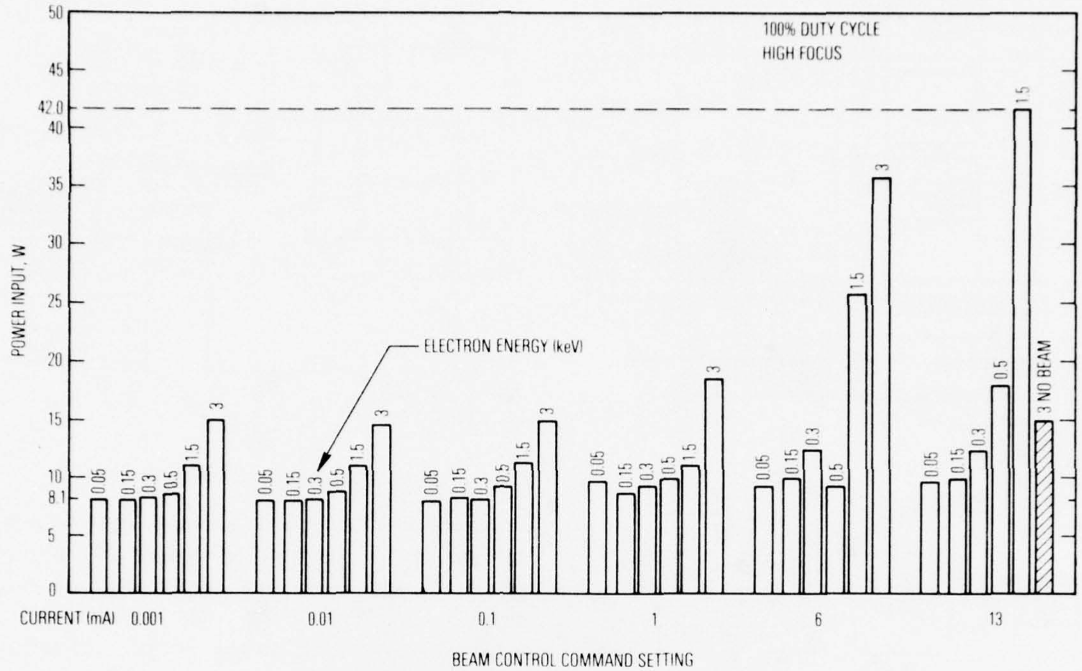


Figure 10.4. Power Requirements for Electron Beam States

11. SC4-2 POSITIVE ION BEAM SYSTEM

11.1 SCIENTIFIC OBJECTIVES

THE POSITIVE ION BEAM SYSTEM PAYLOAD, SC4-2, IS TO BE USED ON THE P78-2 SPACECRAFT FOR THE EJECTION OF CHARGED PARTICLES; POSITIVE ION, ELECTRONS, OR BEAMS CONTAINING BOTH POSITIVE IONS AND ELECTRONS. THE PAYLOAD IS ELECTRICALLY CONNECTED TO THE P78-2 SPACECRAFT GROUND THROUGH A LOW IMPEDANCE PATH SO THAT THE EJECTION OF CHARGE FROM SC4-2 WILL PLAY A LARGE ROLE IN DETERMINING THE POTENTIAL DIFFERENCE BETWEEN SPACECRAFT GROUND AND THE AMBIENT PLASMA. A NUMBER OF DIFFERENT CHARGING PROGRAMS ARE PLANNED FOR SC4-2, SINCE THE EJECTION OF POSITIVE IONS AND ELECTRONS CAN BE COMMANDED INDEPENDENTLY. WHEN SPACECRAFT GROUND IS AT OR NEAR PLASMA POTENTIAL, SC4-2 CAN BE USED TO DRIVE SPACECRAFT GROUND EITHER POSITIVE OR NEGATIVE BY THE EJECTION OF ELECTRONS OR IONS, RESPECTIVELY. WHEN THE SPACECRAFT GROUND POTENTIAL IS HIGHLY NEGATIVE WITH RESPECT TO THE AMBIENT PLASMA, TWO TECHNIQUES WILL BE EMPLOYED TO REDUCE THE SPACECRAFT GROUND TO AMBIENT PLASMA POTENTIAL DIFFERENCE: (1) THE NEUTRALIZER FILAMENT, AT SPACECRAFT GROUND POTENTIAL OR BIASED WITH RESPECT TO SPACECRAFT GROUND, WILL BE USED TO EMIT ELECTRONS; (2) A QUASI-NEUTRAL BEAM CONTAINING BOTH POSITIVE IONS AND ELECTRONS WILL BE USED AS A LOW IMPEDANCE SOURCE TO THE AMBIENT PLASMA. A WIDE DYNAMIC RANGE IN EJECTED PARTICLE ENERGY, BEAM CURRENT, AND SOURCE BIAS WILL ALLOW FOR A STUDY OF THE IMPORTANCE OF THESE QUANTITIES IN CONTROLLING THE SPACECRAFT GROUND POTENTIAL. TABLE 11.1 LISTS THE VARIOUS MODES IN WHICH THE PAYLOAD CAN BE OPERATED. IN ADDITION, VEHICLE POTENTIAL CONTROL WILL BE POSSIBLE FOR PREDETERMINED PERIODS.

11.2 MEASURING TECHNIQUE

PAYLOAD SC4-2 CONSISTS OF THREE UNITS INTEGRATED INTO ONE BOX: A POWER PROCESSOR ASSEMBLY, AN EXPELLANT ASSEMBLY, AND AN ION SOURCE. AN INSTRUMENT LINE DRAWING IS SHOWN IN FIGURE 11.1. THE FUNCTION OF THE POWER PROCESSOR ELECTRONICS IS TO RECEIVE AND CONVERT THE POWER AND COMMANDS FROM THE SPACECRAFT INTO A FORM TO OPERATE AND CONTROL THE ION SOURCE, PROVIDE TELEMETRY DATA, AND TO OPERATE THE CONTROL VALVE OF THE EXPELLANT ASSEMBLY. XENON GAS IS STORED IN THE EXPELLANT

Table 11.1 Operational Modes of SC4-2

Mode	Purpose	Beam Particles	Ion Source Bias (kV)	Ion Current (mA)	Electron Source Bias (V)	Electron Current (mA)
1	a	Positive Ions	1.0 2.0	0.3, 1.0, 1.4 0.4, 1.5, 2.0	0 0	0 0
2	b, d	Low Energy Electrons	0	0	0	0.002, 0.02, 2
3	b, d	Positive Ions and Electrons	1.0 2.0	0.3, 1.0, 1.4 0.4, 1.5, 2.0	0 0	$I_i \leq I_e \leq 2$* Same as above
4	c, d	Positive Ions and Electrons From a Biased Source	0	0	-10, ±25, +100 +500 ±1000	Same as above
			1.0	0.3, 1.0, 1.4	Same as above	Same as above
			2.0	0.4, 1.5, 2.0	Same as above	Same as above

a. To charge the spacecraft ground to a high negative potential with respect to the plasma potential.

b. To maintain the spacecraft ground at plasma potential.

c. To charge the vehicle to a positive potential with respect to plasma potential.

d. To return a highly negative spacecraft ground to plasma potential.

* Spacecharge limited.

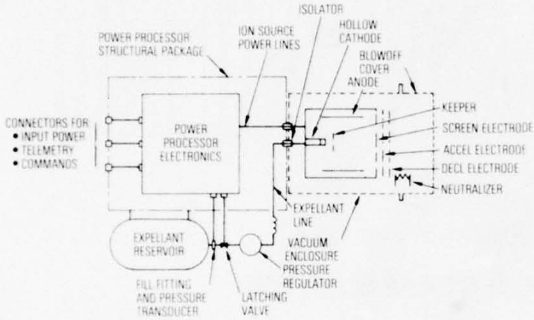


Figure 11.1. Payload Line Drawing

TANK. When the latching control valve is opened, xenon flows through a pressure regulator, an expellant line, a pourous plug, an electrical isolator, and then through a hollow cathode into the ion chamber. The regulator and the tungsten pourous plug maintain the flow of xenon at a constant rate independent of the pressure in the reservoir. The isolator allows the ion source to be maintained at large positive potentials with respect to spacecraft ground while keeping the expellant assembly at spacecraft ground. Figure 11.2 illustrates details of the ion chamber and its power supplies. Electrons are produced in the hollow cathode as a result of a discharge created in the region between the keeper and cathode. These electrons, while flowing to the cylindrical anode, ionize xenon atoms in the region between the anode and cathode. An accelerator structure outside the ionization chamber, kept at a negative potential with respect to spacecraft ground, produces the electric field to draw the ions out of the chamber and to focus them into a beam.

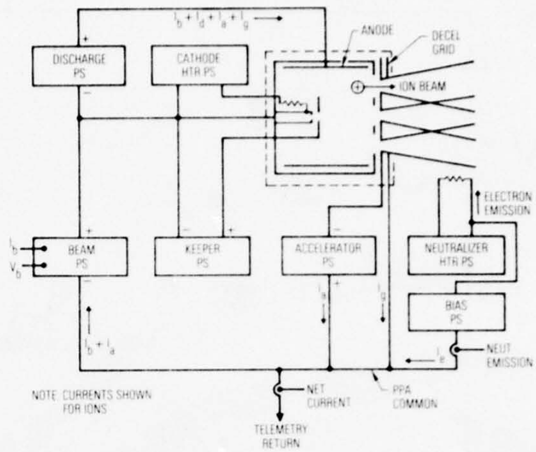


Figure 11.2. Ion Chamber Block Diagram

A grounded, downstream deceleration disk reduces the penetration outside the spacecraft of the electric field from the accelerator or ion source. The energy of the ejected ions, determined by the potential of the ionization chamber, is controlled by the beam power supply. Downstream of the decelerator grid there is a filament that can be heated to produce electrons and that can be biased either positive or negative with respect to spacecraft ground.

Three currents measured in the SC4-2 payload determine the spacecraft charging control, (1) the ions ejected are directly measured in the beam power supply, (2) the electrons ejected from the filament neutralizer are measured directly, and (3) the net current leaving the SC4-2 package is measured. The net current electrometer permits a measurement of emitted electron or ion current from a low of one μA/mA to a high of two μA/mA.

11.3 FUNCTIONAL BLOCK DIAGRAM

The Power Processor Assembly functional block diagram is shown in Figure 11.3. Input power to the Power Processor Assembly is first regulated by a "buck" switching regulator that converts the unregulated 24 to 32 V input bus voltage to a regulated 21 VDC. An input filter is used to prevent the ripple current generated by the line regulator from appearing on the input power lines.

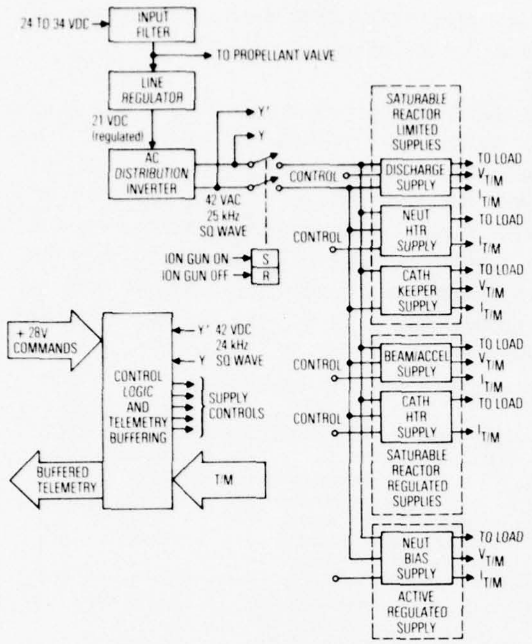


Figure 11.3. Power Processor Assembly

Electrical isolation is maintained between the input power lines, the command lines, telemetry, and the outputs of the various supplies. The isolation of the command lines is obtained by using relays; the isolation between input, output, and telemetry lines is achieved by using an output transformer and, where required, includes isolated voltage-sense windings and a current transformer on the primary for voltage and current telemetry, respectively.

The output current levels of the discharge supply are set by levels I, II, and III command signal to latching relays in the "Discharge Output Current" block. Voltage and current T/M signals for both supplies are transformer-isolated.

11.4 OPERATIONAL ASPECTS

The ion source of SC4-2 is enclosed in vacuum housing, which permits testing of the instrument during satellite integration. In orbit this cap is swung open by a squib-activated release mechanism. The ion source is started by first opening the latching valve downstream of the gas reservoir, thereby starting the xenon gas flow. After the cathode is heated, a high voltage is applied to the keeper starting a keeper cathode discharge; this in turn starts an anode-to-cathode dishcarge, turns the heater current off, and reduces the keeper voltage. After a discharge has been started, energetic ions can be ejected by commanding the beam voltage to one of two positive levels. The neutralizer can be independently started to emit electrons and can be biased with respect to spacecraft ground. Singly-ionized xenon ions can be emitted with energy of either one or two keV. At each of these energies, three current levels can be obtained in the range from approximately 0.3 mA to 2 mA. The neutralizer can be set to emit in five current ranges from 2 mA to 2μA, and can be biased either positive or negative with respect to spacecraft ground at five voltages from 10 V to one kV (Table 11.1). To increase the dynamic range a current of 10 A xenon ions can be emitted from the ion source when the cathode-to-anode discharge is out and the cathode-to-keeper discharge is on.

12. SC5 RAPID SCAN PARTICLE DETECTOR

12.1 SCIENTIFIC OBJECTIVES

The Rapid Scan Particle Detector will measure the flux of electrons and ions incident to the spacecraft in directions perpendicular and parallel to the spin axis of the satellite. These measurements will enable researchers to determine the number density, temperature, and bulk flow of the plasma and the relationship of these quantities to the occurrence of spacecraft charging. In addition, SC5 will be used to monitor the response of the plasma to the operation of the Electron and Positive Ion Beam System, SC4, and to provide a synoptic survey of the plasma characteristics as a function of local time, altitude, and geomagnetic conditions.

12.2 MEASURING TECHNIQUE

The Rapid Scan Particle Detector is comprised of two sets of spectrometers mounted perpendicular and parallel to the spin axis of the satellite. Each set of spectrometers consists of eight sensors. Four measure electrons and four measure

IONS. THESE SENSORS ALLOW A DETERMINATION OF THE DIFFERENTIAL FLUX IN THE ENERGY RANGE FROM 50 EV TO 1.1 MEV IN ELECTRONS AND 50 EV TO 35 MEV IN THE IONS.

FOR PARTICLES WITH ENERGIES LESS THAN 60 KEV, THE FLUX DETERMINATION IS MADE USING TWO SETS OF ELECTROSTATIC ANALYZERS; ONE SET FOR PARTICLES IN THE RANGE FROM 50 EV TO 1.7 KEV AND ONE SET FOR PARTICLES IN THE RANGE FROM 1.7 KEV TO 60 KEV. IN BOTH SETS, THE ENERGY DISCRIMINATION IS ACCOMPLISHED USING A THREE-PLATE CYLINDRICAL ELECTROSTATIC ANALYZER (ESA) AS SHOWN IN FIGURE 12.1. BY GROUNDING THE OUTER PLATES AND STEPPING THE CENTER PLATE THROUGH FOUR NEGATIVE VOLTAGES, THE INSTRUMENT SIMULTANEOUSLY ANALYZES THE ELECTRON FLUX USING THE INNER PLATES AND IONS USING THE OUTER PLATES.

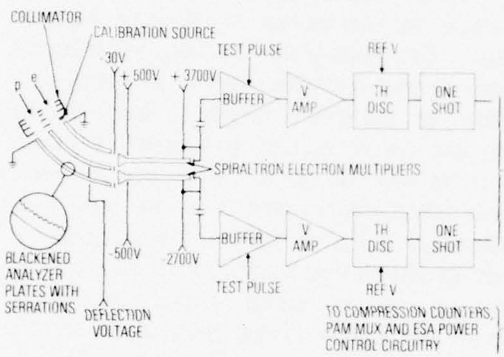


Figure 12.1. Cylindrical Electrostatic Analyzer

THE PARTICLES ARE DETECTED BY A SPIRALTRON ELECTRON MULTIPLIER (SEM) AT THE OUTPUT OF THE CURVED PLATES. THE FRONT END OF THE ELECTRONS AND ION SEMS ARE BIASED AT +500 V AND -500 V, RESPECTIVELY. LOW ENERGY PARTICLES ARE ACCELERATED BY THESE VOLTAGES TO ENSURE THEIR EFFICIENT DETECTION BY THE SEM.

THE SEMS HAVE A NOMINAL OPERATING VOLTAGE OF 3000 V. THE OUTPUT ENDS OF THE SEMS ARE, THEREFORE, BIASED NOMINALLY AT +3500 AND +2500 V, RESPECTIVELY, FOR ELECTRONS AND IONS. THE BIAS VOLTAGE IS COMMANDABLE TO ANY OF SIXTEEN SEPARATE LEVELS. THIS ARRANGEMENT ALLOWS THE SEM TO BE BIASED INITIALLY AT FAIRLY LOW VOLTAGES (LOW GAIN) AND TO INCREASE THE BIAS VOLTAGES (AND GAINS) IF GAIN FATIGUE IS EXPERIENCED. THIS HAS THE ADVANTAGE OF DELAYING FATIGUE, SINCE THE FATIGUE IS A FUNCTION OF THE TOTAL CHARGE REMOVED FROM THE SEM AND NOT THE ACCUMULATED COUNTS.

THE COUNTS ARE OBSERVED IN EACH VOLTAGE STEP AFTER AN ACCUMULATION INTERVAL OF 200 MSEC. IN ADDITION, IN EACH ELECTROSTATIC ANALYZER THE COUNTS ARE READ OUT WITH ZERO VOLTAGE ON THE CENTER PLATE. THIS PROVIDES A MEASURE OF THE BACKGROUND. IN TABLE 12.1, THE ENERGY RANGES FOR EACH CHANNEL ARE LISTED. THE ANALYZERS HAVE AN ACCEPTANCE CONE OF 7 BY 5 DEG AND THE INTEGRATED GEOMETRIC FACTOR OF 10^{-4} AND 10^{-2} CM^2-STER FOR ELECTRONS AND IONS, RESPECTIVELY.

Table 12.1. ESA Energy Detection Ranges

ESA Energy Channel	Energy Detection Ranges (keV)	
	Low Energy ESA	High Energy ESA
0	background	background
1	0.05-0.12	1.70-4.20
2	0.12-0.30	4.20-10.2
3	0.30-0.70	10.2-25.0
4	0.70-1.70	25.0-60.0

FOR PARTICLES WITH ENERGIES GREATER THAN 60 KEV, THE FLUX MEASUREMENT IS MADE USING SOLID STATE SPECTROMETER (SSS) SUBASSEMBLIES AS SHOWN IN FIGURE 12.2. ENERGY ANALYSIS IN THESE SPECTROMETERS IS ACCOMPLISHED BY TOTALLY DEPLETED SILICON SURFACE BARRIER SOLID-STATE DETECTORS.

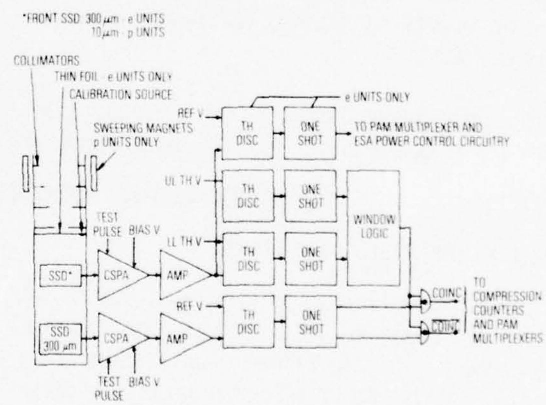


Figure 12.2. Solid State Spectrometer

THESE DETECTORS PRODUCE A CHARGE PULSE PROPORTIONAL TO THE INCIDENT PARTICLE'S ENERGY. THE CHARGE PULSE IS CONVERTED TO A VOLTAGE BY A

LOW NOISE CHARGE-SENSITIVE PREAMPLIFIER. THIS VOLTAGE IS THEN AMPLIFIED AND FED TO A THRESHOLD DETECTOR.

IN EACH SOLID-STATE SPECTROMETER THERE ARE TWO SOLID- STATE DETECTORS ARRANGED IN SERIES. FOR A GIVEN THRESHOLD VOLTAGE THIS CONFIGURATION ALLOWS THE SIMULTANEOUS MEASUREMENT OF THE FLUX OF PARTICLES IN TWO ENERGY RANGES. A LOGIC WINDOW IS INCLUDED SUCH THAT IF A PULSE IS OBSERVED ONLY IN THE FRONT DETECTOR (ANTICOINCIDENT) IT IS ASSIGNED TO A LOW ENERGY BIN, WHILE IF A PULSE IS OBSERVED SIMULTANEOUSLY IN BOTH DETECTORS (COINCIDENT) THE PULSE IS ASSIGNED TO A HIGH ENERGY BIN.

THE ELECTRON AND PROTON SOLID STATE SPECTROMETERS ARE VERY SIMILAR. THE PRINCIPAL DIFFERENCES ARE THE FOLLOWING:

1. FOR THE FRONT SOLID-STATE DETECTORS THE ELECTRON SENSOR HAS A THICKNESS OF 300μM AND AN AREA OF 50 MM^2 WHILE THE PROTON UNIT HAS A THICKNESS OF 10μM AND AN AREA OF 25 MM^2. BOTH REAR DETECTORS HAVE A THICKNESS OF 300μM AND AN AREA OF 100 MM^2.

2. THE ELECTRON SENSOR USES SN^{119} AS AN IN-FLIGHT CALIBRATION SOURCE WHILE THE ION SENSOR USES AM^{241} DEGRADED BY A NICKEL FOIL.

3. A THIN ALUMINIMUM FOIL (2.1 MM) IS USED IN FRONT OF THE ELECTRON UNIT TO ELIMINATE PROTONS WITH ENERGIES LESS THAN 250 KEV.

4. SWEEPING MAGNETS ARE USED IN FRONT OF THE PROTON UNIT TO PREVENT LOW ENERGY ELECTRONS FROM REACHING THE DETECTORS. THE USE OF A VERY THIN FRONT DETECTOR REQUIRES THAT ONLY ELECTRONS WITH ENERGIES LESS THAN 40 KEV BE ELIMINATED. HIGHER ENERGY ELECTRONS WILL PASS THROUGH THE FRONT DETECTOR WITHOUT DEPOSITING SUFFICIENT ENERGY TO PRODUCE A FALSE COUNT.

5. THE ELECTRON SSS CONTAINS AN ADDITIONAL FIXED THRESHOLD DISCRIMINATOR AND ONE-SHOT, WHICH ARE USED TO ACTIVATE THE AUTOMATIC ESA POWER SHUTDOWN CIRCUITRY DURING PERIODS OF EXCESSIVELY LARGE ELECTRON FLUX LEVELS.

6. THE ELECTRON SSS HAS AN ADDED ABSORBER BETWEEN THE TWO DETECTORS TO IMPROVE THE SPECTRAL DATA AT 1 MEV. THIS CONFIGURATION GIVES AN ADDITIONAL INTEGRATED MEASUREMENT FOR ELECTRONS ABOVE 1.1 MEV.

AS IN THE ELECTROSTATIC ANALYZER, THE SOLID STATE SPECTROMETER ACCUMULATES COUNTS FOR 200 MSEC IN EACH ENERGY CHANNEL. IN THE SSS'S FASTEST SWEEP RATE, THE FLUX IS MEASURED CONSECUTIVELY IN FIVE ENERGY CHANNELS FOR BOTH COINCIDENT AND ANTICOINCIDENT PARTICLES. IN THIS OPERATING MODE, THE SSSS RETURN A TOTAL OF TEN DIFFERENTIAL FLUX MEASUREMENTS FOR ELECTRONS AND IONS SIMULTANEOUSLY EACH SECOND. THE GEOMETRIC FACTOR FOR THE ELECTRON AND ION SOLID-STATE SPECTROMETERS ARE 3.5×10^{-3} CM^2-SR AND 2×10^{-2} CM^2-SR RESPECTIVELY. THE ENERGY RANGE FOR EACH CHANNEL IS LISTED IN TABLE 12.2.

Table 12.2. Energy Detection Ranges

Electron Solid State Spectrometer

Channel Designation	E Energy Loss Range (keV)	Electron Detection Energy Range (keV)	Proton Contaminant Range (keV)	Mode Type
EA0	25-41	30-45	255-270	anti
EA1	41-67	45-70	270-290	anti
EA2	67-118	70-120	290-330	anti
EA3	118-300	120-550	330-365	anti
EA4	168-300	170-265	365-430	anti
EC0	25-41	950-∞	-	coinc
EC1	41-67	980-1100	-	coinc
EC2	67-118	70-950	-	anti
EC3	-	950-∞	-	single
EC4	-	980-1100	-	single

Proton Solid State Spectrometer

Channel Designation	E Energy Loss Range (keV)	Proton Detection Energy Range (keV)	Mode Type
PA0	30-60	70-100	anti
PA1	60-120	100-165	anti
PA2	120-240	165-290	anti
PA3	240-410	290-450	anti
PA4	410-750	450-725	anti
PC0	30-60	15000-35000	coinc
PC1	60-120	6000-15000	coinc
PC2	120-240	2400-6000	coinc
PC3	240-410	1200-2400	coinc
PC4	410-750	725-1200	coinc

12.3 FUNCTIONAL BLOCK DIAGRAM

FIGURE 12.3 IS A FUNCTIONAL BLOCK DIAGRAM OF THE RAPID SCAN PARTICLE SPECTROMETER. THE SYSTEM CONSISTS BASICALLY OF EIGHT SENSOR COMPONENTS; FOUR ELECTROSTATIC ANALYZER ASSEMBLIES AND FOUR SOLID- STATE SPECTROMETER ASSEMBLIES. TWO ELECTROSTATIC ANALYZER ASSEMBLIES AND TWO SOLID-STATE SPECTROMETER ASSEMBLIES ARE ORIENTED TO LOOK PARALLEL TO THE SPIN AXIS AND AN IDENTICAL SET IS ORIENTED TO LOOK PERPENDICULAR TO THE SPIN AXIS.

Each electrostatic analyzer assembly, since it detects both ions and electrons, returns two measurements in each 200 msec accumulation interval. Similarly, the solid state spectrometers return both a coincident and anticoincident measurement each 200 msec. A total of 16 measurements are made in each 200 msec block. In the instrument's highest scan rate, a complete spectral sample consisting of 80 measurements is returned each second. In addition, there is a PAM multiplexer and signal processor. This allows any given channel to be sampled every 240 msec.

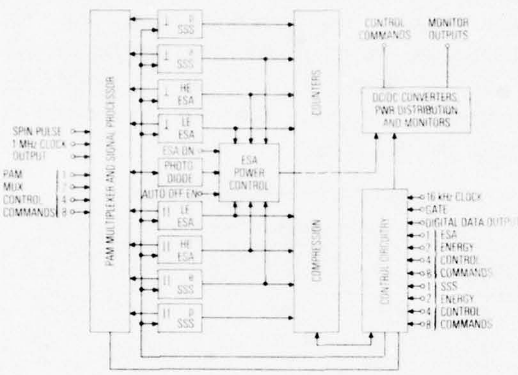


Figure 12.3. Control Circuits

The remaining components of the instrument are:

1. A compression counter where the count rates are compressed so as to minimize the telemetry requirements.

2. The control circuitry that assigns the operating modes for the ESAs and SSSs and controls the transfer of the digital data from the instrument to the satellite data handling system.

3. The ESA power control circuitry that provides for an automatic shutoff of the ESAs if the count rates reach a level that could cause premature degradation of the channeltron electron multiplier gains.

4. The DC-to-DC converter, power distribution, and monitor subsystem that contains the high voltage power supplies, DC-to-DC converter, and analog voltage and temperature monitors.

12.4 OPERATIONAL ASPECTS

The instrument is designed such that the number of consecutive 200 msec readouts in any channel can be changed by command. The ESAs and SSSs can be commanded independently to dwell for 1, 2, 4, 8 .... up to 256 consecutive readouts or can be assigned to dwell continuously in any one channel.

The high time resolution broadband data available using the PAM multiplexer is controlled separately from the digital data. There are 45 separate subcommutated commands for the broadband data. The broadband data can be read out of only one channel at a time, however, the large number of subcommutated commands provides versatility in the way in which the instrument sequences through the various channels. The broadband can be set to sample a given channel or a given detector or to cycle through all the channels in combinations of detectors.

13. SC6 THERMAL PLASMA ANALYZER

13.1 SCIENTIFIC OBJECTIVES

The SC6 Thermal Plasma Analyzer is intended to measure the ambient thermal plasma and the electrostatic potential of the satellite with respect to the ambient plasma. The ion density is measured in the range 10^1 to 10^5 per cm^3 and the electron density is measured in the range of 1 to 10^4 cm^3. The particle temperature is measured from 0.5 eV to 100 eV. The satellite potential is measured in the range of -100 V to + 100 V. In addition, the instrument mounted on the satellite body will measure the flux of photoelectrons from the satellite.

The measurements of the Thermal Plasma Analyzer will be used in the following manner. By comparing these results with the SC5 and SC9 particle measurements, the relative contributions of thermal plasma and supra-thermal plasma to the satellite potential will be determined. Changes in the satellite potential induced by operation of the SC4 Positive Ion System will be measured accurately. The geophysical characteristics of

THE THERMAL PLASMA ASSOCIATED WITH THE PLASMASPHERE, PLASMAPAUSE, AND ISOLATED REGIONS OF THERMAL PLASMA IN THE MAGNETOSPHERE WILL BE STUDIED. IN PARTICULAR, INSTABILITIES IN THE THERMAL PLASMA ASSOCIATED WITH VLF WAVES WILL BE STUDIED.

13.2 MEASURING TECHNIQUE

THE SC6 THERMAL PLASMA ANAYLZER CONSISTS OF THREE IDENTICAL INSTRUMENTS, WHICH ARE PLANAR PARTICLE TRAPS. TWO INSTRUMENTS ARE MOUNTED AT THE END OF A 3-M BOOM PERPENDICULAR TO THE SPACECRAFT SPIN AXIS. THE OTHER INSTRUMENT IS MOUNTED ON THE +X END OF THE SPACE VEHICLE. THE SURFACE NEAR THE BODY-MOUNTED INSTRUMENT AND ONE OF THE BOOM-MOUNTED INSTRUMENTS IS PARALLEL TO THE X-AXIS OF THE SATELLITE, WHICH IS ALSO THE SATELLITE'S SPIN AXIS. THE OTHER BOOM-MOUNTED INSTRUMENT HAS THE VECTOR NORMAL TO THE APERTURE DIRECTED RADIALLY OUT FROM THE X-AXIS. THE ARRANGEMENT OF THE INSTRUMENTS ON THE SATELLITE IS SHOWN IN FIGURE 2.2.

THE INSTRUMENTS ARE STANDARD PLANAR PARTICLE TRAPS WITH THE ABILITY TO FUNCTION AS RETARDING POTENTIAL ANALYZERS (RPA) AND ARE SHOWN IN FIGURE 13.1. THE INSTRUMENTS HAVE A CYLINDRICAL BAFFLE MOUNTED IN FRONT OF EACH APERTURE. THE PURPOSE OF THIS BAFFLE IS TO MINIMIZE THE COLLECTION OF PHOTOELECTRONS FROM PARTS OF THE SPACE VEHICLE NEAR THE APERTURE. IDEALLY, THE ONLY PHOTOELECTRONS MEASURED WILL BE THOSE THAT HAVE BEEN RETURNED TO THE VEHICLE BY THE SATELLITE POTENTIAL. THE BAFFLE PROVIDES AN UNRESTRICTED FIELD OF VIEW 30 DEG WIDE; THE FULL-WIDTH-AT-HALF-MAX FIELD OF VIEW IS 60 DEG WIDE. THE INTERNAL PARTS OF THE INSTRUMENTS CONSIST OF TWO APERTURE GRIDS, TWO RETARDING POTENTIAL GRIDS, A PHOTOELECTRON SUPPRESSOR GRID, AND A COLLECTOR PLATE. ALL THE GRIDS ARE MADE OF 40 BY 40 WIRES TO THE INCH MESH OF 1 MIL DIAMETER, GOLD-PLATED TUNGSTEN WIRE.

WHEN IONS ARE TO BE COLLECTED, THE COLLECTOR IS HELD AT -100V WITH RESPECT TO THE RETARDING POTENTIAL AND THE RETARDING POTENTIAL GRIDS ARE STEPPED THROUGH A SEQUENCE OF THIRTEEN POTENTIALS: -20 V, -10 V, 0 V, +1 V, +2 V, +3 V, +4 V, +5 V, +10 V, +30 V, +50 V, +70 V, +100 V. WHEN ELECTRONS ARE TO BE COLLECTED, THE POLARITIES OF THE POTENTIALS ON THE COLLECTOR PLATE AND THE RETARDING GRIDS ARE REVERSED. AT ALL TIMES, THE SUPPRESSOR GRIDS ARE HELD AT -50 V WITH RESPECT TO THE POTENTIAL ON THE COLLECTOR PLATE. BASED ON GROUND COMMANDS, THE TWO INSTRUMENTS ON THE BOOM CAN COLLECT IONS OR ELECTRONS, AND SIMILARLY, THE BODY-MOUNTED INSTRUMENT CAN BE COMMANDED TO COLLECT IONS OR ELECTRONS.

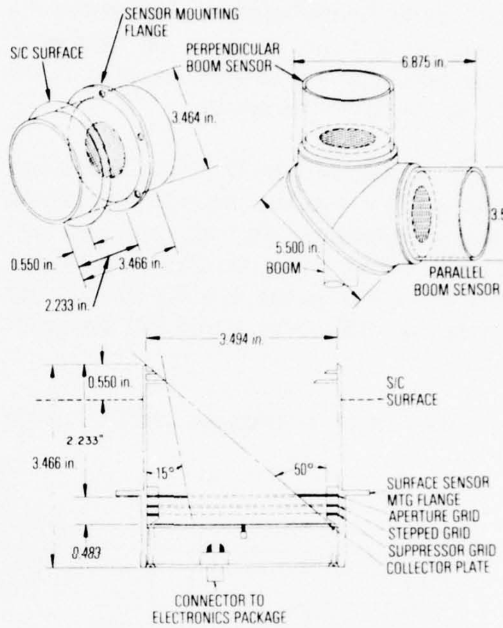


Figure 13.1. Retarding Potential Analyzer

AFTER A SEQUENCE OF RETARDING POTENTIALS HAS BEEN APPLIED, THE RETARDING GRIDS ARE HELD AT 0 V WITH RESPECT TO EXPERIMENT BIAS POTENTIAL FOR A WHILE TO MEASURE DENSITY FLUCTUATIONS. TO FURTHER STUDY DENSITY VARIATIONS, IT IS ALSO POSSIBLE TO STOP THE OPERATING CYCLE BY GROUND COMMAND AT ANY POINT IN THE CYCLE.

THE CURRENTS FROM THE INSTRUMENTS ARE MEASURED BY LINEAR, RANGE SWITCHING ELECTROMETERS. EACH RANGE COVERS ONE DECADE OF INPUT CURRENT AND THE MAXIMUM AND MINIMUM CURRENTS THAT CAN BE MEASURED ARE 10^{-8} AMPS AND 10^{-13} AMPS. AS THE OUTPUT FROM THE ELECTROMETER APPROACHES THE MAXIMUM OR MINIMUM WITHIN A RANGE, THE ELECTROMETER IS AUTOMATICALLY SWITCHED TO THE NEXT RANGE IF THE OUTPUT STAYS NEAR THE MAXIMUM OR MINIMUM FOR MORE THAN 375 msec. The output of each of the electrometers is picked up by the digital encoder 8 times per second.

13.3 FUNCTIONAL BLOCK DIAGRAM

The functions of the SC6 Thermal Plasma Analyzer are shown in Figure 13.2. The principal operating elements and the switches between them are shown as part of the "wiring" diagram. The commands for changing the operating status of the instruments and the meaning of the commands are shown in the blocks on the left of the diagram.

The bias voltage that can be applied upon ground command places a potential difference between the instrument reference level and the spacecraft electrical ground. Thus an applied voltage of +100 V with a bias voltage of +50 V becomes a net potential of +150V with respect to spacecraft ground.

The output from the electrometers, which is in the range of 0 V to 5 V, goes to the digital encoder to be converted into 8-bit words along with an 8-bit word indicating the range level. The data then becomes part of the telemetry stream.

13.4 OPERATIONAL ASPECTS

The experiment uses nine commands to control its functions. Combinations of the first three commands set the instruments into ion or electron gathering modes. Combinations of the next four set the experiment bias voltage. The last two commands turn the experiment sequence clock on and off. The selection of commands will be made on the basis of : (1) operation of SC4 Ion and Electron Beams, (2) realtime geophysical activity as determined from realtime analysis of P78-2 spacecraft data and ground-based observations, and (3) knowledge of the interaction of the P78-2 spacecraft with its environment based on realtime (or nearly realtime) analysis of SC6 data.

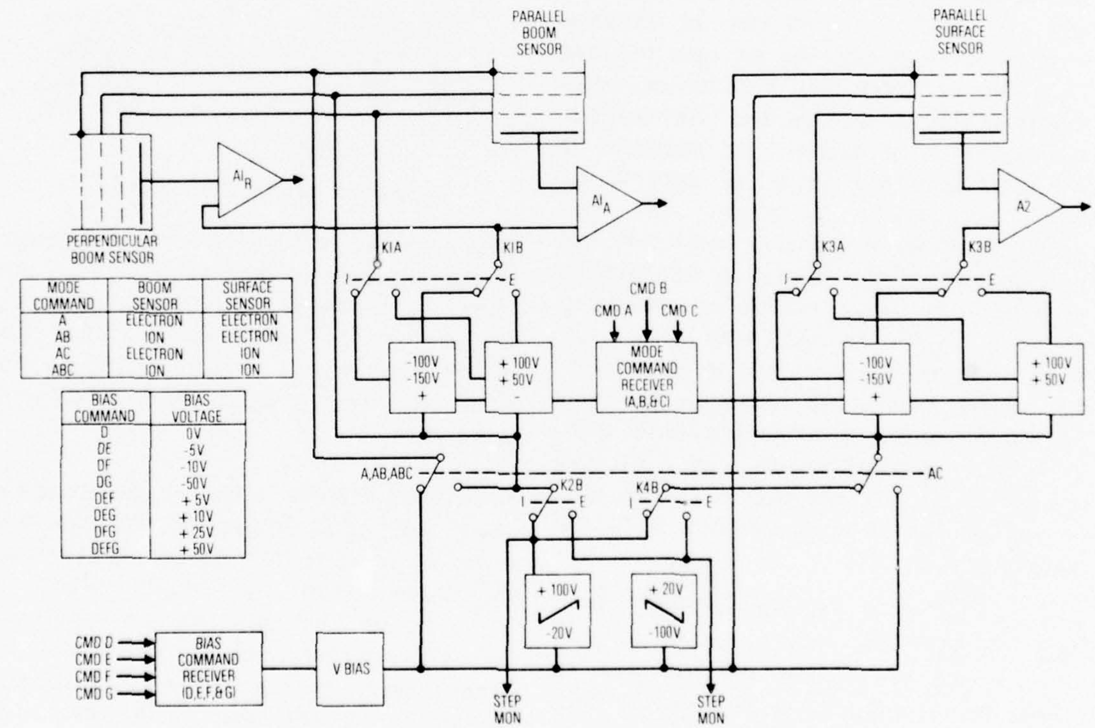


Figure 13.2. Functional Diagram

14. SC7 LIGHT ION MASS SPECTROMETER

14.1 SCIENTIFIC OBJECTIVES

The Light Ion Mass Spectrometer (LIMS) is designed to measure the density, temperature, and composition of the low-energy ion plasma at the near synchronous altitude orbit of the P78-2 satellite. The characteristics of charged particle currents associated with a free body in space are a function of the satellite potential, and this potential is established so as to satisfy the requirement that the net current be zero. In order to understand the complex plasma-satellite interaction, all important charged particle populations must be identified and measured. The cold plasma (E 100<eV) component is important at and near synchronous orbit altitudes and at times can be the dominant component in terms of density, exceeding 100 ions/cm^3. Any detailed study of spacecraft charging effects must therefore have a continuous measure of the characteristics of the cold plasma surrounding the spacecraft. Calculations of the spacecraft plasma sheath and its consequent effect upon other experiments such as the electric field measurements require knowledge of the ambient plasma density, temperature, composition, and flow characteristics.

14.2 MEASURING TECHNIQUE

The LIMS consists of three heads and one central electronics package. Each sensor head consists of a retarding potential analyzer, ion mass spectrometer, ion detector, and associated electronics as illustrated in Figure 14.1. The retarding potential analyzer grid is driven by a stepping power supply with 32 logarithmically-spaced discrete voltage steps ranging from 0.0 to 100 V. The mass analyzer is a 90-deg sector permanent magnet with entrance and exit aperture placed so as to obtain first-order focusing. After leaving the retarding potential analyzer and prior to entering the mass analyzer, the ions are accelerated by a post-accelerated potential. The ion mass analyzed is determined by selecting a particular value of post-acceleration potential. That is, for a given value of post-acceleration potential, only ions with the proper mass-to-charge ratio will be focused upon the exit plane and hence will be detected. The mass analyzer is designed to be sensitive to the ions H^+, $^4He^+$, and $^{16}O^+$ with corresponding values of the post-acceleration potential of 800, 200, and 50 V, respectively.

The ions that are focused upon the exit slit are detected by a channel electron multiplier with a 3-mm dia aperture. The entrance end of the multiplier is biased at -2600 V in order to aid in focusing the ions from the exit slit onto the multiplier. This also serves to reject secondary electrons and photoelectrons, as the multiplier entrance is the most negative point in the system. Pulses from the channel multiplier are amplified, discriminated, and shaped for transmission to the central electronics package.

The three LIMS sensor heads and associated system are labeled as follows:

- SC7-1 — Sensor head located in the bellyband with FOV centered perpendicular to the spin axis
- SC7-2 — Sensor head located on the forward end of the spacecraft with FOV centered along the spin axis
- SC7-3 — Sensor head located on the bottom of the spacecraft with FOV centered along the spin axis and in the opposite direction to that of SC7-2.

14.3 FUNCTIONAL BLOCK DIAGRAM

Figure 14.1 shows a block diagram of a sensor head. The ion optics assembly consists of the grids, the entrance aperture, the 90-deg sector magnet, the exit aperture, and the channel electron multiplier (CEM). The retarding potential (for ion energy analysis) and the post-acceleration potential (for mass analysis) are supplied by voltage supplies that are controlled by precision reference generators in the central electronics package. The preamplifier and discriminator serve to produce shaped pulses from the CEM and these pulses are transmitted to accumulators in the central electronics package. There is also a means to change the pulse level discriminator thresholds in order to assess possible gain degradation of the CEM. The low voltage power supply powers the preamplifier-discriminator as well as the high voltage supply for the CEM. The high voltage is enabled by a separate command so that the instrument can be operated during ground checkout without endangering the high voltage supplies and channel multiplers. The high voltage is normally 2600 V, but can be increased to 3000 or reduced to 2200 by command in order to aid in diagnosing the gain state of the channel electron multiplier.

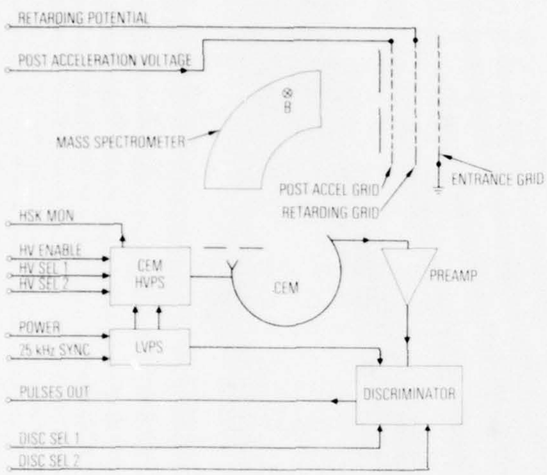


Figure 14.1. Light Ion Mass Spectrometer

The central electronics package uses standard CMOS logic to interface between the sensor heads and the spacecraft command and data systems. Mode commands are decoded to produce proper sequences and values of the retarding potential and post-acceleration voltages. The pulse data from the sensor heads are routed to accumulators and on to shift registers for transmission to the data system. Synchronizing signals, from the spacecraft data system, control the internal cycling of the instrument so that it is synchronized with the vehicle time code word. Bi-level status indicators transmitted to the data system and into the downlink serve to verify commands, the instrument mode state, and the internal cycle sequences. Analog monitors serve to monitor the post-acceleration supplies, the retarding potential supplies, the channel multiplier supplies, and the sensor head temperatures.

14.4 OPERATIONAL ASPECTS

There are eight instrument operation modes, selectable by ground command. The modes change the internal ion optics voltage so as to change the particle energy and mass analyzed. However, the sequence of head selection and data accumulation is completely independent of the instrument mode, and the timing relationships do not change. The modes are detailed as follows:

Mode 0: O^+ - The post-acceleration potential is set at approximately 50 V so that the mass analyzer is sensitive to O^+ ions only. The retarding potential analyzer is stepped through 32 voltage levels in 2 sec.

Mode 1: He^+ - The post-acceleration potential is set at approximately 200 V so that the mass analyzer is sensitive to He^+ ions. As in Mode 0, the retarding potential analyzer is stepped through 32 voltage levels in 2 sec.

Mode 2: H^+ - The post-acceleration is set at approximately 800 V so that the mass analyzer is sensitive to H^+ ions. As in Mode 0 and 1, the retarding potential analyzer is stepped through 32 voltage levels in 2 sec.

Mode 3: Density - In this mode, the retarding potential is fixed at zero volts, and the post-acceleration voltage is swept through the entire mass range of 1 to 16 AMU/charge in 2 sec.

Calibration Modes - In these modes the detector thresholds and channeltron high voltages are stepped in a sequence in order to assess any possible degradation in the sensor sensitivity.

Mode 4: O^+ and Calibrate

Mode 5: He^+ and Calibrate

Mode 6: H^+ and Calibrate

Mode 7: Automatic and Calibrate - This mode is a

REPEATING SEQUENCE OF MODE 0, 1, 2, AND 3 IN ORDER. EACH MODE IS ON FOR 64 SEC AND THUS ONE COMPLETE MODE 7 CYCLE LASTS FOR 256 SEC. ADDITIONALLY, A CALIBRATION SEQUENCE OCCURS EVERY 18 HR.

THE MODE SELECT COMMANDS, NUMBERS 5 AND 6, AND THE CALIBRATION ENABLE COMMAND, NUMBER 7 ARE ENCODED INTO THE 8 MODES ACCORDING TO TABLE 14.1.

Table 14.1. Payload Operating Modes

Mode	Command 5	Command 6	Command 7	Measurement
0	0	0	0	O^+
1	1	0	0	H_e^+
2	0	1	0	H^+
3	1	1	0	Density
4	0	0	1	O^+ & Cal
5	1	0	1	H_e^+ & Cal
6	0	1	1	H^+ & Cal
7	1	1	1	Auto & Cal
0 = OFF 1 = ON				

THE RETARDING POTENTIAL AND POST-ACCELERATION SUPPLIES IN EACH SENSOR HEAD ARE CONTROLLED BY COMMON REFERENCE GENERATORS IN THE SC7-4 ELECTRONICS PACKAGE. THUS, THE STATES OF THE HEADS WITH REGARD TO PARTICLE ENERGY AND TYPE ARE IDENTICAL AT ANY GIVEN TIME. HOWEVER, DUE TO TELEMETRY LIMITATIONS, IT IS NOT POSSIBLE TO TRANSMIT DATA FROM ALL THREE HEADS SIMULTANEOUSLY. THUS, A PRIMARY ACCUMULATOR SAMPLED 16 TIMES PER SEC AND TWO SECONDARY ACCUMULATORS A AND B SAMPLED ONCE PER 2 SEC ARE EMPLOYED. THE THREE SENSOR HEADS ARE CONNECTED IN SEQUENCE TO THE PRIMARY ACCUMULATOR FOR 2 SECONDS EACH IN THE ORDER 1-2-1-3-1-2-1-3, ETC. A GIVEN HEAD IS CONNECTED TO THE PRIMARY ACCUMULATOR FOR THE DURATION OF ONE 2-SEC, 32-STEP RETARDING POTENTIAL ANALYZER SEQUENCE (MODES 0, 1 AND 2) OR ONE POST-ACCELERATION SWEEP (MASS SWEEP) SEQUENCE (MODE 3). DURING THIS INTERVAL, THE OTHER TWO HEADS ARE EACH CONNECTED TO A SECONDARY ACCUMULATOR AND DATA ARE ACCUMULATED AT THE RETARDING POTENTIAL ANALYZER ZERO POTENTIAL STEP. THUS, WHILE THE HEAD CONNECTED TO THE PRIMARY ACCUMULATOR MEASURES THE ENTIRE RETARDING CURVE AND, HENCE, ION DENSITY AND TEMPERATURES, THE OTHER TWO HEADS MEASURE THE DENSITY ONLY DURING THE SAME 2-SEC INTERVAL. THE SEQUENCE OF SELECTING THE PRIMARY ACCUMULATOR HEAD WAS CHOSEN SO THAT THE HEAD (SC7-1) WITH FOV PERPENDICULAR TO THE SPIN AXIS WILL BE SAMPLED TWICE AS OFTEN AS THE HEAD (SC7-2 AND 3), WHICH ARE PARALLEL TO THE SPIN AXIS.

15. SC8 ENERGETIC ION COMPOSITION EXPERIMENT

15.1 SCIENTIFIC OBJECTIVES

THE ENERGETIC ION COMPOSITION EXPERIMENT, SC8, MEASURES THE MASS COMPOSITION OF THE HOT PLASMAS ENVELOPING THE P78-2 SPACECRAFT. THE ION FLUX MEASUREMENTS SPAN THE ENERGY REGION FROM 100 eV TO 32 keV AND THE MASS RANGE FROM 1 TO GREATER THAN 160 AMU.

THE OBJECTIVES OF THE EXPERIMENT FALL INTO TWO GENERAL CATEGORIES: (A) SPACECRAFT CHARGING PHENOMENA, AND (B) PLASMA INTERACTION PROCESSES. THE SC8 EXPERIMENT SUPPORTS UNDERSTANDING THE SPACECRAFT CHARGING PHENOMENA IN SEVERAL WAYS. (1) THE COMPOSITION AND SPATIAL ANISOTROPIES OF THE POSITIVE IONS IN THE AMBIENT HOT PLASMA THAT IS REQUIRED TO UNDERSTAND AND TO MODEL THE SHEATH REGION AROUND THE SPACECRAFT DURING CHARGING EVENTS IS DETERMINED. (2) THE PHOTOIONIZED GASEOUS AND ION CONTAMINANTS EMITTED BY THE SPACECRAFT (WHICH HAS BEEN OBSERVED PREVIOUSLY ON ATS-5 AND ATS-6 WITHOUT MASS IDENTIFICATION) ARE MEASURED. (3) THE ION COMPOSITION OF THE PLASMA PRIOR TO CHARGING EVENTS IS MEASURED IN ORDER TO ASSESS THE CAPABILITIES FOR PREDICTING CHARGING EVENTS ON THE RECONFIGURATION OF THE MAGNETOSPHERIC CURRENT SYSTEM PRIOR TO THE ONSET OF GEOMAGNETIC SUBSTORMS. (4) TEMPORAL AND RADIAL DEPENDENCIES OF THE PLASMA COMPOSITION ARE DETERMINED TO AID IN MODELING THE HOT PLASMA ENVIRONMENT FOR SATELLITE ORBITS AT HIGHER AND LOWER ALTITUDES AND INCLINATIONS THAN THE P78-2 SPACECRAFT ORBIT. (5) FINALLY, SELECTED PLASMA CONDITIONS ARE MEASURED DURING WHICH ION FLUXES FROM THE SC4 ION GUN ARE RETURNED TO THE SPACECRAFT.

THE SC8 EXPERIMENT SUPPORTS UNDERSTANDING THE PLASMA INTERACTION PROCESSES IN SEVERAL WAYS. (1) PLASMA AND FIELD CONDITIONS THAT PRODUCE IONOSPHERIC ION ACCELERATION WILL BE investigated. (2) The local time and geomagnetic latitude distributions of the source regions of field-aligned ionospheric ions will be investigated. (3) The plasma and field conditions that produce the precipitation of energetic particles from the trapped populations will be investigated. (4) The large-scale and small-scale transport processes for the hot plasmas will be investigated. (5) Finally, the plasma and field conditions that result in VLF wave generation and amplification in the magnetosphere will be investigated.

15.2 MEASURING TECHNIQUE

The SC8 instrument is an energetic ion mass spectrometer containing three parallel analyzer units, each of which measures ions in a different energy region of the range from 0.1 to 32 keV. Each unit consists of a crossed electric and magnetic field velocity filter (Wein filter) in series with an electrostatic analyzer (ESA) and a channel electron multiplier sensor. One of the units is shown schematically in Figure 15.1.

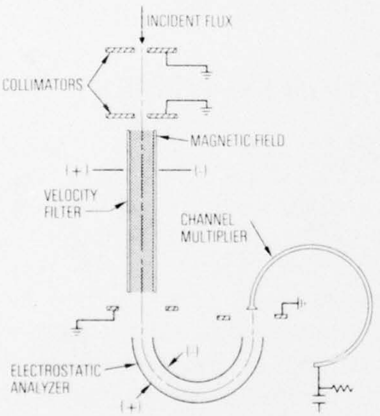


Figure 15.1. Ion Mass Spectrometer

The instrument has two basic modes of operation and two mass ranges of coverage in each mode. The two mass ranges cover from approximately 0.8 to 80 AMU (normal) and 12 AMU to greater than 160 AMU (heavy). In the first operating mode, each of the three analyzer units cycles through four discrete ESA settings in 16 sec, remaining fixed for 2 sec at each setting. During each 2-sec period, the velocity filter voltage is ramped to provide a 32-point mass-per-unit-charge (M/Q) spectrum over one of the two ranges indicated above. Thus, a full mass spectrum is obtained at each of 24 energy points every 16 sec. In the second mode, the velocity filter is locked in one of four discrete values corresponding to M/Q = 1, 2, 4, or 16 for 16 sec, while each ESA is cycled among its eight discrete levels. The ESA voltage is switched every 62 msec. Thus, a 24-point energy-per-unit-charge spectrum from the three units is acquired every 1/2 second at a single M/Q position. After 64 sec on a fixed mass value, the instrument spends 64 sec in Mode 1 to provide information on the background levels obtainable from mass regions between the discrete mass peaks. Following this, the velocity filter is locked on a second mass for 64 sec, again followed by 64 sec in Mode 1. This continues through the four discrete M/Q values. Thus, a complete cycle of the second mode requires 512 sec. Variations in the number and timing of the basic energy and mass values can be selected by realtime commands.

The instrument also includes four broadband electron channels for providing electron background information and for general correlative studies with the plasma ions. Fixed magnetic field analyzers followed by channel electron multipliers span the electron range from 0.07 to 24 keV with central energies at 0.16, 0.73, 3.3, and 16 keV.

15.3 FUNCTIONAL BLOCK DIAGRAM

The data flow from the instrument is illustrated schematically in Figure 15.2. All of the outputs are from channel electron multipliers and the data from each channel are handled in an analogous fashion. Each sensor output is followed by a pulse amplifier, shaper, and discriminator prior to going into a 16-bit counter. The accumulation and read times for the counters are synchronized with the analog functions and controlled by the instrument control logic as indicated schematically by the control logic block. The information in the 16-bit counters is logarithmically compressed to 8 bits prior to being read into the telemetry bit stream by the spacecraft data multiplexer.

An inflight calibration sequence is initiated by

REALTIME COMMAND THROUGH THE CALIBRATION CONTROL LOGIC. THIS SEQUENCE CHECKS ALL OF THE COUNTERS AND BUFFERS BY PROVIDING PULSES AT A FIXED RATE INTO EACH COUNTER. CHANNEL MULTIPLIER AND AMPLIFIER PERFORMANCE IS EVALUATED IN THE CALIBRATION SEQUENCE BY STEPPING THE DISCRIMINATOR THROUGH ITS FOUR SELECTABLE LEVELS FOR EACH OF TWO HIGH VOLTAGE SETTINGS OF THE CHANNEL ELECTRON MULTIPLIERS. THE OPERATING LEVEL OF THE DISCRIMINATOR IS SELECTED BY REALTIME COMMAND.

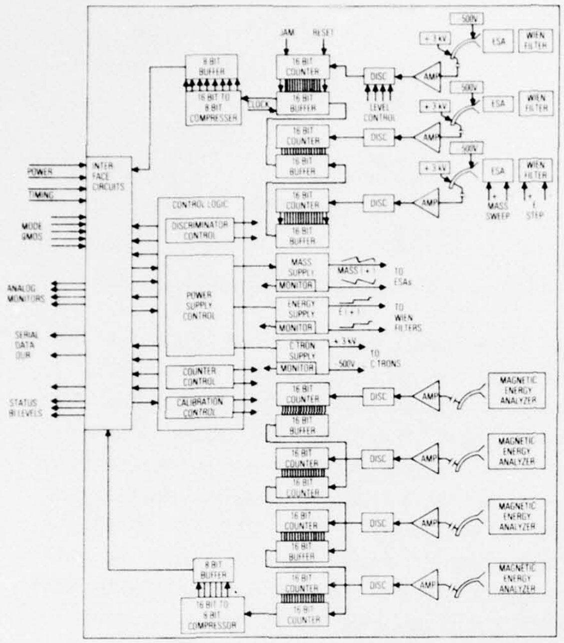


Figure 15.2. Block Diagram

15.4 OPERATIONAL ASPECTS

OPERATING MODES FOR THE INSTRUMENT ARE SELECTED BY REALTIME COMMANDS. AFTER THE INITIAL INSTRUMENT CHECKOUT, IT IS EXPECTED THAT THE INSTRUMENT WILL REMAIN IN A SELECTED MODE FOR AT LEAST 24 HR FOR MOST ROUTINE OPERATIONS. INFLIGHT CALIBRATION OF THE INSTRUMENT WILL BE PERFORMED ABOUT ONCE PER DAY AND IS INITIATED BY REALTIME COMMAND.

DURING THE LIFETIME OF THE SPACECRAFT, MANY DIFFERENT OPERATING MODES WILL BE USED TO INVESTIGATE A WIDE RANGE OF GEOPHYSICAL AND MAN-PRODUCED EVENTS. THESE EVENTS WILL INCLUDE GEOMAGNETIC STORMS AND SUBSTORMS, SOLAR PARTICLE EVENTS, FIELD-ALIGNED ION EVENTS, SOLAR ECLIPSES BY THE EARTH, ION AND ELECTRON GUN OPERATIONS, CHEMICAL RELEASES, AND ELECTROMAGNETIC WAVE INJECTIONS.

16. SC9 UCSD CHARGED PARTICLE EXPERIMENT

16.1 SCIENTIFIC OBJECTIVES

THE PRIMARY OBJECTIVE OF THE UCSD PARTICLE EXPERIMENT IS TO MEASURE CHARGED PARTICLE FLUXES AS A FUNCTION OF ENERGY, DIRECTION, AND TIME. THE CHARGED PARTICLES THAT WILL BE MEASURED CONSIST OF ENVIRONMENTAL ELECTRONS AND IONS AND ALSO PARTICLES EMITTED FROM THE SPACECRAFT SUCH AS PHOTOELECTRONS, SECONDARY ELECTRONS, AND PARTICLES EMITTED BY THE ELECTRON AND POSITIVE ION BEAM SYSTEMS SC4. THE SECONDARY OBJECTIVES OF THE EXPERIMENT ARE TO USE THE MEASURED PARTICLE FLUXES TO INFER PARTICLE VELOCITY DISTRIBUTIONS, SPACECRAFT POTENTIAL, THE LOCATION AND THE MAGNITUDE AND POLARITY OF THE VARIOUS CHARGING CURRENTS TO THE SPACECRAFT.

THE PARTICLE DATA FROM THE UCSD EXPERIMENT, TOGETHER WITH THE DATA FROM THE OTHER EXPERIMENTS, SHOULD PROVIDE A QUANTITATIVE DESCRIPTION OF THE CHARGE STATE OF THE P78-2 SPACECRAFT, AS WELL AS A QUANTITATIVE DESCRIPTION OF THE ENVIRONMENTAL PLASMA, BOTH AS FUNCTIONS OF TIME AND, THEREFORE, AS FUNCTIONS OF THE SATELLITE POSITION IN SPACE. THE ULTIMATE AIM OF THE EXPERIMENT IS TWOFOLD: TO GAIN AN UNDERSTANDING OF THE ELECTRICAL CHARGING AND DISCHARGE PROCESSES OF THE P78-2 SPACECRAFT AND TO GAIN AN UNDERSTANDING OF THE PROCESSES THAT CONTROL THE ENVIRONMENTAL PLASMA.

16.2 MEASURING TECHNIQUE

THE UCSD EXPERIMENT, FIGURE 16.1, HAS FIVE ELECTROSTATIC CHARGED PARTICLE DETECTORS. TWO DETECTORS (ONE FOR NEGATIVE AND ONE FOR POSITIVE PARTICLES) ARE CONTAINED IN EACH ROTATING DETECTOR ASSEMBLY (RDA). EACH RDA CAN BE ROTATED THROUGH A MAXIMUM OF 220 DEG ABOUT THE AXIS THROUGH THE RDA CYLINDRICAL STRUCTURE. THE EXPERIMENT IS MOUNTED ON THE OUTER EDGE OF THE FORWARD END OF THE P78-2 SPACECRAFT. ONE RDA, CALLED THE NORTH-SOUTH (NS) ASSEMBLY, ROTATES SO THAT ITS DETECTORS LOOK IN A PLANE TANGENT TO THE CYLINDRICAL SIDE OF THE spacecraft. The other RDA, called the East-West (EW) detector, looks in a plane that cuts across the top face of the spacecraft. An additional detector of positive particles only is mounted in the main housing facing outwards, and is called the Fixed Detector Assembly (FDA). The rotation capability when combined with the spin of the spacecraft make it possible for the two RDAs to detect particles coming from any direction within more than a hemisphere centered above the top of the spacecraft. The rotation of the RDAs can be stopped at any preselected position upon command. The limits of the range of rotation can also be selected by command so that the assemblies can oscillate over small angular ranges if desired.

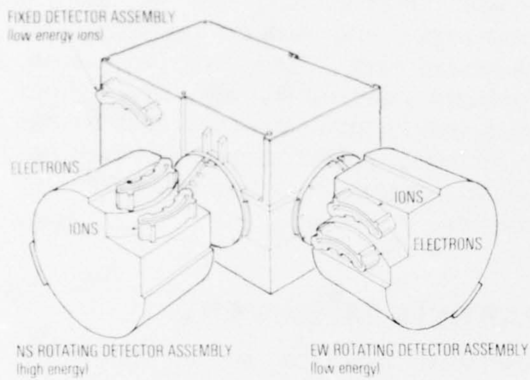


Figure 16.1. Charged Particle Detector

The NS detectors are capable of measuring particles with energies from a few eV up to 81 keV. The fixed detector and the EW detectors detect particles with energies from 0.2 eV up to about 1550 eV. Each scan in energy consists of 64 energy steps spaced exponentially up to the maximum energy with an energy resolution $\Delta E/E$ at each step of approximately 20 percent.

Each of the five charged particle detectors is made from three subassemblies: an electrostatic curved plate energy/unit-charge analyzer; an electrostatic grid structure that acts as a lens to focus upon the sensor those particles that have passed through the energy analyzer; and a Bendix Model 4213-PAC/WL Spiraltron particle sensor with appropriate pulse electronics, which counts the analyzed particles. Figure 16.2 shows a cross section of the detector assembly.

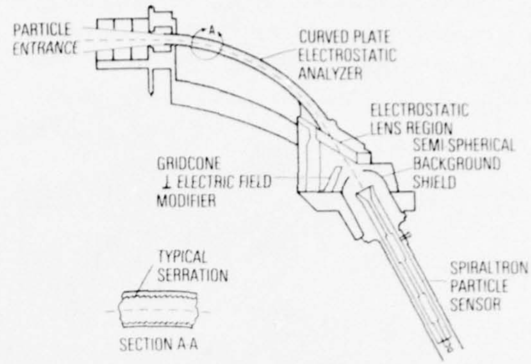


Figure 16.2. Cross Section of Detector Assembly

The curved analyzing plates are unique in that they are ovoidal, i.e., they have different curvatures in the parallel (energy analyzing) and perpendicular directions. In order to obtain azimuthal focusing (focusing in the perpendicular direction) for a spherical geometry, the particles must be bent 90 deg. In an attempt to maintain a large geometric factor the path length has been shortened such that the particles trajectories are deflected 55 deg. The shorter radius curvature in the azimuthal direction (26 percent shorter) results in a proper azimuthal focusing for the shorter path length. Also, the shorter azimuthal radius of curvature results in a neutral focusing in the parallel direction. The shorter path length and the postanalysis electrostatic lens for focusing the parallel direction maintain a large geometric factor and, in addition, good angular resolution. The angular resolution of each sensor is approximately 2.8 deg by 2.6 deg for a monoenergetic spectrum and 2.8 deg by 7 deg for a flat spectrum.

Figure 16.2 (view A-A) shows that the inside of the plates are serrated so that particles striking the sides will be eliminated resulting in a minimum of secondaries with forward momentum. The plates of the energy analyzer are driven by a power supply that can be programmed to supply any one of 64 voltage steps. These steps allow one to analyze particles of energy between less than 1 eV and 81 keV with an energy resolution of about $(0.2E + 2)$ eV full width at half maximum. The analyzer constant is approximately 11; thus several kilovolts must be applied to each plate in

ORDER TO ANALYZE PARTICLES IN THE HIGHER ENERGY RANGE.

ANOTHER UNIQUE FEATURE OF THE ANALYZERS IS THE POSTANALYSIS ELECTROSTATIC LENS. THIS LENS IS A STRUCTURE MADE OF TWO WIRE GRIDS POSITIONED IMMEDIATELY AFTER THE ENERGY ANALYZER. THIS DOUBLE GRID STRUCTURE IS ILLUSTRATED IN FIGURE 16.2. THE FIRST GRID IS HELD AT THE POTENTIAL OF THE INNER PLATE. THE SECOND GRID IS HELD AT THE POTENTIAL OF GROUND. A PARTICLE PASSING THROUGH THIS STRUCTURE IS STRONGLY FOCUSED UPON THE CENTER OF THE SENSOR. FOR THE ELECTRON DETECTORS, A CONE (LABELED GRIDCONE IN FIGURE 16.2) HAS BEEN MOUNTED TO CONTROL THE ELECTRIC FIELD AROUND THE SECONDARY PARTICLE SUPPRESSOR (DISCUSSED BELOW).

THE GEOMETRIC FACTOR H (DIFFERENTIAL ENERGY FLUX = COUNT RATE/H), WHICH RESULTS FROM THE INCLUSION OF THE LENS, IS APPROXIMATELY 3.2×10^{-4} (CM^2 -SR) FOR PROTONS AND 1.6×10^{-4} (γCM^2 -SR) FOR ELECTRONS.

THE REASON FOR THE DIFFERENCE BETWEEN THESE VALUES IS THAT BECAUSE OF HIGHER EXPECTED ELECTRON FLUXES, ONE-HALF OF EACH ELECTRON APERTURE HAS BEEN COVERED. THE GEOMETRICAL FACTOR IS SOMEWHAT ENERGY-DEPENDENT AT LOWER ENERGIES DUE TO BOTH A POSTANALYSIS ACCELERATION THAT OCCURS AT THE SPIRALTRON (FACTORS OF 3 VARIATION IN H OCCURING GRADUALLY AROUND 1 - 3 KEV FOR PROTONS AND 0.1 - 0.3 KEV FOR ELECTRONS), AND A 0.1 - 0.2 -V NOISE LEVEL ON THE HIGH ENERGY ANALYZING PLATES. THE HIGH VOLTAGE SUPPLY IS NOT USED WITH LOW ENERGY DETECTORS; CONSEQUENTLY, THE LOW ENERGY DETECTORS HAVE GOOD RESOLUTION DOWN TO ABOUT 0.2 EV. THE FACT THE ELECTROSTATIC LENS MAINTAINS A LARGE GEOMETRIC FACTOR IS VERY IMPORTANT. SUCH A GEOMETRIC FACTOR RESULTS IN MUCH HIGHER COUNTING RATES THAN ARE NORMALLY AVAILABLE, YIELDING BETTER STATISTICS. IN ADDITION, FINER TIME RESOLUTION CAN BE OBTAINED SINCE THERE IS NO NEED TO REDUCE ALREADY LOW COUNTING RATES. TAKING ADVANTAGE OF THIS FEATURE, THE DETECTORS HAVE MODES THAT ALLOW SAMPLING UP TO 24 TIMES A SECOND IN EITHER ELECTRONS OR IONS.

A BENDIX MODEL 4213-PAC/WL SPIRALTRON PARTICLE SENSOR DETECTS EACH CHARGED PARTICLE THAT HAS PASSED THROUGH THE ENERGY ANALYZER. PULSE ELECTRONICS ATTACHED TO THIS SENSOR AMPLIFIES ITS OUTPUT AND SETS A NOMINAL DEAD TIME OF 3.5μSEC.

THIS RATE LIMITING REJECTS AFTER PULSES AND PROVIDES A STABLE WELL-KNOWN DEAD TIME SO THAT TRUE COUNTING RATES OF 10^7 COUNTS/SEC CAN BE MEASURED UNAMBIGUOUSLY. WITH THE VERY LARGE GEOMETRIC FACTOR, THE LIFETIME OF THE SPIRALTRON SENSORS IS OF PARAMOUNT CONCERN. THEREFORE, THE HIGH VOLTAGE BIASING OF THE SPIRALTRON HAS BEEN ARRANGED SO THAT ONE OF TWO VALUES CAN BE CHOSEN BY GROUND COMMAND. THIS ALLOWS SOME CONTROL OVER THE SPIRALTRON GAIN AFTER DEGRADATION HAS BEGUN.

SUPPRESSION OF SECONDARY ELECTRONS AND SOME ADDITIONAL FOCUSING IS ACCOMPLISHED BY A SEMISPHERICAL SUPPRESSOR SHIELD, FIGURE 16.2, WHICH LIES BETWEEN THE SENSOR AND THE ELECTROSTATIC LENS. THE PROTON SUPPRESSOR IS AT ZERO POTENTIAL AND THE ELECTRON SUPPRESSOR IS AT 0 V FOR ENERGY SELECTION BELOW 100 V AND AT -30 V FOR ENERGY SELECTION ABOVE 100 V.

16.3 FUNCTIONAL BLOCK DIAGRAM

A BLOCK DIAGRAM OF THE EXPERIMENT IS SHOWN IN FIGURE 16.3. THE EXPERIMENT WAS DESIGNED TO ALLOW A GREAT DEAL OF FREEDOM IN THE PROGRAMMED SELECTION OF ENERGIES. THE SIMPLEST ENERGY PROGRAM AVAILABLE IS CALLED SCAN. IN THIS PROGRAM, THE ANALYZER SCANS THROUGH THE 64 DISCRETE EXPONENTIALLY-SPACED ENERGY LEVELS. THE PROGRAM STARTS AT THE LOWEST ENERGY AND PROCEEDS TO THE HIGHEST. EACH ENERGY LEVEL IS MAINTAINED FOR 250 MSEC BEFORE PROCEEDING TO THE NEXT ENERGY LEVEL. AFTER THE 64TH LEVEL, THE CYCLE IS REPEATED. ONE ENTIRE SCAN REQUIRES 16 SEC FOR COMPLETION. THE MORE COMPLICATED ENERGY SELECTION PROGRAM IS CALLED THE SCAN-DWELL MODE. THIS PROGRAM STARTS WITH A SINGLE SCAN AS DESCRIBED ABOVE. AT THE COMPLETION OF THE SCAN, THE ANALYZER JUMPS TO A PREDETERMINED ENERGY LEVEL (ED 1), ONE OF THE 64 SCAN ENERGY LEVELS, AND MAINTAINS THAT ENERGY LEVEL (DWELL) FOR A PREDETERMINED LENGTH OF TIME (DT). AT THE COMPLETION OF THE DWELL, THE ANALYZER PERFORMS A SCAN AND THEN DWELLS AT THE NEXT ENERGY LEVEL (ED 1 + NEL) WHERE NEL IS THE NUMBER OF DISCRETE ENERGY LEVELS BETWEEN ADJACENT DWELLS OF THE SAME

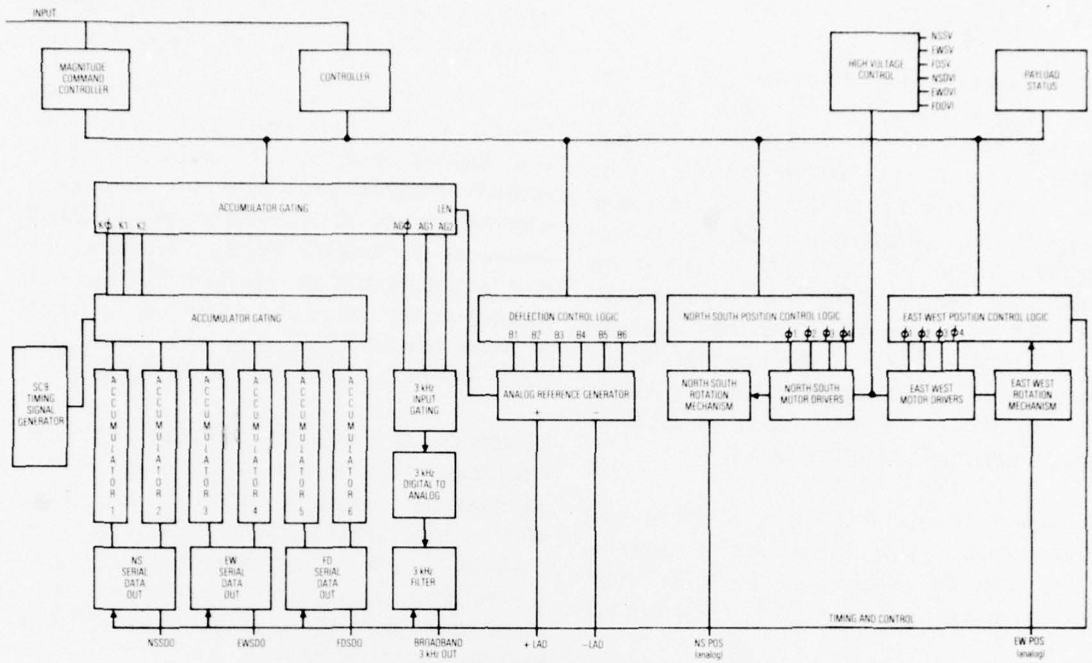


Figure 16.3. Block Diagram

SCAN-DWELL PROGRAM. THIS PROCESS CONTINUES UNTIL A PREDETERMINED NUMBER OF DWELLS (ND) HAVE OCCURRED, AT WHICH TIME THE PROGRAM REPEATS. ALL OF THE ABOVE PARAMETERS (ED 1, DT, NEL, ND) ARE SET BY GROUND COMMAND.

THE ENERGY SELECTION PROGRAMS WERE DESIGNED TO ALLOW BALANCE BETWEEN OBTAINING FULL SPECTRUM INFORMATION AND THE MONITORING OF FAST TIME VARIATIONS AT PARTICULAR ENERGIES. THE PROGRAMMED DWELLS, FOR INSTANCE, ARE EXTREMELY USEFUL IN THE STUDY OF ALFVEN WAVES IN THE MAGNETOSPHERE. WHEN EVEN HIGHER TIME RESOLUTIONS ARE REQUIRED, GROUND COMMANDS CAN BE SENT THAT MODIFY THE ACCUMULATION OF DETECTOR COUNTS. THERE ARE SIX ACCUMULATOR CHANNELS EACH OF WHICH GIVES ONE READING FOR EACH 0.25 SEC. UNDER NORMAL ACCUMULATION, EACH OF THE FOUR ROTATING DETECTORS ARE SIMPLY GATED TO A SINGLE ACCUMULATOR. THE FDA IS PROVIDED WITH TWO ACCUMULATOR CHANNELS. IT IS POSSIBLE TO SAMPLE A DETECTOR AT A HIGHER RATE THAN NORMALLY OBTAINED BY GATING THE OUTPUT OF THE DETECTOR TO MORE THAN ONE ACCUMULATOR AT THE EXPENSE OF INFORMATION FROM SOME OF THE OTHERS. DURING THE DWELLS IT IS POSSIBLE TO OBTAIN UP TO 24 READINGS A SEC FROM ONE DETECTOR, SUBSEQUENTLY INCREASING THE TIME RESOLUTION OF THAT DETECTOR.

EACH OF THE RDAs IS ATTACHED TO THE MAIN HOUSING BY A SHAFT DRIVEN THROUGH WORM GEARS BY A STEPPING MOTOR. THE RDAs ROTATE AT A RATE OF $60/43 \simeq 1.4$ DEG/SEC SO THAT TO COMPLETE THE 220 DEG FORWARD AND REVERSE CYCLE TAKES 314 SECONDS. THE ANGLE SWEEPING PROGRAMS HAVE BEEN DESIGNED TO ALLOW CONSIDERABLE FREEDOM IN THE SELECTION OF ANGLES. THE RDAs CAN BE STOPPED IN A NUMBER OF PREPROGRAMMED POSITIONS. ALSO, THE UNITS CAN BE ROTATED IN A SYNCHRONOUS FASHION OR THE EAST-WEST UNIT CAN BE FIXED WHILE THE NORTH-SOUTH UNIT ROTATES. FINALLY, THROUGH REALTIME MANIPULATION THE RDAs CAN BE PARKED AT ARBITRARY ANGLES OF INTEREST, FOR INSTANCE, THE CLOSEST APPROACH ANGLE TO THE MAGNETIC FIELD.

A DIGITAL FILTER, WHICH CUTS OFF AT 3 KHZ CAN BE CONNECTED BY COMMAND TO ANY OF THE FIVE DETECTORS. THE OUTPUT OF THE FILTER IS SENT TO GROUND VIA THE BROADBAND TRANSMITTER. THE PURPOSE OF THIS CAPABILITY IS TO FOLLOW RAPID FLUCTUATIONS IN THE COUNT RATE SUCH AS MIGHT BE CAUSED BY WAVES IN THE PLASMA OR BY RAPID CHANGES IN THE SPACECRAFT POTENTIAL.

16.4 OPERATIONAL ASPECTS

THE NORMAL MODE OF OPERATION OF THE EXPERIMENT IS

TO ROTATE BOTH RDAS THROUGH THEIR FULL ROTATION ANGLE WHILE THE ANALYZERS SCAN SEQUENTIALLY THROUGH THE 64 DISCRETE EXPONENTIALLY-SPACED ENERGY LEVELS. THE PROGRAM STARTS AT THE LOWEST ENERGY LEVEL AND PROCEEDS TO THE HIGHEST LEVEL FOR EACH DETECTOR. THE TRANSITION TIME BETWEEN ENERGY LEVELS MAY BE ASSUMED TO BE NEGLIGIBLE. THIS NORMAL MODE OF OPERATION IS CALLED THE SCAN ONLY MODE IN WHICH THE ANALYZER ENERGY IS CONTROLLED BY CONSECUTIVE SCAN PROGRAMS.

WHENEVER THE EXPERIMENT IS TURNED ON IT COMES INTO THE NORMAL MODE OF OPERATION UNLESS ADDITIONAL COMMANDS ARE SENT TO COMMAND IT INTO A SPECIAL MODE. MOST SPECIAL MODES OF OPERATION WILL BE CHOSEN AS PART OF THE EXPERIMENT OPERATIONS PLAN. SPECIAL MODES THAT WILL BE FREQUENTLY USED INVOLVE RESTRICTING THE ANGLES OF ROTATION OF THE RDAS TO SPECIAL ANGLE INTERVALS, OR STOPPING THE RDAS AT A CERTAIN FIXED POSITION. OTHER SPECIAL MODES WILL INTERSPERSE THE ENERGY SCAN PROGRAM WITH DWELL INTERVALS WHEN THE ANALYZER ENERGY IS FIXED FOR PREDETERMINED PERIODS BY COMMAND. THE BROADBAND TRANSMISSION OF THE FILTERED COUNT RATE SIGNAL IS ALSO A SPECIAL MODE CHOSEN BY COMMAND.

SPECIAL MODES OF OPERATION WILL BE USED DURING THE EXPERIMENT CHECKOUT SEQUENCE, DURING THE TRANSFER ORBIT, AND DURING TIMES WHEN THE ELECTRON AND ION BEAM EXPERIMENTS ARE OPERATED. DURING THE TRANSFER ORBIT THE ELECTRONICS WILL BE TURNED ON TO PREVENT THE EXPERIMENT FROM GETTING TOO COLD. DATA WILL BE TRANSMITTED DURING PORTIONS OF THE TRANSFER ORBIT. THE RDAS WILL NOT BE ROTATING AT THIS TIME BECAUSE OF THE HIGH SPIN RATES OF THE VEHICLE. DURING EXPERIMENT CHECKOUT A NUMBER OF SPECIAL MODES OF OPERATION WILL BE TESTED TO ASCERTAIN THE EXPERIMENT PERFORMANCE. THE COMMAND SEQUENCE FOR THE CHECKOUT OPERATION WILL BE PART OF THE ORBITAL OPERATIONS PLAN. DURING INITIAL OPERATION OF THE SC4 ELECTRON AND POSITIVE ION BEAM SYSTEMS, THE RETURN CURRENTS TO THE SPACECRAFT AT THE SC9 PAYLOAD WILL BE MEASURED. THE SC9 AND SC4 WILL SUBSEQUENTLY BE OPERATED SO THAT THE MEASURED CURRENTS ARE NOT LARGE ENOUGH TO DAMAGE THE SPIRALTRON. EACH SPIRALTRON HAS A LIFETIME DETERMINED BY A MAXIMUM NUMBER OF COUNTS THAT IT CAN TOLERATE. NEAR THE END OF ITS LIFETIME, THE RESPONSE OF A SPIRALTRON WILL DEGRADE. AT TIMES THE BIAS ON THE SPIRALTRON MAY BE CHANGED BY COMMAND IN ORDER TO INCREASE THEIR LIFETIME AND DETERMINE THE STATUS OF DEGRADATION. THERE WILL BE OTHER PERIODS OF ORBITAL OPERATIONS WHEN SPECIAL MODES WILL BE USED FOR STUDYING PARTICULAR PHENOMENA OR FOR CARRYING ON COLLABORATIVE STUDIES WITH OTHER EXPERIMENTS.

17. SC10 ELECTRIC FIELD DETECTOR

17.1 SCIENTIFIC OBJECTIVES

ONE OF THE PRIMARY GOALS OF THE ELECTRIC FIELD DETECTOR DIFFERENTIAL MEASUREMENTS IS THE OBSERVATION OF THE STEADY STATE CONVECTIONAL ELECTRICAL FIELDS THAT ARE KNOWN TO EXIST AT THE PLANNED ORBITAL ALTITUDE OF THE P78-2 SATELLITE. THE EXISTENCE OF THESE FIELDS IS INFERRED FROM THE EXTRAPOLATION OF CONVECTIONAL PLASMA VELOCITIES IN THE HIGH LATITUDE IONOSPHERE TO SYNCHRONOUS ALTITUDE AND FROM THE OBSERVATION IN IMP VI DATA OF HIGH AMPLITUDE TRANSIENT ELECTRIC FIELDS IN THE MIDNIGHT MERIDIAN DURING THE ONSET PHASE OF AURORAL SUBSTORM EVENTS. THESE LARGE AMPLITUDE TRANSIENT ELECTRIC FIELD EVENTS ARE ONE OF SEVERAL POSSIBLE INJECTION MECHANISMS FOR THE PERIODIC INCREASES OF MAGNETOSPHERIC PARTICLES THAT HAVE BEEN OBSERVED WITH EXPERIMENTS SIMILAR TO THE SC9 UCSD CHARGED PARTICLE EXPERIMENT DURING THE ONSET PHASE OF THE AURORAL SUBSTORM EVENTS ON THE ATS SERIES OF SATELLITES.

ANOTHER GOAL OF THIS EXPERIMENT IS TO MEASURE ELECTRIC FIELDS FROM TRANSIENT EVENTS SUCH AS ELECTROSTATIC DISCHARGE ON SELECTED SPACECRAFT INSULATING SURFACES. THIS ANTENNA, ALONG WITH THREE OTHER SC1 ANTENNAS, WILL BE USED TO CHARACTERIZE ELECTROMAGNETIC INTERFERENCE IN THE VICINITY OF THE SPACECRAFT. THE COMMON MODE SIGNAL OF THIS EXPERIMENT RELATES ELECTRIC FIELDS IN THE UNDISTURBED AMBIENT MEDIUM OF THE PLASMA.

COMMON MODE DATA EXCURSIONS FROM THE ELECTRIC FIELD EXPERIMENT ON THE IMP VI SATELLITE WERE SHOWN TO CORRESPOND TO SPACECRAFT CHARGING EVENTS. THE COMMON MODE PART OF THE SC10 ELECTRIC FIELD DETECTOR SHOULD PROVE USEFUL IN UNDERSTANDING SPACECRAFT CHARGING (A) BECAUSE OF the very good temporal resolution available from this simple measurement, (b) because of the possibility of extrapolating the P78-2 spacecraft results to lower and higher satellite altitudes, (c) because of the expected sensitivity of this experiment to active charging events provided by the SC4 experiment, and (d) because of the ease of folding these events into morphological studies of charging events as a function of orbital position, local time, and auroral activity.

17.2 MEASURING TECHNIQUE

The SC10 electric field experiment is a NASA-supplied double floating ensemble that will measure DC electric fields in the ambient plasma and also spacecraft charging events. The experiment consists of three payload packages. The SC10-2 and SC10-3 units are unfurlable antennas. When deployed, these antennas will form a 100-m tip-to-tip dipole. The SC10-1 electronics package contains high input impedance amplifiers, high precision differential amplifiers, and a low frequency spectrum analyzer. The experimental objectives are twofold. The differential signal impressed upon the dipole antenna will yield direct measurement on the ambient convectional electrical fields in the plasma of geophysical interest. Also, the common mode signal of a single antenna will monitor spacecraft charging events. The 100-m dipole antennas are used as double floating probes. The inner 30 m sections of these 50-m, 1/4-inch diameter antennas are coated with Kapton insulation to move the outer 20-m active probe areas away from the plasma sheath of the satellite that can overlap and thus contaminate the probe measurements.

These long antennas are expected have unique signal-to-noise characteristics compared to the other antenna aboard the P78-2 satellite. Because of these characteristics, the 100-m dipole antenna supplied by this experiment is shared with the SC1-7 and SC1-8 HF and VLF experiments. An electrical interface, shown in Figure 17.1, runs between the SC10-2 and SC10-3 antenna packages and the SC1 preamplifiers by means of a 10-K resistor in-line with the low frequency preamplifiers.

In addition to this cross-coupling to the SC1 experiment, one of the 0.2 to 200 Hz RMS analyzers in the SC10-1 electronics package can be commanded to detect the output of the X-axis of the SC11 magnetometer output. The commandable feature is indicated in the block diagram shown in Figure 17.2. When operating in the magnetic field mode, this portion of the SC10 experiment will provide morphological data relative to the E and B noise at the orbit of the P78-2 satellite.

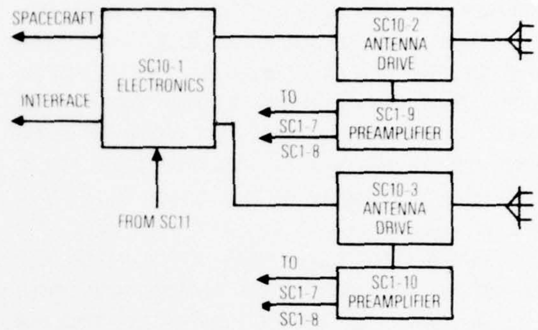


Figure 17.1. Intrapayload Functions

17.3 FUNCTIONAL BLOCK DIAGRAM

The block diagram of the SC10 experiment is shown in some detail in Figure 17.2. The signals from the SC10-2 and SC10-3 antennas are monitored directly with several voltage gains (common mode). The differential signal between the antennas is likewise monitored with several voltage ranges. In addition, these signals are monitored in the Fourier domain as RMS signals in four frequency bands between 0.2 and 200 Hz. The SC10 experiment outputs to telemetry are the fourteen primary words listed in Table 17.1. In addition, a realtime, wideband FM-FM link is available on command and is planned for operations up to 3 hr/day in order to cover a number of different local time regions. As indicated in Table 17.1, this link will provide electric field data in the realtime domain from 0 to 200 Hz frequency and bandwidth.

Although the maximum voltage range of the common mode amplifiers is set at 5 keV (Table 17.1), the SC10-2 -3 and packages contain spark gap protection to limit the maximum excursion of the two 50-m antennas to 3.5 kV. This protection is required to limit the maximum voltage in orbit on these antennas to a voltage range where spurious

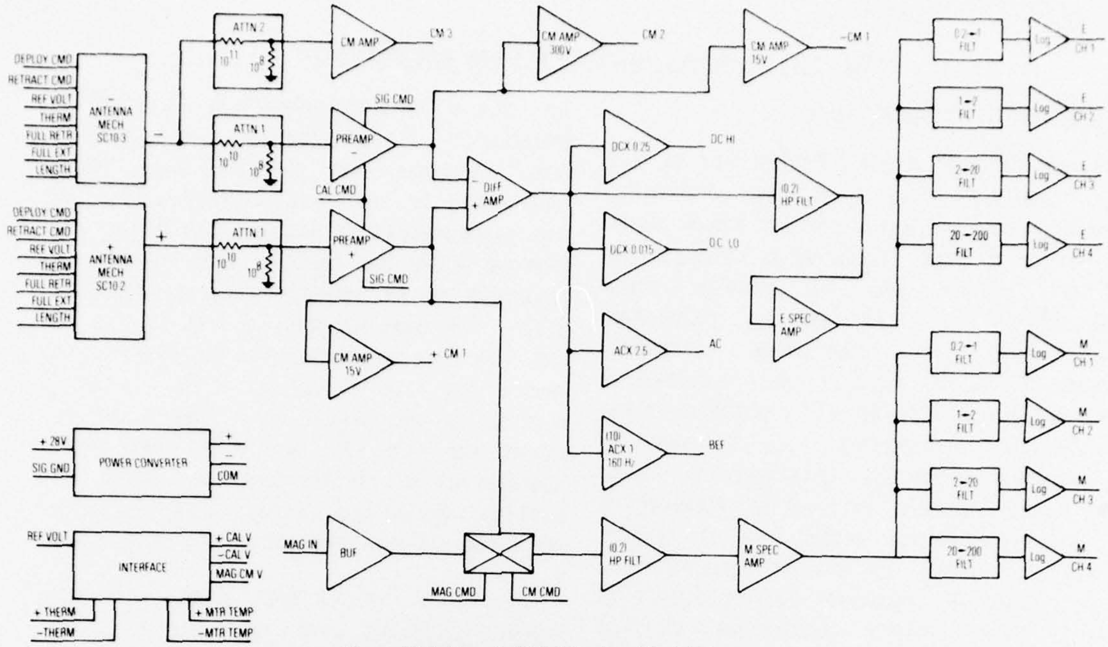


Figure 17.2. Electric Field Monitor Block Diagram

HIGH VOLTAGE DISCHARGES TO THE ANTENNA MECHANISMS WILL NOT PRODUCE EQUIPMENT FAILURES IN EITHER THE INTERCONNECTING EXPERIMENT PACKAGES OR TO NEARBY SPACECRAFT SYSTEM FUNCTIONS. THE ELECTROSTATIC ENERGY DISCHARGED THROUGH THESE SPARK-GAPS ON FIRING IS EXPECTED TO CORRESPOND TO THE 40 PF BASE CAPACITY OF THE ANTENNA MECHANISMS TO GROUND. IT IS EXPECTED THAT THESE SPARK-GAPS WILL DISCHARGE ONLY DURING THE HIGHEST VOLTAGE CHARGING EVENTS AND THESE CONTROLLED DISCHARGES WILL BE MONITORED ON THE ± 5 KEV COMMON MODE TELEMETRY OUTPUTS INDICATED IN TABLE 17.1.

Table 17.1. Measurement Modes

Format	Common Mode		Differential	
digitized waveform	3 ranges	a) ±15 V	3 gains	a) X.025
		b) ±300 V		b) X.25
		c) ±5,000 V		c) X2.5
digitized fourier analyzed wave	4 frequency bands	a) 0.1 to 1.0 Hz	4 frequency bands	a) 0.1 to 1.0 Hz
		b) 1 to 2 Hz		b) 1 to 2 Hz
		c) 2 to 20 Hz		c) 2 to 20 Hz
		d) 20 to 200 Hz		d) 20 to 200 Hz
FM-FM	not available		DC to 200 Hz VCO transmission up to 3 hr/day.	

17.4 OPERATIONAL ASPECTS

THE SC10 ANTENNAS WILL NOT BE DEPLOYED UNTIL SEVERAL WEEKS AFTER SPACECRAFT ORBIT INSERTION IN ORDER TO GIVE OTHER EXPERIMENTS, WHICH ARE SENSITIVE TO THE SATELLITE SHEATH, A BASELINE PERIOD WITHOUT THESE LONG DOUBLE FLOATING PROBES. AFTER THIS INITIAL PERIOD, THESE ANTENNAS WILL BE DEPLOYED IN THREE STAGES TO THREE ANTENNA LENGTHS TO STUDY THE PROBE CHARACTERISTICS OF THESE ANTENNAS WITH VARYING DEGREES OF OVERLAP FROM THE SATELLITE SHEATH. THE DEPLOYMENT MOTORS OF THESE ANTENNAS HAVE SPACE BRUSH MATERIAL TO ALLOW ADDITIONAL CHANGES IN THE ANTENNA LENGTH DURING THE COMPLETE LIFETIME OF THE SATELLITE. IT IS EXPECTED THAT THE ANTENNAS LENGTHS WILL BE KEPT AT 100 M TIP-TO-TIP FOR THE DURATION OF THE P78-2 SPACECRAFT LIFETIME.

THE GAIN FUNCTIONS OF THE ELECTRONICS PACKAGE CAN BE CALIBRATED WITH INTERNAL AC AND DC VOLTAGE SOURCES. THIS CALIBRATION SEQUENCE IS ACTIVATED BY GROUND COMMAND (FIGURE 17.2) AND WILL BE USED ONLY INFREQUENTLY. IT IS ANTICIPATED THAT THE DATA FROM THIS LOW POWER EXPERIMENT WILL BE ACQUIRED DURING ALL NORMAL PCM DATA TRANSMISSIONS. WIDEBAND ELECTRIC FIELD DATA WILL BE TRANSMITTED ON A TIME SHARING BASIS. WIDEBAND DATA FROM THE SC10 EXPERIMENT ARE HARDWIRED IN THE SATELLITE DATA PROCESSOR TO BE TRANSMITTED SIMULTANEOUSLY WITH WIDEBAND DATA FROM THE SC11 AND SC9 EXPERIMENTS. THIS WILL SIMPLIFY DATA REDUCTION SINCE THESE THREE EXPERIMENTS ARE RELATED TO THE GENERAL STUDY OF WAVE-PARTICLE INTERACTIONS.

18. SC11 MAGNETIC FIELD MONITOR

18.1 SCIENTIFIC OBJECTIVES

DATA FROM THE MAGNETIC FIELD MONITOR WILL BE USED TO ANALYZE THE FIELD ALIGNED AND DISTRIBUTED CURRENT SYSTEMS IN THE LOW LATITUDE REGION AROUND SYNCHRONOUS ALTITUDE. MAGNETOPAUSE CROSSINGS ARE TO BE EXPECTED, AND THE MAGNETIC FIELD MEASUREMENTS WILL CONTRIBUTE TO COORDINATED INVESTIGATIONS OF MAGNETOPAUSE STRUCTURE. WIDEBAND (~100 HZ) MAGNETIC FIELD MEASUREMENTS, SIMULTANEOUS WITH WIDEBAND SC10 ELECTRIC FIELD AND SC9 PARTICLE MEASUREMENTS WILL BE USED IN WAVE-PARTICLE INTERACTION INVESTIGATIONS. THESE DATA SHOULD CONTRIBUTE TO A BETTER UNDERSTANDING OF THE MAGNETOSPHERE DYNAMICS AS IT EFFECTS SPACECRAFT CHARGING. THE MAGNETIC FIELD DATA WILL ALSO BE USED IN SPACECRAFT CHARGING MODELS TO COMPUTE LOCAL PARTICLE TRAJECTORIES AND FOR ENVIRONMENTAL MODELING.

18.2 MEASURING TECHNIQUE

THE INSTRUMENT IS A TRIAXIAL FLUXGATE MAGNETOMETER. EACH AXIS HAS A RANGE OF APPROXIMATELY ±500 γ(1 = 1 NT). TO REDUCE ABSOLUTE ERRORS IN THE MEASUREMENT OF THE MAGNETIC FIELD, A MAGNETICS CONTROL PROGRAM IS BEING IMPLEMENTED. IT INCLUDES BOTH SUBSYSTEM AND SYSTEM LEVEL MEASUREMENTS. THE MAGNETOMETER SENSOR IS LOCATED AT THE END OF A 4-M BOOM. THE SENSOR AXES, X, Y, AND Z, ARE ACCURATELY ALIGNED WITH THE CORRESPONDING SPACECRAFT AXES (SEE FIGURE 2.2). AN ERROR ANALYSIS PERFORMED BY THE SPACECRAFT MANUFACTURER ESTIMATES THAT THE ABSOLUTE ACCURACY OF MEASUREMENTS OF THE AMBIENT MAGNETIC FIELD COMPONENT ALONG THE SPACE VEHICLE'S X-AXIS WILL BE BETTER THAN ONE GAMMA AT ONE SIGMA CONFIDENCE LEVEL. ERRORS IN THE OTHER TWO AXES WILL BE LESS THAN IN THE X-AXIS. THE SPACECRAFT'S SPIN PROVIDES INFLIGHT INFORMATION ABOUT THE MAGNETOMETER ZERO LEVELS AND THE SPACECRAFT MAGNETIC FIELD COMPONENTS ALONG THOSE TWO AXES.

18.3 FUNCTIONAL BLOCK DIAGRAM

A BLOCK DIAGRAM IS SHOWN IN FIGURE 18.1. THE ANALOG OUTPUT (0-5 V) OF EACH AXIS IS PROCESSED BY A 4-BIT SUBTRACTOR. THE RESIDUAL VOLTAGE IS THEN AMPLIFIED BY A FACTOR OF APPROXIMATELY 13. THE AMPLIFIED VOLTAGES AND ANALOG REPRESENTATIONS OF THE STATE OF THE 4-BIT SUBTRACTORS ARE FED TO THE SPACECRAFT'S A/D CONVERTOR (ON LINES MARKED "X FINE," "X COARSE," ETC. IN FIGURE 18.1). GROUND CALIBRATIONS OF THE 4-BIT SUBTRACTORS ARE THEN USED TO RECONSTRUCT THE ANALOG OUTPUT OF EACH AXIS FROM THE TELEMETERED COARSE AND FINE SIGNALS. THE RESOLUTION OF THE MAGNETIC FIELD MEASUREMENT IS 0.3 γ. THE SAMPLING RATE IS FOUR VECTORS PER SEC. THE FLUX GATE SIGNALS ARE FILTERED BY A LOW PASS FILTER WITH A POLE AT 2 HZ, TO REDUCE ALIASING OF THE SAMPLED DATA. THE SIX WORDS, COARSE AND FINE FOR EACH AXIS, ARE SAMPLED CONSECUTIVELY BY THE A/D CONVERTOR. DURING THIS SAMPLING INTERVAL THE INPUTS TO THE SUBTRACTORS ARE CONTROLLED BY A SPACECRAFT "HOLD GATE" SIGNAL.

AS A BACKUP, THE FILTERED SIGNALS FROM EACH FLUXGATE AXIS ARE ALSO FED DIRECTLY TO THE SPACECRAFT'S A/D CONVERTOR WHERE THEY ARE SAMPLED CONSECUTIVELY AT A REPETITION RATE OF 1 VECTOR PER SEC. THE RESOLUTION OF THIS DATA IS ~4 γ.

THE SIGNALS FROM THE SPIN AXIS FLUXGATE (X-AXIS) ARE FED DIRECTLY WITHOUT FILTERING TO A SPECTROMETER IN THE ELECTRIC FIELD DETECTOR SC10. THE SC10 EXPERIMENT HAS THE CAPABILITY BY GROUND COMMAND OF SELECTING THIS SIGNAL, OR AN INTERNAL SIGNAL, AS INPUT TO THE SPECTROMETER. THE BANDWIDTH OF THE MAGNETIC FIELD SIGNAL TO THE SPECTROMETER IS APPROXIMATELY 100 HZ. THE X-AXIS SIGNAL IS ALSO TELEMETERED BY THE BROADBAND TELEMETRY SYSTEM. THE X-AXIS SIGNAL IS BANDPASS FILTERED AND AMPLIFIED BY A FACTOR OF 500, WHICH RESULTS IN A SENSITIVITY OF THE SIGNAL TO THE SPACECRAFT WIDEBAND TELEMETRY OF 200 M γ/V. THE HIGH FREQUENCY ROLL OFF OF THE BANDPASS FILTER IS APPROXIMATELY 100 HZ. THE LOW FREQUENCY ROLL OFF IS SELECTABLE BY COMMAND AS EITHER 1 OR 5 HZ.

18.4 OPERATIONAL ASPECTS

AFTER INITIAL INFLIGHT OPERATIONS, CURRENT PLANS CALL FOR REALTIME DATA TO BE EXAMINED ONCE PER WEEK TO MEASURE INSTRUMENT ZERO LEVELS AND SPACECRAFT FIELDS IN THE SPIN PLANE. A CALIBRATION PULSE, WHICH INDICATES THE SENSITIVITY OF ALL THREE AXES, WILL BE SENT DURING THESE DATA INTERVALS. IT IS ANTICIPATED THAT VECTOR MAGNETOMETER DATA WILL BE ACQUIRED DURING ALL

NORMAL PCM DATA TRANSMISSIONS. BROADBAND MAGNETOMETER DATA WILL, HOWEVER, BE TRANSMITTED ON A TIME-SHARING BASIS.

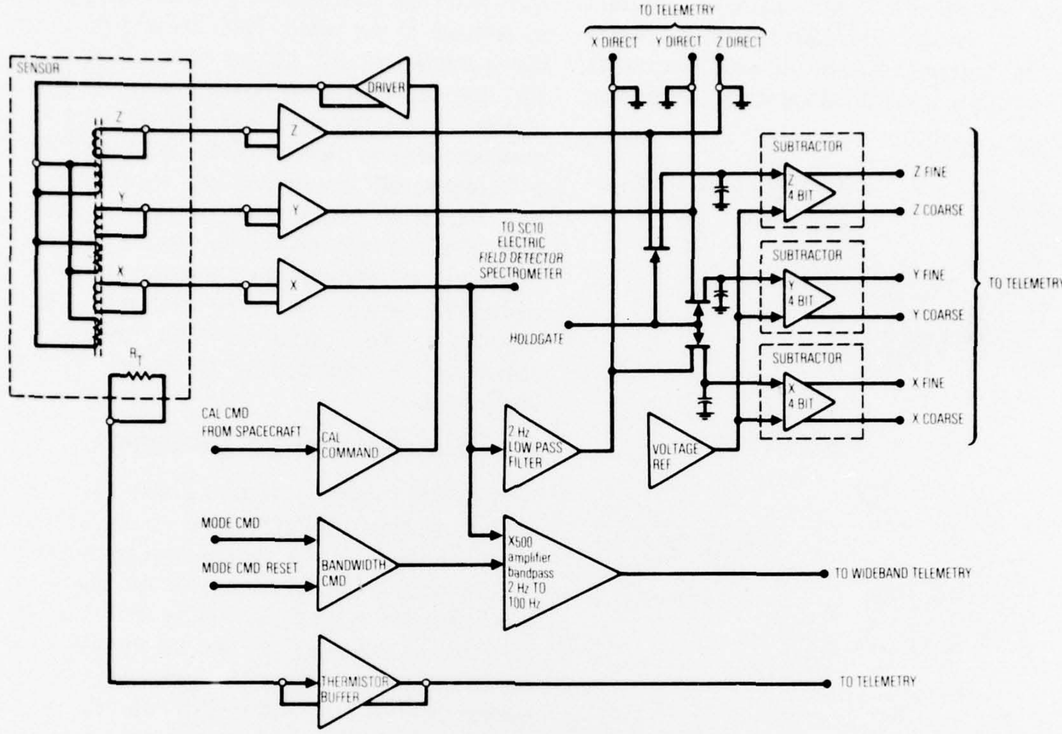


Figure 18.1. Magnetic Field Monitor Block Diagram

19. ML12 SPACECRAFT CONTAMINATION

19.1 SCIENTIFIC OBJECTIVES

THE ML12 EXPERIMENT IS DESIGNED TO DETERMINE IF SPACECRAFT CHARGING CONTRIBUTES SIGNIFICANTLY TO THE RATE OF CONTAMINATION ARRIVING AT EXTERIOR SPACECRAFT SURFACES. THE CONTAMINATION TRANSPORT MODE UNDER INVESTIGATION INVOLVES THE IONIZATION OF MOLECULES OUTGASSED OR RELEASED BY THE VEHICLE WITHIN THE VEHICLE PLASMA SHEATH AND THEIR SUBSEQUENT ELECTROSTATIC REATTRACTION TO THE VEHICLE. MEASUREMENTS OF INCIDENT CONTAMINATION RESULTING FROM BOTH CHARGED AND NEUTRAL MOLECULES WILL BE COMPARED WITH THE RESULTS OF OTHER EXPERIMENTS, SUCH AS THOSE THAT DETERMINE THE SPACECRAFT SURFACE POTENTIALS AND THE PLASMA SHEATH DIMENSIONS. CARE WILL BE TAKEN TO CORRELATE CONTAMINATION EVENTS WITH CONTROLLED CHANGES IN SPACECRAFT POTENTIAL CAUSED BY ACTIVATION OF THE ONBOARD ELECTRON AND ION BEAM SYSTEMS (SC4). THE ML12 EXPERIMENT ALSO PROVIDES A CONTAMINATION MONITOR FOR OTHER EXPERIMENTS ON THE P78-2 SPACECRAFT.

19.2 MEASURING TECHNIQUE

TWO SENSOR TYPES WILL BE FLOWN. ONE TYPE IS A COMBINATION RETARDING POTENTIAL ANALYZER (RPA) AND TEMPERATURE CONTROLLED QUARTZ CRYSTAL MICROBALANCE (TQCM) SHOWN IN FIGURE 19.1. WITH IT, DISTINCTION CAN BE MADE BETWEEN CHARGED AND UNCHARGED ARRIVING MOLECULES, AND INFORMATION CONCERNING THE TEMPERATURE DEPENDENCE OF CONTAMINATION ADSORPTION AND DESORPTION RATES CAN BE OBTAINED. THE OTHER SENSOR TYPE, THERMAL CONTROL COATING (TCC) TRAYS, FIGURE 19.2, EXPOSES SAMPLES OF DIFFERENT SPACECRAFT SURFACE MATERIALS TO ARRIVING CONTAMINATION AND CONTINUOUSLY MEASURES THE TEMPERATURE AND HENCE SOLAR ABSORPTANCE (α_S) OF THESE MATERIALS. CHANGES IN α_S OF SPACE STABLE SAMPLES WILL BE ENTIRELY ASCRIBED TO CONTAMINATION

EFFECTS WHEREAS CHANGES IN OTHER SAMPLES WILL RESULT FROM A COMBINATION OF CONTAMINATION, VACUUM, PHOTOCHEMICAL, AND RADIATION EFFECTS. UPON GROUND COMMAND, SOME SAMPLES WILL GO THROUGH A HEATING SEQUENCE DESIGNED TO ROUGHLY DETERMINE THE TEMPERATURE AT WHICH CONTAMINATION IS DESORBED.

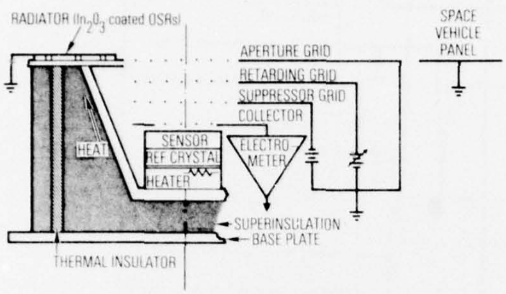


Figure 19.1. RPA/TQCM Sensor

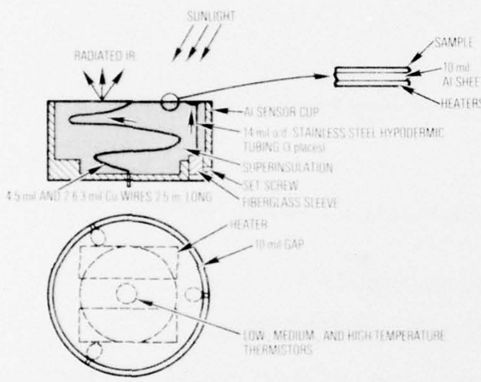


Figure 19.2. TCC Sensor

THERE ARE TWO OF EACH TYPE OF SENSOR ON THE SATELLITE. BOTH TCC TRAYS AND ONE RPA/TQCM VIEW RADIALLY, THE OTHER RPA/TQCM VIEWS AXIALLY FROM THE "FORWARD" END OF THE SPACE VEHICLE. SIMULTANEOUS MEASUREMENT OF ION CURRENTS AND MASS DEPOSITION RATES WILL PERMIT THE CALCULATION OF AVERAGE CHARGE-TO-MASS RATIOS OF DEPOSITED CONTAMINANTS. HOWEVER, THE INSTRUMENT SENSITIVITIES AND ARRIVING PARTICLE FLUXES WILL PROBABLY BE SUCH THAT SOME TIME INTEGRATION WILL BE REQUIRED FOR THESE DETERMINATIONS. CONTROL OF THE TEMPERATURE OF THE QCMS WILL ENHANCE THEIR STABILITIES AND PERMIT MEASUREMENT OF CONTAMINANT DEPOSITION AT SEVERAL TYPICAL SATELLITE SURFACE TEMPERATURES.

INFORMATION ON THE SAMPLE DEGRADATION BY CONTAMINANTS WILL BE OBTAINED BY COMPARING THE DATA FROM THE TQCM AND TCC SENSORS. ANY INCREASE IN α_S OF THE SPACE STABLE SAMPLES ON THE TCC TRAYS WHICH CAN BE CORRELATED WITH MASS DEPOSITION AS MEASURED BY THE NEARBY TQCM, CAN BE ASSOCIATED WITH A CONTAMINANT THAT ABSORBS SOLAR RADIATION IN THE NEAR ULTRAVIOLET THROUGH INFRARED SPECTRAL REGIONS. A MEASURED MASS DEPOSITION THAT DOES NOT CORRELATE WITH AN INCREASE IN α_S COULD MEAN THAT A "NONABSORBING" CONTAMINANT WAS COLLECTED. IF THIS COLLECTION SHOULD BE FOLLOWED BY A PERIOD WHEN $dM/dT \leq 0$ AND $d\alpha_S/dT > 0$, THEN A POSITIVE INDICATION OF ENVIRONMENTAL DEGRADATION OF THE CONTAMINANT WOULD HAVE BEEN OBTAINED. SUCH DEGRADATION COULD OCCUR AS THE RESULT OF ABSORPTION OF ULTRAVIOLET RADIATION BY THE CONTAMINANT.

19.3 FUNCTIONAL BLOCK DIAGRAMS

THE RPA/TQCM DIAGRAM IS SHOWN AS FIGURE 19.3. THE RPA IS CONVENTIONAL EXCEPT THAT IT HAS A LARGE (3.05 SR) FIELD OF VIEW AND AN ANNULAR COLLECTOR SO THAT SOME OF THE INCOMING FLUX CAN REACH THE MASS DETECTOR SITUATED JUST BELOW IT. THE RPA GRID MAY BE COMMANDED TO ANY OF THE FOLLOWING POTENTIALS OR BE CAUSED TO CONTINUOUSLY CYCLE THROUGH THEM AT 8 SEC/STEP: -100, -10, -1, 0, 1, 10, 100, 500 V. THE COLLECTOR IS APPROXIMATELY 1 CM^2; THE ELECTROMETERS WILL MEASURE CURRENT IN THE 10^{-12} TO 10^{-8} A RANGE TO A RESOLUTION OF APPROXIMATELY 10^{-12} A. THIS CORRESPONDS TO 6×10^{10} TO 6×10^{14} ELECTRONS PER SQUARE METER PER SEC OR THE EQUIVALENT IN IONIZED MOLECULES.

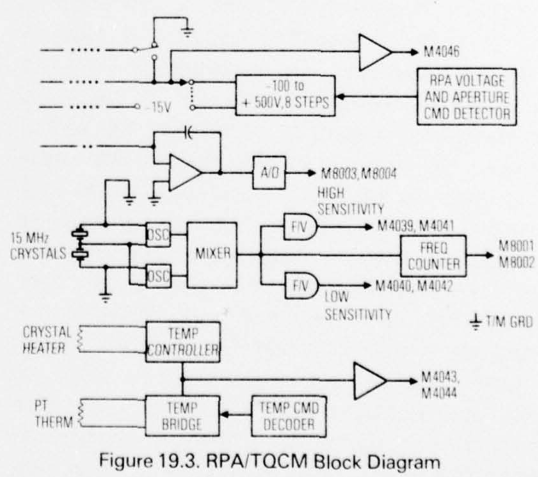


Figure 19.3. RPA/TQCM Block Diagram

THE FIRST GRID IS USUALLY AT TELEMETRY GROUND

POTENTIAL, BUT MAY BE COMMANDED TO RPA GRID POTENTIAL TO INCREASE THE EFFECTIVE AREA OF THE APERTURE. THE SURROUNDING CONDUCTIVELY COATED RADIATOR IS CONNECTED TO TELEMETRY GROUND THROUGH APPROXIMATELY 10 OHMS. THE SPACE VEHICLE SURFACE AROUND ALL FOUR SENSORS IS ALSO CONDUCTING AND GROUNDED SO THAT LOCAL PERTURBATIONS TO THE ELECTRIC-FIELD ARE MINIMIZED.

FIGURE 19.4 SHOWS A BLOCK DIAGRAM OF THE TCC EXPERIMENT. EACH TCC PACKAGE CONSISTS OF A SAMPLE TRAY AND A SIGNAL-PROCESSOR; THE DESIGN OF THE LATTER WAS UPGRADED FROM THAT USED ON PREVIOUS FLIGHTS. THE SAMPLE DISCS WILL HAVE ONE OR TWO OF THE THREE RANGE OVERLAPPING THERMISTORS CONNECTED. A FULL SET OF THERMISTOR VALUES WILL BE RECORDED EVERY 16 SECONDS FROM EACH TRAY THROUGHOUT THE MISSION. IN ADDITION, SIX SAMPLES ARE EQUIPPED WITH HEATERS DESIGNED TO HEAT THEM TO MAXIMUM TEMPERATURE OF 212°F WITH THREE STEPS BELOW THE MAXIMUM. THE CALIBRATED SAMPLE HEATERS WILL BE ACTIVATED ON GROUND COMMAND. THE SAMPLES ARE HEATED FOR ONE HOUR AND THEN ALLOWED TO COOL FOR TWO HOURS SO THAT ANY CHANGE IN α_S CAN BE RECORDED BEFORE THE NEXT HEATING CYCLE STEP. THE SEQUENCE OF FOUR HEATING STEPS OCCURS AUTOMATICALLY AFTER THE COMMAND IS ISSUED.

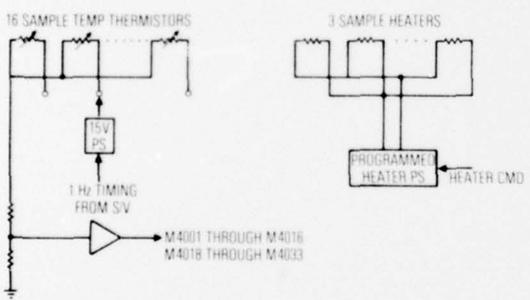


Figure 19.4. TCC Block Diagram

19.4 OPERATIONAL ASPECTS

EACH RPA/TQCM IS FITTED WITH A SPRING-LOADED HINGED COVER THAT IS RELEASED ON GROUND COMMAND. THE COVERS PROTECT THE SENSORS AND RADIATORS FROM CONTAMINATION DURING SATELLITE FABRICATION AND LAUNCH. THE ML12-7 COVER WILL BE OPENED EARLY IN TRANSFER ORBIT. OPENING THE ML12-6 COVER MUST AWAIT VEHICLE SPIN DOWN IN THE FINAL ORBIT. THE TCC TRAYS HAVE COVERS THAT WILL BE REMOVED THROUGH A DOOR IN THE PAYLOAD FAIRING JUST PRIOR TO LAUNCH. ALL FOUR COVERS ARE FITTED WITH EXTERNAL CONTAMINATION WITNESS PLATES TO BE REMOVED BEFORE LAUNCH. INFRARED AND WEIGHT PER UNIT AREA ANALYSIS OF THESE PLATES WILL ROUGHLY CHARACTERIZE THE SATELLITE SURFACE CONTAMINATION SPECIES AND QUANTITY AS LAUNCHED.

TCC AND TQCM PORTIONS OF THE EXPERIMENT WILL BE ACTIVATED EARLY IN THE TRANSFER ORBIT. THE DATA OBTAINED, HOWEVER, WILL BE LIMITED TO GROUND CONTACT PERIODS SINCE THE VEHICLE TAPE RECORDER WILL NOT BE OPERATING. ALSO, THE LIKELIHOOD OF HIGH VOLTAGE DISCHARGE PRECLUDES OPERATION OF THE RPA AND DIGITAL FREQUENCY COUNTER PORTIONS OF THE PAYLOAD UNTIL THE FINAL ORBIT.

THE TCC SAMPLE HEATER SEQUENCE IS ACTIVATED BY GROUND COMMAND. THE SAMPLES ARE HEATED FOR ONE HOUR AND THEN ALLOWED TO COOL FOR TWO HOURS SO THAT ANY CHANGE IN α_S CAN BE RECORDED BEFORE THE NEXT HEATING CYCLE STEP. THE SEQUENCE OF FOUR HEATING STEPS OCCURS AUTOMATICALLY AFTER THE COMMAND IS ISSUED. IT MAY BE TERMINATED IF NECESSARY; IF NO ACTION IS TAKEN, THE PAYLOAD RETURNS TO NORMAL OPERATION AUTOMATICALLY AFTER THE FOURTH HEATING STEP.

THE TQCM TEMPERATURE CONTROLLER COMMANDS ARE "FREE RUN", "-60°C", "-30°C", "0°C", "30°C", AND "100°C". THESE SIX STATES ARE SELECTED WITH A 4-BIT MAGNITUDE COMMAND. THIS PORTION OF THE PAYLOAD, ML12-8, REMAINS ON THROUGHOUT THE MISSION.

THE RPA ELECTROMETERS AUTOMATICALLY SWITCH BETWEEN HIGH AND LOW SENSITIVITY RANGES. THE ELECTROMETRY POLARITY MAY BE COMMANDED TO ION COLLECTION OR TO SELECT THE DOMINANT CHARGE SPECIES. THESE MODES, ALONG WITH THE APERTURE GRID CONNECTION AND RPA GRID VOLTAGE (OR CYCLE MODE), ARE SELECTED WITH 6-BIT MAGNITUDE GROUND COMMANDS.