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THE PLASMA INTERACTION EXPERIMENT (PIX) DESCRIPTION AND FLIGHT QUALIFICATION TEST PROGRAM

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ABSTRACT

The Plasma Interaction Experiment (PIX) is a battery powered preprogrammed auxiliary payload on the Landsat-C launch. This experiment is part of a larger program to investigate space plasma interactions with spacecraft surfaces and components. The varying plasma densities encountered during available telemetry coverage periods are deemed sufficient to determine first order interactions between the space plasma environment and the biased experimental surfaces. The specific objectives of the PIX flight experiment are to measure the plasma coupling current and the negative voltage breakdown characteristics of a solar array segment and a gold plated steel disk. Measurements will be made over a range of surface voltages up to ±1 kilovolt. The orbital environment will provide a range of plasma densities. The experimental surfaces will be voltage biased in a preprogrammed step sequence to optimize the data returned for each plasma region and for the available telemetry coverage.

INTRODUCTION

The Plasma Interaction Experiment (PIX) is part of an overall program to develop design criteria for spacecraft surfaces such as solar arrays which operate at high voltages while exposed to the charged particle space plasma environment.

PIX, an auxiliary payload on the Landsat-C mission, scheduled for launch March 5, 1978, will orbit on the Delta launch vehicle 2nd stage, and use the vehicle S-band telemetry system. Since the PIX utilizes the Delta launch vehicle attitude control and telemetry batteries, approximately 30 minutes of PIX data will be obtained from the circular polar orbit (500 N.M.). The varying plasma densities encountered in the 30 minute period are deemed sufficient to determine interactions between the space plasma environment and the experimental surfaces.

Studies have been conducted in ground facilities to investigate the plasma interaction with high voltage surfaces. However, in these ground test facilities, there are serious limitations, such as uncertain simulation of the environment and the distortion of the electric fields in

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the plasma by the metal vacuum tank walls, which strongly influence the test results. Hence, it is not possible to state conclusively that the test conditions represent those that will be found in space.

The objective of the PIX Project is to obtain engineering data that is necessary to design high voltage systems that can be exposed directly to the space environment and to obtain flight data that will serve as a reference set for future ground testing.

The PIX is designed to investigate the following specific areas:

Determine the interaction between the space plasma environment and a solar array segment biased to positive and negative voltages by measuring the plasma coupling current

Determine arcing characteristics in space

Determine the interaction between the space plasma and an isolated metal disk to positive and negative voltages by measuring the plasma coupling current

This paper presents a description of the PIX spacecraft, the solar array and disk experimental surfaces, the electronic design, mechanical structure, vehicle interfaces and the functional and qualification test programs. Also described are problems and solutions associated with high voltage breakdowns in a vacuum and plasma environment relative to the development of a preprogrammed, battery-operated payload employing surfaces biased to ±1 kilovolt.

DESCRIPTION OF EXPERIMENTS

There are three experimental surfaces in the PIX system; a solar array experiment and disk No. 1 both mounted on the experiment plate and disk No. 2 mounted on the electronics box (fig. 1). The solar array experiment consists of a series string of twenty-four 2×2 cm, 10 ohm-cm silicon solar cells with fused silicia cover glass (area ~100 cm^2) mounted on a fiberglass board. Conventional bar interconnects (area ~5 cm^2) are used in the array circuit. These interconnects are connected to the bias power supply and will form the current collecting area for this experiment. The fiberglass border around the solar cells is painted with white thermal paint. This surface along with the cover slides will float electrically when the bias voltage is applied to the interconnects. These electrically floating insulator surfaces will determine the extent of the coupling current that will be measured during the flight.

The disk No. 1 experiment consists of a gold plated metal disk 3 cm diameter (area ~10 cm^2) resting on a 20 cm diameter (area ~325 cm^2) Kapton sheet (5 mil thick). The purpose of this experimental surface is to determine the effect of the Kapton on the coupling current collected by the disk as a function of the bias voltage and the plasma density. Surrounding the Kapton sheet is a white painted fiberglass ring. The purpose of this ring is to insure that the Kapton sheet edges stay down.

The third experiment (disk No. 2) is a gold plated disk similar to the one used in the disk No. 1 experiment. This experiment is the key to the interpretation of the PIX flight data. This data is permanently connected to the bias power supply and acts as a control surface. It is electrically isolated from ground yet its surroundings are at spacecraft potential. Therefore, it will provide a reference current collection value to determine the effect of the Kapton insulation in disk No. 1 experiment and the solar cell cover slides and fiberglass border on the solar array experiment. In addition, the data from this experiment can be used as an indicator of the local plasma density.

The solar array experiment and the disk No. 1 experiment are mounted on the experiment plate which is at spacecraft ground potential. This grounding provides a known voltage surface surrounding the experimental surfaces. These experiments will be switched into the bias circuit sequentially and the currents collected through the plasma environment will be compared to that collected by the disk No. 2 experiment. Since the biased metal areas are similar (within a factor of 2), the effect of the surrounding insulator area can be determined. This data will then be compared with that obtained with the experiments operated in ground facilities at similar plasma densities to determine tank wall effects on this interaction.

The PIX will be the first experiment to provide plasma interaction data outside a vacuum chamber. The space plasma interaction experiment (SPHINX) was designed to investigate thoroughly this interaction phenomenon but the SPHINX spacecraft was lost on the Titan-Centaur proof flight due to a launch vehicle failure. Several of the PIX components are residual inventory items from the SPHINX program.

Equipment Description

General. - The PIX is shown in figure 1 prior to mating with the launch vehicle. Major items shown are the experiment plate, and the electronic enclosure box with the interconnecting harness. The PIX weighs approximately 75 pounds. Major items are described below.

Experiment plate. - The plate is 36 inches in diameter truncated to 32 inches high for launch vehicle clearance purposes. Construction is of 1/10 inch thick magnesium with channel reinforcement on the back side (fig. 2). The plate was treated with Dow 17 Anodic finish and covered with aluminum foil thermal tape. The plate serves as part of the experiment ground plane and provides a well defined mounting surface for the solar array segment and the disk.

Electronics enclosure box. - The box is 23" × 22.8" × 12" (W×H×D), constructed of riveted, channel reinforced magnesium plate. The exterior plate is 1/10 inch thick and was treated with Dow 17 Anodic coating and covered with aluminum foil thermal tape. Figure 3 shows the box with the face and rear covers removed. The PIX electronics, mounted on three shelves inside the box, include the battery, electrometer package, power distribution electronics package, the sequencer/multiplexer, and the high voltage power supply.

Also shown in figure 3 is a second gold plated steel disk which is essentially identical to the disk on the experiment plate. This disk serves as a reference surface for comparison to the solar array segment and the other disk.

The functions of this equipment are described in detail in subsequent paragraphs.

MECHANICAL DESIGN

The basic structure of the PIX spacecraft consists of two major subassemblies (fig. 1) which are designated the Enclosure Box and the Experiment Plate. Each subassembly is attached to the launch vehicle independently, and thus requires its own interface support structure. Both subassemblies, with the exception of the Enclosure Box interface support angles, were fabricated from AZ-31B magnesium alloy material. The support angles were made from 6061-T6 aluminum alloy extrusions. All surfaces were anodized after fabrication and before assembly.

The Experiment Plate consists of a truncated, 36 inch diameter circular plate stiffened in both directions with formed, channel-type stiffeners (fig. 2). The smooth side of the plate acts as a background and support surface for the solar array and disk experiments. The stiffeners were located and designed to give a fundamental natural frequency greater than 50 Hz. This insures adequate separation from lower mode launch vehicle frequencies. The stiffeners were fabricated from 0.1 inch thick sheet and riveted to the plate using a 2 inch rivet spacing. All corners were reinforced with riveted angle type clips. The launch vehicle adapter structure for the Experiment Plate consists of two angles with eight nut plates attached in place to insure rapid attachment and alignment with the launch vehicle attach brackets.

The Enclosure Box (fig. 3) is a rectangular, box shaped structure which houses the experiment electronics. The interior of the enclosure consists of three stiffened trays or shelves which are attached to channel type frame member. The channel frame members are then attached to six cover sheets to form a completely rigid, deep, box-beam type structure.

All electrical components are mounted on the trays to yield, as near as possible, an distribution of weight. The battery and electrometer, the heaviest components, are attached to the bottom tray which is the stiffest one. This tray has an upper and lower cover sheet attached to internal stiffeners while the remaining two trays have only one upper sheet attached to stiffeners. The Sequencer/Multiplexer and the Power Distribution Box, which are the lightest of the electrical components, are mounted to the middle tray while the high voltage power supply is tied to the upper or third tray. All trays are stiffened such that the loads are transferred directly from the components to the cover plates and then into the support brackets. Riveted construction is used throughout, except for the front, back, and bottom cover plates. The plates are attached with screws and nut plates so that access to all interior parts can be obtained.

Outgassing of the enclosure is accomplished through eight holes in the cover plates. Two 1-inch diameter holes are located in sides and six 1½-inch holes are in the back cover. All holes are screened with 100×100 mesh and reinforced with doubler plates. The doubler plates are designed to yield panel strength and stiffness equal to or greater than the panel without holes. Venting between compartments and of the bottom tray is accomplished through a $1\frac{1}{2}$-inch holes in each tray. These holes also serve as access holes for the electrical harness. The launch vehicle adapter structure consists of two aluminum angles which are riveted to the sides of the enclosure. These angles contain eight nut plates which are used for easy attachment to the launch vehicle PIX attach brackets.

A structural analysis of the Enclosure Box indicated that the stresses due to the launch environment would be relatively low. Therefore, the design was based primarily on natural frequency requirements. The design goal was to keep the fundamental frequency of any major component above 50 Hz. Tests later revealed that this objective was met and that the fundamental frequency was approximately 68 Hz. This frequency corresponds to the out-of-plane bending frequency of the trays. Overall frequencies of the box were much higher.

THERMAL CONTROL SYSTEM

The thermal control system of the PIX spacecraft is passive. Heat generated internally is conducted to the shelves and covers of the Electronics Enclosure Box. Aluminum foil tape is used as thermal coatings on the outside surfaces and also on the inside of the front cover of the Electronics Enclosure Box. Aluminum foil tape is also used on both the front and back surfaces of the experiment plate, including the stiffeners. White paint is used on the frames of the disk No. 1 and solar array experiments.

All parts of the Electronics Enclosure Box, excluding components, were initially treated with Dow 17 to protect the magnesium structure from corrosion.

The only other thermal control device used was to insulate the battery mounting screws and place a thin sheet of G-10 epoxy-fiberglass under the battery. This was done to thermally isolate the battery from the lower shelf because the battery temperature prediction without insulation violated the maximum allowable battery temperature.

Materials

Aluminum foil tape. - To control the electronic components from becoming too hot if the electronics enclosure box was in the sun or too cold if it was in the shade, Mystic 7402L aluminum foil tape was used on the outside surfaces of the box. The tape also served the purpose of electrically grounding the outside of the box; a constraint imposed by the space experiment. The tape was also used on the inside surface of the front cover (sun facing side) to reduce the internal radiation to the electronic components.

The tape was used on the front and back surfaces of the experiment plate primarily as an electrical ground since the temperature of the plate is not as critical as the electronic components. It was necessary, however, that the tape have certain thermal properties to provide acceptable temperature levels. This tape has a low outgassing silicone adhesive, but before the tape is applied, it is perforated with pinholes ½-inch apart. This permits outgassing of the adhesive and avoids blistering.

Paint. - For both low outgassing and a known emittance, 3M 401-A10 White Velvet paint was applied to the frames of the two experiments on the Experiment Plate (see fig. 1). This was done for cosmetic purposes and also because the 3M White Velvet paint has a low outgassing rate and is compatible with the surfaces as well as the environment. For this application the thermal control aspects of the paint are secondary.

G-10 Fiberglass. - In order to increase the thermal resistance between the lower shelf and the battery, a sheet of G-10 epoxy-fiberglass was placed underneath the battery. Also, the battery was secured to the lower shelf at 12 locations with insulated screws.

Dow 17 surface treatment. - Each magnesium part was subjected to Dow 17 surface treatment before the parts were covered with the aluminum foil tape. The Dow 17 chemical treatment (anodizing) provides excellent paint base qualities, corrosion resistance, and electrical insulation for all forms and alloys of magnesium.

ELECTRICAL SYSTEM

The function of the PIX power system is to convert the spacecraft battery power to regulated and unregulated voltages to meet the PIX experiment requirements. The PIX spacecraft power system consist of only two components, the battery and the Power Distribution Electronics (PDE). The battery is the sole source of operating power during the flight. During ground testing, however, an external power supply can be connected to the system. Battery power is fed to the PDE where it is converted to the appropriate voltage levels required by the components within the experiment system. Figure 4 is a block diagram of the electrical system, experiment system and all interfaces. Both the battery and the PDE were qualified on the spacecraft in accordance with "The PIX Flight Model Spacecraft Environmental Test Plan."

Battery

The battery consists of twenty hermetically sealed nickel-cadmium cells and is rated at 3 ampere-hours. The cells are Eagle-Picher, type RSN-3A, originally purchased for the SPHINX B-C program to GSFC high reliability specifications. The battery package is a lightweight, open-type structure, fabricated and assembled at LeRC. This type of battery was qualified for the GOES and SPHINX spacecraft. The battery is capable of operating PIX for at least three hours with a discharge voltage of 24 to 26 volts. A battery test connector on the side of the experiment package provides access for battery charging or cell monitoring.

Power Distribution Electronics (PDE)

The Power Distribution Electronics (PDE) is a flight backup component from the SPHINX experiment package, modified to meet PIX requirements. The modifications are listed below:

Command relays were by-passed to increase system reliability.

Steering diodes were added to prevent inadvertent feed back of voltage to the Delta launch vehicle interface.

Added noise suppression diodes across coil of the PIX turn on relay.

Reworked ground system to reduce noise on the 5 V dc bus.

Internal battery power is enabled when the Delta interface connector is mated, but PIX is not turned on until one of the redundant "turn-on" commands is received from the Delta Guidance Computer. This command turns on the PDE which provides the various voltages to the components of the experiment system. Power conditioning circuits within the PDE provide regulated ±15 V dc, +5 V dc, and a 20 kHz square wave at 40 V ac peak to peak power to the electrometer. The PDE also accepts signals and commands from the sequencer/multiplexer and HVPS for control of the HVPS.

COMMUNICATIONS AND CONTROL SYSTEM

The PIX spacecraft utilizes the Delta launch vehicle telemetry system which is compatible with the STDN requirements as defined by the GSFC Data Systems Standard X-560-63-2. A simplified block diagram of system including the Delta launch vehicle telemetry is shown in figure 5.

The PIX entire data handling system consists of one component; a sequencer-multiplexer (SEQ-MUX). The function of the SEQ-MUX is to control the high voltage power supply (HVPS), and the PDE in a preprogrammed sequence; and multiplex, code, and condition the spacecraft data for transmission to Earth.

The preprogramming is performed by a permanently burned programmable read only memory (PROM). The capacity of the PROM is 512 8 bit words. The contents of the memory are read out at one minute intervals and control various functions of the PDE and the HVPS. The memory is programmed in a manner as to provide maximum amount of data considering the available tracking station coverage and the varying plasma densities in space.

The SEQ-MUX receives the spacecraft status, current, voltage, and temperature data; and multiplexes and codes it into a PCM - NRZ-L format. A filter is utilized in the SEQ-MUX to condition the data to reduce intermodulation products that could cause interference with adjacent launch vehicle telemetry channels.

The output of the SEQ-MUX then interfaces with the launch vehicle telemetry system. The conditioned output PCM data is routed to an IRIG No. 9 (±7½ percent deviation with a center frequency of 3.9 kHz) subcarrier oscillator then to the S-band transmitter for transmission to STDN ground stations.

The characteristics of the SEQ-MUX are shown below:

Number of channels - 16 Total
- Frame Sync. Channels - 4
- Discrete Channels - 2 (8 bits each)
- Analog Channels - 4
- Digital Channels - 6

Frame Sync. Pattern - MSB 111 010 111 0010 000 LSB
- Sampling Rate - 1 sample/second
- Bit rate - 64 BPS
- Word per bit - 8 bits
- Minor Frame Length - 1 second
- Major Frame Length - 2 second
- Number of Subframes - 2
- Type Code - PCM
- Code Format - NRZ-L
- Accuracy - Less than 0.4 percent FS (excluding signal condition)

EXPERIMENT ELECTRONICS

The PIX experiment electronics system consists of a HVPS and an electrometer. The HVPS is used to apply both positive and negative voltages in increments as small as 60 Volts to the experiment surfaces. The plasma coupling current is measured by an electrometer capable of current measurements from about 2 milliamps to 10^{-9} amps. A more detailed description follows.

High Voltage Power Supply (HVPS)

The function of the HVPS is to supply programmable bias voltages to the PIX disk and solar array experiments. The supply is capable of supplying output voltages from 0 to ±1 kV in 16 steps. Programmed commands from the SEQ/MUX control the output of the HVPS. The HVPS is a flight qualified unit obtained from the SPHINX program residual inventory. Minor modifications were required to make the HVPS compatible with the PIX experiments. These modifications consisted of:

- Disabling the high range output (±16 kV)
- By-passing the range switch relays
- Adding a stage to the output filter
- Rewiring unused reed switches to provide for electrometer calibration
- Adding a 200 MEG-OHM resistor for the electrometer calibration function

After functional testing the HVPS was then qualified on the spacecraft in accordance with the "PIX Flight Model Spacecraft Environmental Test Plan."

Description. - A brief description of the operation of the HVPS follows (refer to fig. 6). On PIX turn-on, power is applied to the high voltage circuits of the HVPS. A digital command signal from the SEQ/MUX is converted to an analog reference signal which is proportional to the output voltage. An error signal generated from a comparison of a feedback signal and the analog reference voltage is then fed to a series pass regulator that controls voltage to the parallel inverter circuit. The inverter circuit directly controls the output transformer and therefore the supply output. Polarity is maintained by an inverting amplifier that is switched in as required so that a positive signal to the regulator is always maintained. The HVPS is turned off by clamping the reference signal to ground. The transformer output is halfwave rectified through selected polarity diodes, filtered, and current limited. Over current protection occurs at approximately 2.5 MA at ±1 kV. During an overload condition the HVPS sends a shutdown signal to the PDE which results in a command turn on by the SEQ/MUX ten seconds later.

High voltage electrometer. - The high voltage electrometer used on the PIX program was the flight backup unit from the SPHINX Project. The electrometer contains three identical channels, each designed to measure currents from 10^{-10} to 10^{-4} amps at potentials up to plus or minus 16 kV.

The primary electrometer modification required for use on the PIX program was to lower the value of the sensing resistor in each channel input, shifting the current measuring range one decade (10^{-9} to 10^{-3} amps). Also, the data output format of each electrometer channel was redesigned from digital parallel output, to a digital serial output. A brief description follows (fig. 7).

Description. - Each of the PIX experiments is connected to a separate electrometer channel.

Current flow to an experiment surface is sensed by a log amplifier circuit which provides a reference signal to one input of a comparator. The comparator output controls the up/down count mode of a 10 bit binary counter. The counter is clocked from a free running oscillator. The counter output provides an input to a 10 bit digital to analog converter (DAC). The DAC output is fed to the remaining comparator input, and this closes the loop. The counter is then driven up or down as required to balance the comparator input. When balanced, the binary code of the current sensed by the log amplifier is equal to the counter output (or DAC input).

This circuit will always dither a count either way of a balanced condition, but because only the 8 most significant bits of the counter are read out, a stable reading is obtained.

All three electometer channels are read and clocked out simultaneously in a serial mode, and stored in the SEQ/MUX (about 0.5 sec). The data is then multiplexed sequentially into the PIX data format with channels one, two, and three in word positions four, five, and six, respectively. Electrometer data is updated in both frames of PIX data, or once per second.

Channel one of the electrometer is connected via reed switches to the disk No. 1 on the experiment plate. Channel two of the electrometer is connected via reed switches to the solar array segment on the experiment plate. Channel three of the electrometer is hard wired to the disk No. 2 on the front of the enclosure box. Electrometer channels one and two are alternately connected to a 200 meg calibration resistor in the

HVPS via additional reed switches to provide an end to end system calibration. Channel one is configured for calibration when channel two is connected to its experiment and visa versa.

In addition to the above resistor, which provides calibration data for both polarities of channels one and two, a single point calibration mode of the electrometer is available. When commanded by the SEQ/MUX into the calibrate mode all three channels output a signal corresponding to a negative 0.1 microamp.

QUALIFICATION AND FLIGHT READINESS

The PIX components were a combination of previously designed, and qualified components from a past flight program (SPHINX), and newly designed components with no previous qualification or flight experience. Modifications to the existing SPHINX hardware were made as required to meet the PIX experiment requirements. With the exception of a flight backup battery and a telemetry sequencer multiplexer, the PIX hardware inventory consists of only one protoflight spacecraft. Table I summarizes the qualification and flight testing of all PIX spacecraft components.

Program Assurance Approach

The assurance effort planned and implemented on the PIX project was established to provide a nominal confidence level whereby the design and flight constraints would be met. Major emphasis was directed toward obtaining a reliable system through space level quality workmanship standards and the use of space qualified components from earlier programs for most of the design. For new components, commercial parts and burn-in at the system level were adopted as acceptable practices.

Qualification Test Philosophy

Qualification of the PIX system followed the guidelines for a protoflight program as noted in the GSFC General Environmental Test Specification S-320-G-1 of October 1969. Further, the results of the qualification test program were a prime consideration in developing a flight-ready determination.

R&QA Support

One member of the Office of the LeRC Reliability and Quality Assurance Office was assigned to support PIX and was responsible for reviewing and evaluating all aspects affecting reliability and quality during the build and test phases of the program. Special attention was given to in-process inspection of electrical and electronic assemblies, and the observance and/or monitoring of all qualification tests conducted at the LeRC facilities.

All problem reports generated during the period preceding final shipment were submitted to the R&QA representative for review and sign-off concurrence.

PLASMA TESTING

A plasma test program was conducted in two different sized facilities at the LeRC using both a simulated set of experiments and the PIX flight units. The purpose of conducting these tests was to learn how these surfaces would behave as a function of applied voltage and plasma densities: to assist in the development of models, to verify the proper operation of the flight sequence, and to obtain a ground simulation set of data for comparison with the flight results.

The tests were conducted in the LeRC Geomagnetic Substorm Simulation Facility (6 ft diam vacuum chamber) and the Spacecraft Environmental Simulation Facility (15 ft diam vacuum chamber). The ambient pressure in both chambers was 5×10^{-6} torr or better. All test results reported in this section are for room temperature and no sunlight conditions.

The plasma sources for both facilities were simple bombardment thruster discharge chambers (without accelerating grids). A nitrogen plasma was generated and allowed to diffuse into the chambers. A single source was used in the Substorm Simulation Facility while two sources were used in the larger chamber. The plasma conditions in both facilities were determined from Langmuir probe readings.

The simulated PIX experimental surfaces were a plain stainless steel disk, a stainless steel disk on a Kapton sheet (without a fiberglass guard ring) and a solar array segment mounted on a fiberglass board (without the painted fiberglass border). These three experiments were mounted on a grounded aluminum plate. The dimensions of the mounting plate and all experimental surfaces matched that of the PIX flight units.

The principal result of the ground testing was that the PIX experimental surface would provide sufficient information to satisfy the objectives of the flight. The data is still being processed to develop models to aid in interpreting the flight results.

VIBRATION TESTING

The PIX spacecraft has been qualification tested in accordance with the specifications given in the document entitled: PIX Flight Model Spacecraft Environmental Test Plan; dated July 15, 1977. The vibration and shock specifications in this document are based on the requirements specified by the Delta Project Office at the Goddard Space Flight Center. The qualification test program was carried out in two parts; sine and random testing at Lewis Research Center and shock testing at McDonnell Douglas Corporation in Huntington Beach, California. The sequence of testing was done in the following order according to specifications:

sine, random, and then shock. In all cases the Experiment Plate and the Enclosure Box were qualified separately on flight simulated brackets in order to duplicate, as near as possible, the actual flight environment.

Both the Experiment Plate and the Enclosure Box survived, without damage, all phases of the qualification tests. All electrical systems performed normally at the conclusion of the testing program. The only mechanical anomaly that occurred was the loosening of the electrometer connector bracket during the sine qualification test. The bracket came loose because the screws attaching the bracket in place were too short and failed to properly engage the locking mechanism of the mating nut plates. These screws were replaced by longer screws and the package was subsequently retested at sine qualification levels. At the conclusion of testing the bracket remained fixed in place.

THERMAL VACUUM TESTS

In order to provide confidence that the PIX spacecraft would operate in a variety of temperature environments, a series of three thermal vacuum tests were conducted. The initial component temperature conditions for these tests were: (1) 45° F (15° F below nominal); (2) 60° F (nominal); and (3) 75° F (15° above nominal) with a simulated flight profile. The spacecraft was instrumented with thermocouples at various locations.

In the first test, the components were cooled to approximately 40° F by cooling the shroud to -200° F before PIX startup. During PIX operation the shroud was returned to 70° F. This represented a cold start with operation during the transition from cold to warm environment.

In the second test, the components were increased to 60° F by maintaining the shroud at 70° F before PIX startup. During PIX operation, the shroud was cooled to -280° F. This represented an ambient start with operation during the transition from a warm to cold environment.

In the third test, the component temperatures were initially at 75° F. The shroud was then cooled to -250° F and a solar simulator turned on to provide one solar constant incidence on the Experiment Plate for approximately 1.1 hours before PIX startup. After 10 minutes of PIX operation, the solar simulator was reduced to one half solar flux for the next 1.5 hours and then increased to three fourths solar flux for the duration of PIX operation (2¼ hr). This approximated the flight profile.

In all of these tests, the PIX spacecraft operated successfully for a total period of 10 hours without any component temperature limits being exceeded.

LAUNCH ASCENT TESTING

Since PIX is turned on approximately 74 minutes after launch, the need for sufficient venting to provide for the required outgassing rates was recognized early in the program. Although a mathematical analysis indicated the venting provisions in the PIX design was more than adequate, a launch ascent test was performed to verify proper operation. The launch ascent test performed followed the predicted pressure profile for launch for the first 90 seconds, and then tank pumping continued to a nominal tank pressure of 1×10^{-6} torr. PIX turn on was set at 60 minutes after start of the test to provide for some degree of over test. Successful completion of the launch ascent test provided verification that the PIX hardware was adequately vented.

PIX SUPPORT EQUIPMENT

Several pieces of Ground Support Equipment (GSE) were employed in carrying out the PIX program. Typical of the many constraints placed on secondary payloads was the restriction that no launch vehicle interface testing be conducted with the actual experiment. PIX was to be mated mechanically and electrically to the launch vehicle and then flown. This necessitated the design and fabrication of the required mechanical templates and an electrically functional "interface checkout box" to verify proper interface functions. This unit was provided to McDonnell Douglas for use in their vehicle testing. In this manner command telemetry, and electrical interlock functions were confimed as operating properly.

Just as an "interface checkout box" was required for launch vehicle testing to simulate PIX functions, a delta interface test box was required to operate the PIX electronics while simulating the delta functions. This unit also contained provisions for operating PIX from external power when operation from the PIX battery was not desired.

A PIX data display unit was designed and fabricated which decoded the PIX PCM and converted the binary data to decimal and displayed all PIX parameters. This unit was used whenever local data display was required at a test site to monitor PIX operation.

Primary PIX data monitoring and reduction was done in the PIX telemetry van. The van is a 35' trailer outfitted as a telemetry station, office, and served to transport the PIX in its shipping container.

Several small test boxes were also required to test individual components prior to system testing. Other test gear included a battery charger, a high voltage load box to simulate experiment loads, and miscellaneous special test cables.

CONCLUDING REMARKS

The total PIX program from the time of approval through launch, required 20 months to complete. The flight package was assembled eight months before launch; however, the desired flight sequence was not available for programming into the system until four months before launch. Prior to obtaining the actual flight sequence, several experimental sequences were used to test and debug the system. Approximately 90 hours of system level testing was conducted prior to flight.

Development and testing of this preprogrammed secondary payload was carried out in a manner typical of most piggy-back spacecraft projects. System testing to qualification levels was conducted on the flight package for shock, vibration, thermal, vacuum, and plasma environments. All testing with operating experiment surfaces was performed in a vacuum chamber with a plasma source required to provide the simulated environment within the limits of the vacuum chamber size.

The high voltages developed in the PIX system necessitated good venting practice of the components and enclosure. This provides for sufficient outgassing before turn on to prevent arc over.

This program was accomplished in 20 months by assembling one operational spacecraft and a mock-up model. The mock-up was used to fit check component layouts, as a harness template, and to perform initial system level testing. The flight model was subjected to all environmental testing at the qualification level. There was no backup spacecraft built, but rather backup units for selected components were prepared and ready for installation, if needed.

TABLE I

System	Component	Part number	Serial number	Category	Testing			
					Vibration test	Thermal vacuum plasma test Phase A	Vacuum plasma test Phase B	Vacuum plasma test Phase C
Power	Battery	In-house	01	Flt. and B/U	X	X	X	X
	Pwr. dist.	242-10009	-1	Flt.	X	X	X	X
	H.V. pwr. sup.	242-10007	-2	Flt.	X	X	X	X
TLM and data	SEQ/MUX	CR638093	01	Flt. and B/U	X	X	X	X
	Electrom.	242-10006	-1	Flt.	X	X	X	X
Exp. plate	Solar array	Spectrolab	01	Flt.	X	X	X	X
	Disk No. 1 (main)	In-house	01	Flt. and B/U	X	X	X	X
	Disk No. 2 (ref)	In-house	01	Flt. and B/U	X	X	X	X
Structure	Exp. plate	In-house	01	Flt.	X	X	X	X
	Elect. encl.	In-house	01	Flt.	X	X	X	X
S/C wiring	Connectors	Deutsch	--	Flt.	X	X	X	X
	Harness	Hi-temp	--	Flt.	X	X	X	X
Thermal	Tape	Mystik	#7402	Flt.	X	X	X	X

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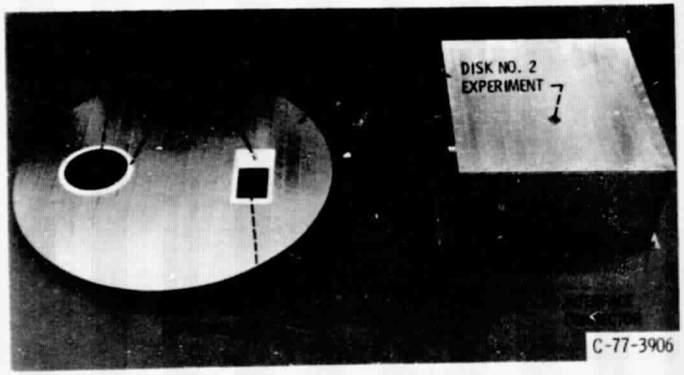

Figure 1. - PIX project. Experiment plate: 36 inch diameter X, 32 inch cutoff. Electronics enclosure: 21.5 x 23 x 12 inch.

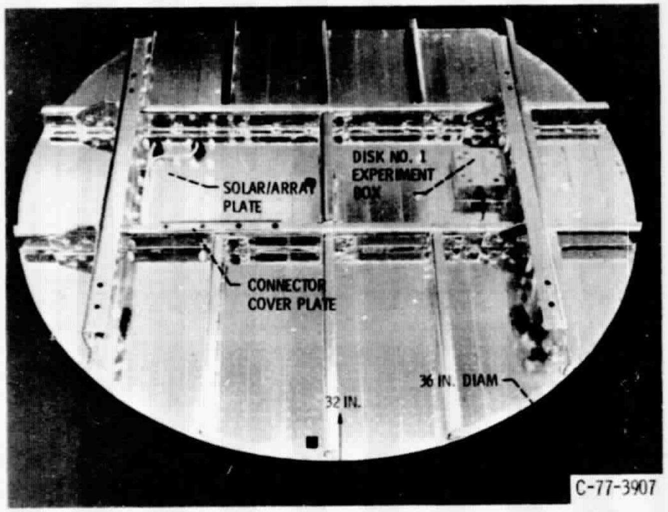

Figure 2. - Experiment plate, rear view.

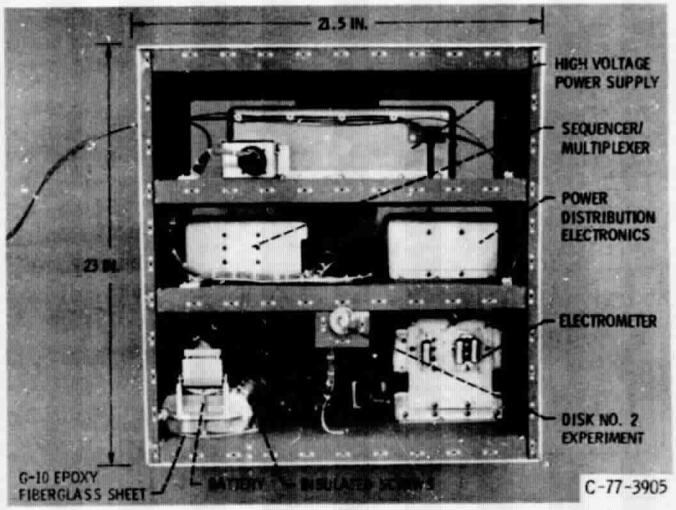

Figure 3. - Electronics enclosure, front view.

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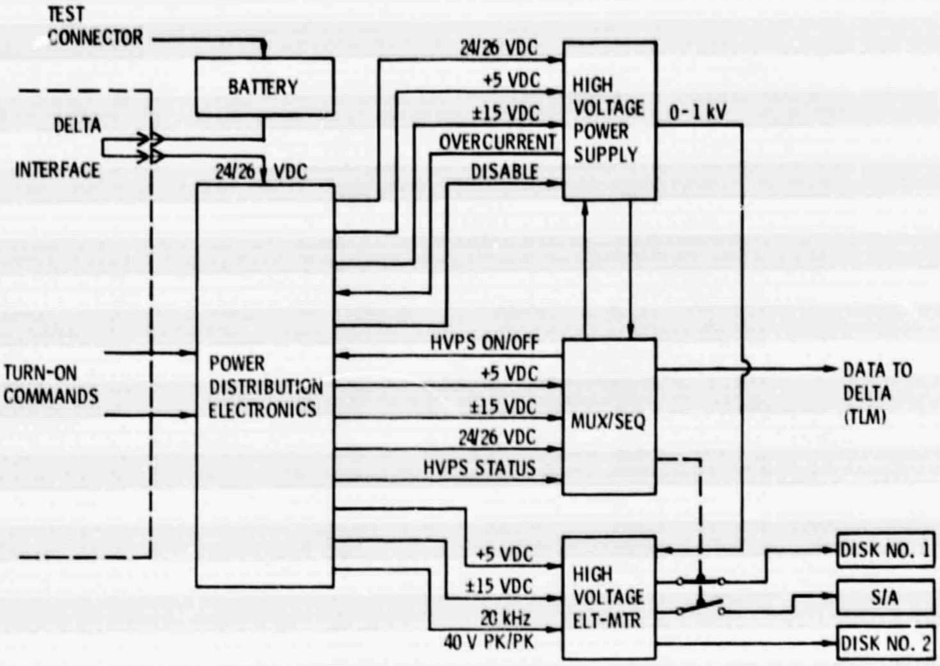

Figure 4. - PIX electrical system block diagram.

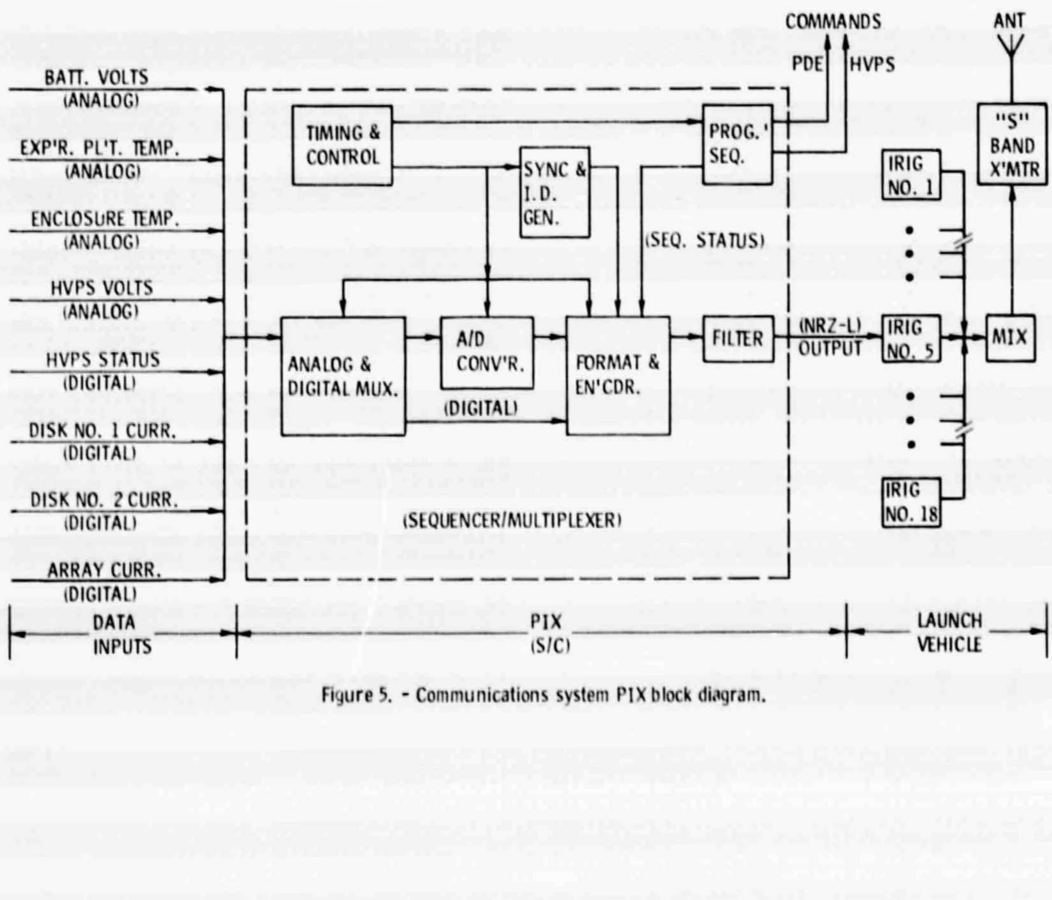

Figure 5. - Communications system PIX block diagram.

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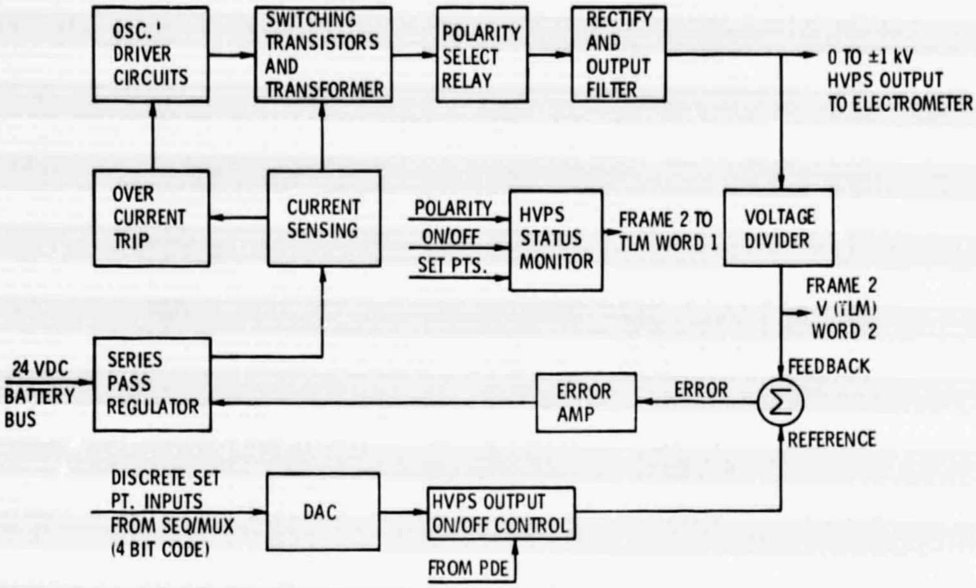

Figure 6. - High voltage power supply block diagram.

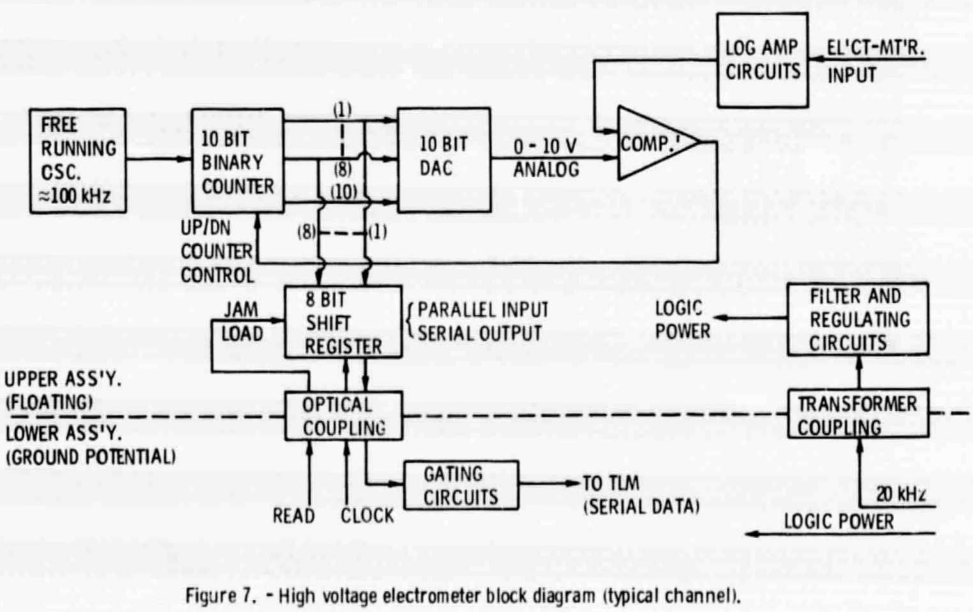

Figure 7. - High voltage electrometer block diagram (typical channel).

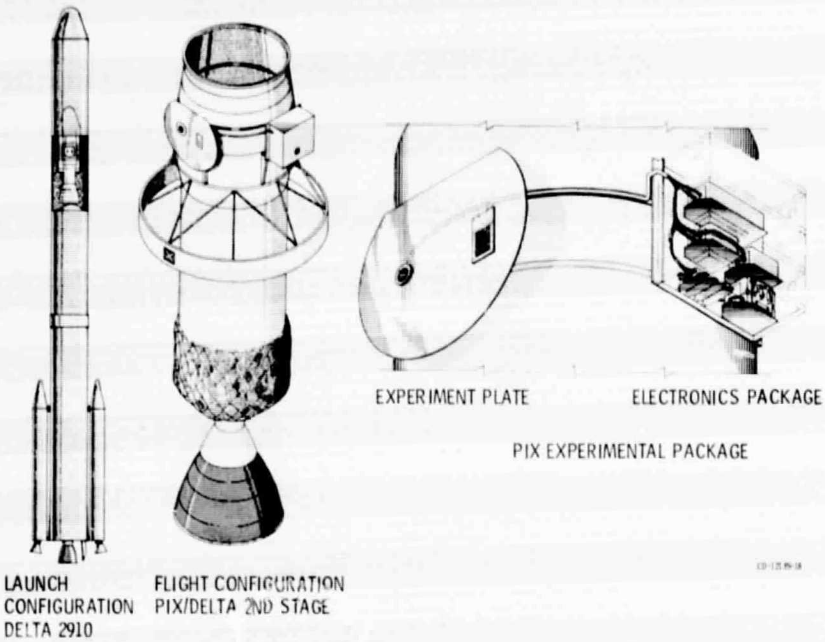

Figure 8. - PIX launch vehicle configuration.

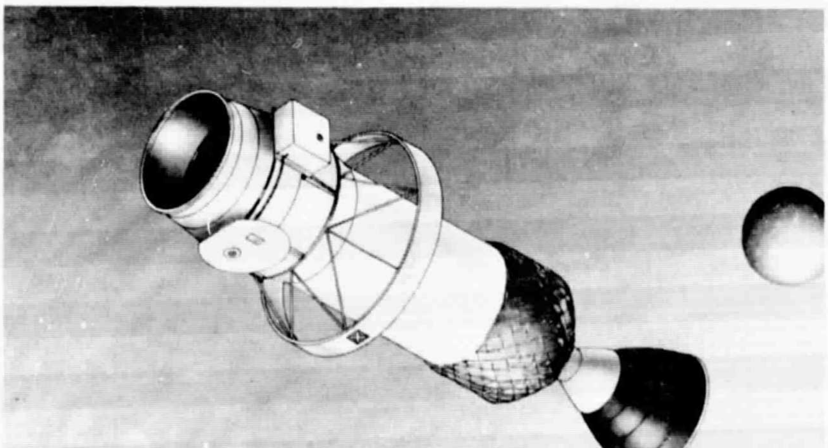

Figure 9. - Plasma interaction experiment (PIX).

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