DOUGLAS PAPER 4906
FEBRUARY 1968

A LOW-ENERGY SOLAR COSMIC RAY EXPERIMENT FOR OGO-F

M.H. WOLPERT
P.R. SATTERBLOM
D.W. BURTIS
and
A.J. MASLEY

Presented at the 14th Nuclear Science Symposium
Los Angeles, California
31 October – 2 November 1967

DOUGLAS MISSILE & SPACE SYSTEMS DIVISION

MCDONNELL DOUGLAS CORPORATION

A LOW-ENERGY SOLAR COSMIC RAY EXPERIMENT FOR OGO-F

by

M. H. Wolpert, P. R. Satterblom
D. W. Burtis and A. J. Masley
Space Physics Branch
Space Sciences Department
Missile & Space Systems Division

ABSTRACT

The Douglas OGO-F Low-Energy Solar Cosmic Ray Experiment measures the differential energy spectrum of protons (5 MeV to 80 MeV) and alphas (18 MeV to 160 MeV) using two double-diffused, totally depleted silicon diodes. The pulse amplitude discrimination system, the data multiplexing scheme, and the in-flight calibrator are discussed.

ACKNOWLEDGEMENT

This paper is based on work performed under NASA Contract No. NAS 5-9324.

INTRODUCTION

This experiment was originated and designed by the Douglas Space Sciences Department to study solar cosmic radiation. The objectives of this study are to help understand solar cosmic ray acceleration mechanisms, interplanetary propagation, and interactions with the Earth's magnetic field and ionosphere. Protons and alpha particles are identified and their intensity and energy distribution determined. The experiment, which will be orbited on the polar OGO-F satellite, is capable of measuring events more intense than any previously observed.

SENSORS

The instrument uses two double-diffused, totally depleted silicon diodes as detectors.

TELESCOPE

A schematic of the detector telescope configuration is shown in Figure 1. The detectors are located on a common axis with a separation of 36 mm. The cone half-angle is 28°. The entrance to the telescope is covered with a 38. 5 mg/cm^2 (= 43μ) nickel foil that stops protons with energies less than 3. 4 MeV. The collimator is designed to limit the geometry factor of the front detector and to reduce the effect of electron funneling. The geometry factor of the front detector and collimator is G_A = 2. 674 cm^2-ster. The telescope has G_T = 0. 545 cm^2-ster.

SYSTEM BLOCK DIAGRAM

Figure 2 depicts a system block diagram separated into five logic sections. Section 1, the Particle Sorter, amplitude, sorts coincident pulse pairs into alphas and protons. The second section, the Pulse-Height Analyzer (PHA), is employed to divide the amplitude ranges into 11 alpha and 12 proton channels.

M-36005 B

DOUGLAS OGO-F SOLID STATE DETECTOR TELESCOPE

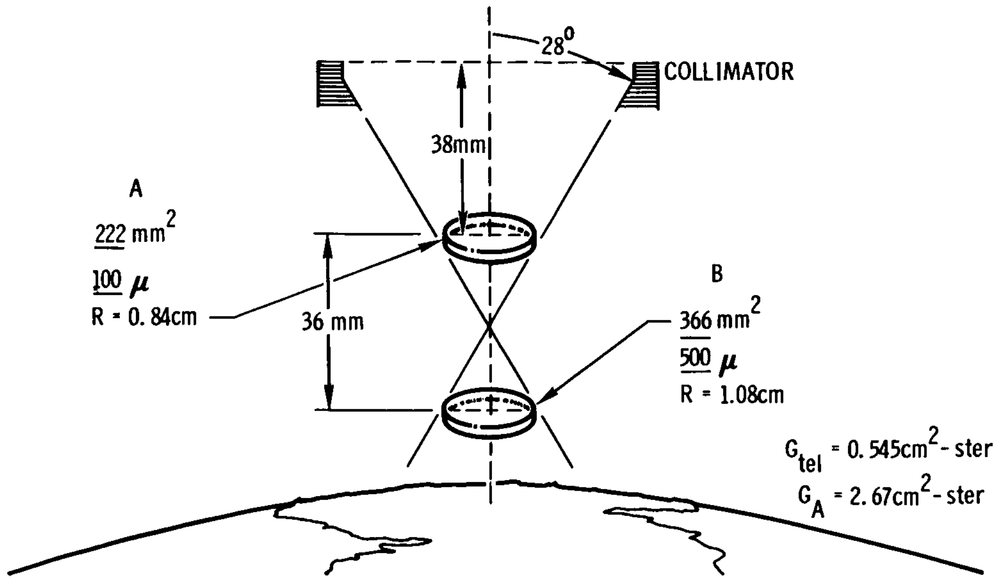

FIGURE 1

SYSTEM BLOCK DIAGRAM

M-45133B

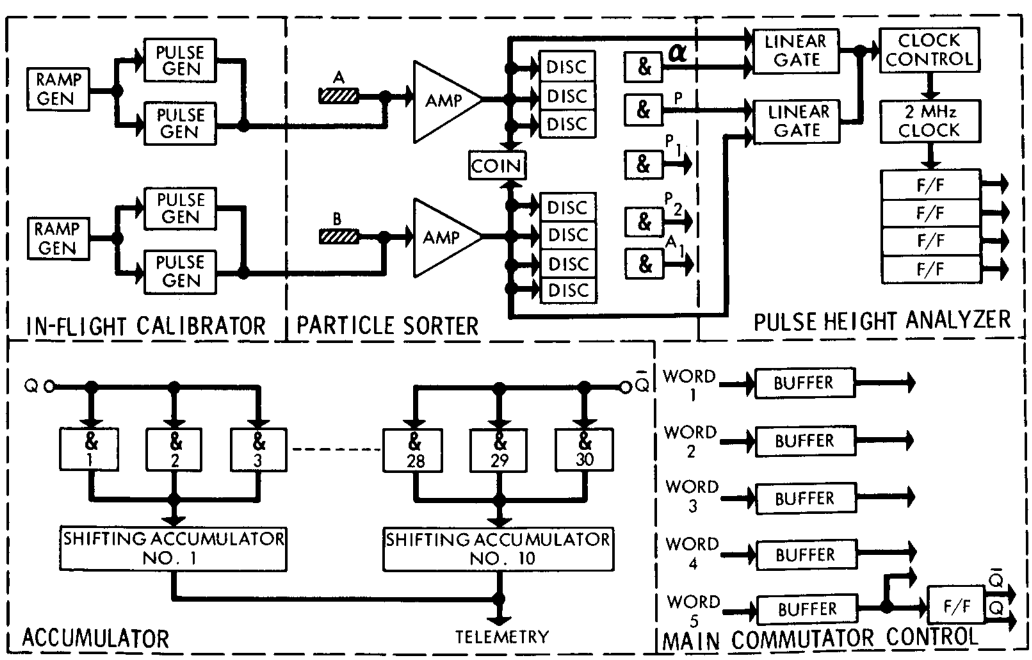

FIGURE 2

The third section, Accumulation and Multiplex, is used to funnel the 30 channels of experiment information into ten shifting accumulators. The Main Commutator Control is the fourth section. Its function is to interface spacecraft system timing with output information. Section 5, the In-Flight Calibrator (IFC) measures the gain of each amplifier, the threshold of each discriminator and PHA channel, and tests overall system operation.

EXPERIMENT INFORMATION

The 30 channels of experiment data are shown in Figure 3. Channels 1 through 14 are proton data, and Channels 15 through 26 are alpha data. The remaining four channels are I1 through I3 and a source-IFC channel. P3 through P14 and A2 through A12 are outputs of the Pulse-Height Analyzer. P1 and P2 and A1 are obtained from window discriminators and "and" gates in the Particle Sorter.

M-28796A

TABLE OF DIGITAL ACCUMULATOR OUTPUT CHANNELS

CHANNEL (NO.)	ENERGY (MeV) PROTONS	
1	5 - 6	P1
2	6 - 8	P2
3	8 - 11	P3
4	11 - 13	P4
5	13 - 16	P5
6	16 - 21	P6
7	21 - 24	P7
8	24 - 28	P8
9	28 - 33	P9
10	33 - 39	P10
11	39 - 46	P11
12	46 - 55	P12
13	55 - 66	P13
14	66 - 80	P14
	ALPHAS	
15	18 - 21	A1
16	21 - 23.5	A2
17	23.5 - 28	A3
18	28 - 36	A4
19	36 - 48	A5
20	48 - 56	A6

CHANNEL (NO.)	ENERGY (MeV)	
	ALPHAS	
21	56 - 67	A7
22	67 - 80	A8
23	80 - 94	A9
24	94 - 112	A10
25	112 - 136	A11
26	136 - 160	A12
	INTEGRAL CHANNELS	
27	P: 5 - 80 α: 21 - 160 MeV	I1
28	α: 21 - 160 MeV	I2
29	P: > 80 MeV	I3
30	SOURCE AND IFC	S
	ANALOG OUTPUT	
1	P: > 5 MeV; α > 21 MeV; e > 0.25 KeV	

FIGURE 3

PARTICLE SORTING

The Particle Sorter is shown in detail in Figure 4. Solid-State Radiations Model 113 flat pack, integrated circuit-amplifier systems are used. RC wave shaping is employed, yielding pulses with 400-nsec rise and 1.5-μsec fall times. The frequency response is flat to 50 kHz and falls off by 2 db at 100 kHz.

A coincidence circuit, with a resolving time of 350 nsec, is employed to establish single particle analysis. The circuit consists of two integrated circuit-differential comparitators and a one shot. The output of the coincidence circuit is fed to a delay generator so that the coincidence pulse may also be used as a strobe for the "and" gates.

Pulses from the A and B amplifiers are fed to seven differential amplitude discriminators. Complementary outputs from each of the discriminators

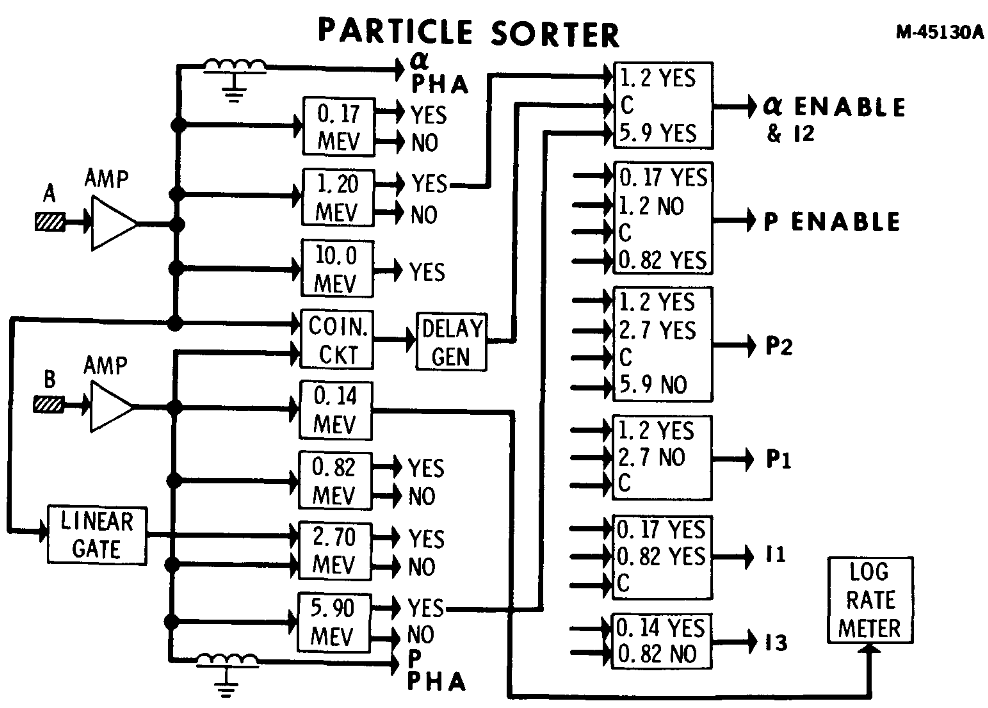

FIGURE 4

are available for full logic flexibility. RC feedback around the discriminator produces uniform output pulses.

Particle sorting and signature is obtained from six "and" gates. The "and" gates, labelled alpha, enable or proton enable when satisfied, select either A or B amplifier signals, respectively, for pulse-height analysis. The alpha "and" gate is also the second integral channel. The other four gates select P1, P3, I1 and I3. A log-rate meter is used to count all B amplifier pulses from protons with energy greater than 80 MeV.

The logic of this section has been operated at 100 kHz with no loss of information.

PULSE-HEIGHT ANALYZER

The Pulse-Height Analyzer is shown in Figure 5. It is a 16 channel, RC run-down-type analyzer that sorts alphas from 26 to 140 MeV into 11 channels

M-45132B

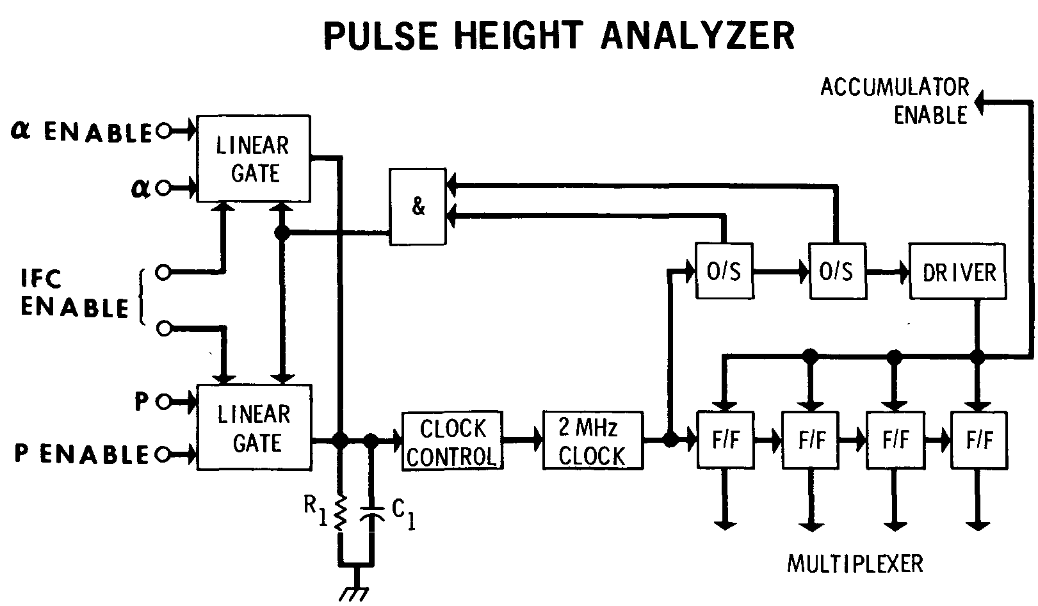

FIGURE 5

and protons from 8 to 80 MeV into 12 channels. Entrance is obtained through either the alpha or proton linear gate. This linear gate is a closed loop peak and hold differential amplifier. When the gate is enabled, its output voltage rises toward the input amplitude. The difference in these amplitudes is compared by a differential stage such that the output, upon exceeding the input by a few microvolts, closes the gate. The output voltage then falls toward ground with a time constant set by R_1 and C_1. This type of nonlinear rundown is employed to shrink the higher energy and expand the low-energy channels, giving rise to more evenly spaced energy boundaries.

Linearity and amplitude reproduction of the gate has been found to be better than 1%. Gate operation up to 50 kHz is easily obtained. The output gate pedestal is less than 40 mV and extremely stable over temperature. The ratio of input to output voltages, when the device is off, is better than 1000:1.

The clock control module is an amplitude to time converter. When the linear gate output is above the control module's threshold, the 2-MHz clock runs. Clock counts are then fed to a four bit counter. The binary number is finally decoded and a pulse stored in the appropriate accumulator. After the clock starts, the linear gates are inhibited for 20 μsec, 10 μsec to allow the flip-flops (F/F) to count and settle, and 10 μsec to allow decoding, storage, and reset. Sixteen channels are available from the analyzer, but for this application the eight highest clock-count channels are combined by pairing those adjacent, giving 12 separate channels.

ACCUMULATOR AND MULTIPLEX

The Accumulator and Multiplex scheme is shown in Figure 6. The experiment uses 10 shifting accumulators, each of which is preceded by three parallel gates that alternately select, for fixed time intervals, one of the three inputs for accumulation.

ACCUMULATORS AND MULTIPLEXER

M-45131

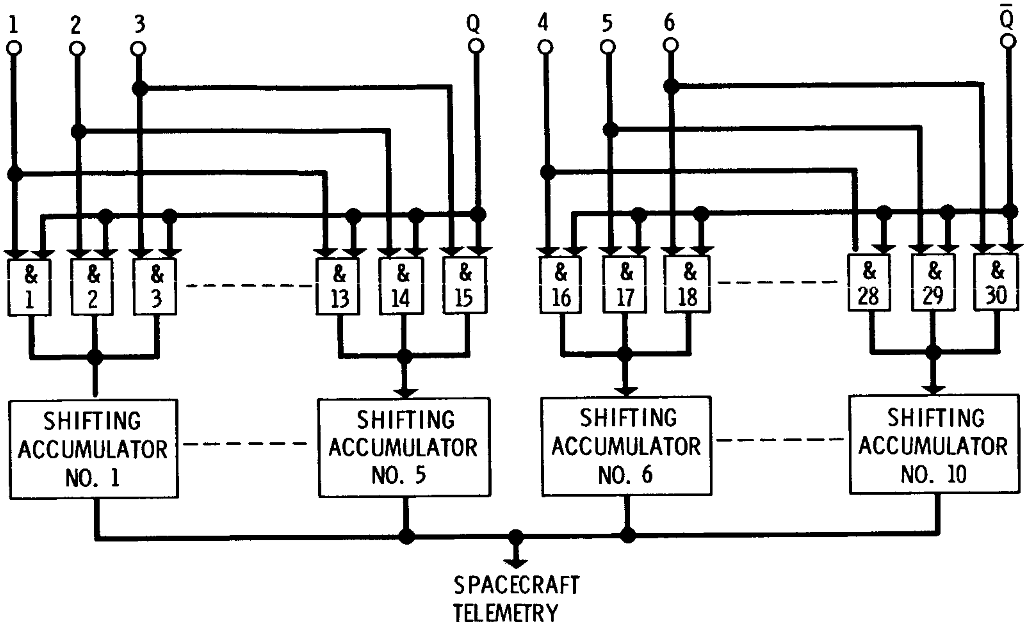

FIGURE 6

During tests, the accumulators and gates have properly accepted information at 150 kHz and the accumulators have accurately shifted out information at 64 kHZ, the highest telemetry rate. Power requirement for each flip-flop under dynamic conditions is no greater than 1.15 mW.

MAIN COMMUTATOR CONTROL

The Main Commutator Control section, Figure 7, controls the accumulation periods, the input gate programming, and the shifting of information into the spacecraft telemetry system. Five digital words are assigned to this experiment on each telemetry main commutator, or main frame, cycle. The two groups of five accumulators each shift out their contents on alternate cycles.

While one group of five accumulators is shifting data to the telemetry, it is inhibited from receiving information. At the same time, the other group of five accumulators is not inhibited. Since there are five assigned words per

MAIN COMMUTATOR CONTROL

M-45134 A

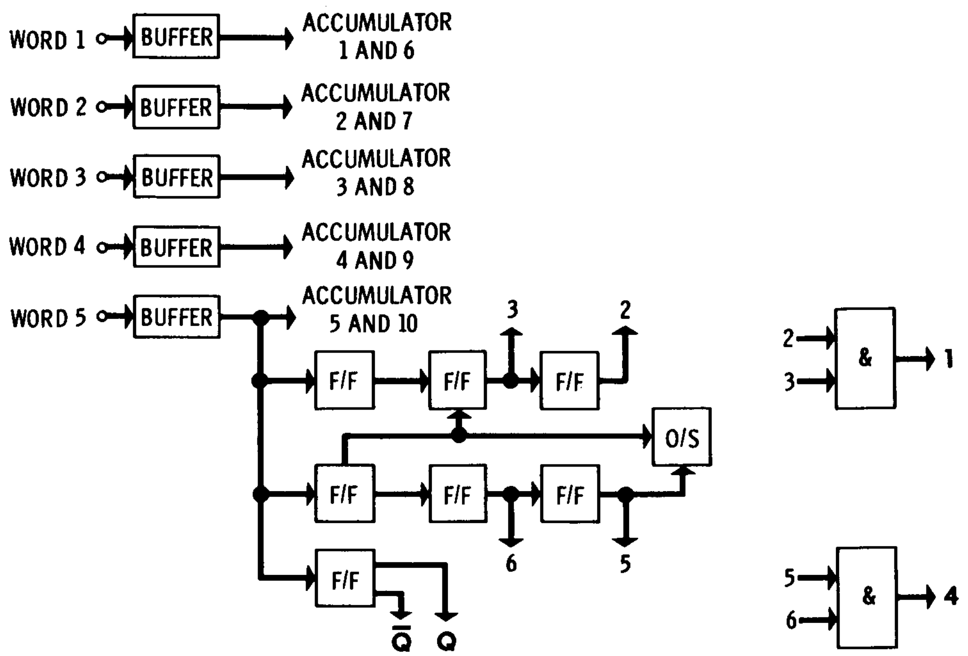

FIGURE 7

main frame and 30 experiment channels of information, it requires six main frames to read out a complete experiment cycle. Timing for the multiplexing method is obtained from the two sets of three flip-flops, driven by Word Buffer 5. Each set of flip-flops, which is one main frame out of synchronization, has a cycle of six telemetry main frames and generates three accumulator control signals. Accumulator control Signals 1 through 3 operate the first five accumulators and Control Signals 4 through 6 operate the second five accumulators. Each control signal is "on" for two main frames and "off" for four, allowing the fraction of accumulation time to be 33%.

IN-FLIGHT CALIBRATOR

The In-Flight Calibrator (IFC), Figure 8, provides an electronic means for measuring the reference voltages on each of the seven discriminators, as well as the channel boundaries of the Pulse-Height Analyzer. Once every

IN-FLIGHT CALIBRATOR

M-45135B

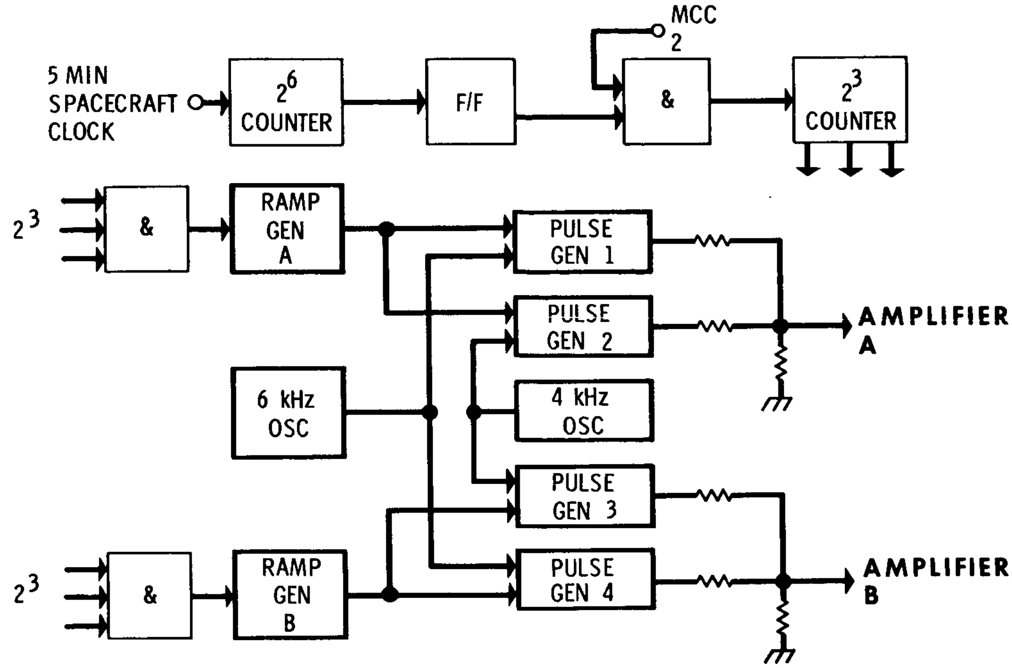

FIGURE 8

160 minutes, a calibration sequence is started. The first sequence begins 20 minutes after each "power-on" command. During this sequence, seven separate pulse trains (ramps), whose pulse amplitudes are linearly increasing with time, are generated and routed to the input of the charge-sensitive preamplifiers. The range of amplitudes from the amplifiers into each discriminator encompasses its threshold. The number of pulses that exceed the threshold of that discriminator, which is a measure of the discriminator-reference voltage, is counted by one of the accumulators. The ramp consists of fast rise (100 nsec) slow RC decay (10 μsec) pulses at a frequency of 4 or 6 kHz, depending on the particular discriminator. The duration of the ramp is 216 msec, which gives approximately 900 or 1300 pulses at 4 or 6 kHz, respectively. The integral linearity of the ramp is better than 1%.

After discriminator calibration, the ramp is routed successively to each input of the PHA. All ten accumulators are used to count the number of pulses that lie within the boundaries of each channel. In order to cover the 12 separate PHA outputs with ten accumulators, the input gate sequence is different for the two proton and alpha PHA input ramps. The calibration program takes 43 main frames; however, only during six main frames is there any loss of normal experiment data. The accuracy of this calibrator is within 0. 57% over the operating temperature range.

In addition to this electronic device, an alpha particle source, Am^{241}, is placed between the two detectors on the wall of the spacer separating them. The source is coated to degrade and broaden the alpha-particle energy spectrum. The measurement of the number of counts exceeding the 2. 7 MeV threshold will allow an absolute determination of the gains of the amplifier systems. The output pulse rate of the 2. 7-MeV discriminator is monitored, by the Source-IFC channel, once every six main frames. During alternate accumulations of the IFC channel, the amplifier pulses are sent to the discriminator. The output records: B pulses greater than 2. 7 MeV; A and B pulses greater than 2. 7 MeV. The cycle is then started again. Once every 24 main frames the output of this channel is programmed to be nine binary "ones", which serve as a flag for data processing synchronization.

EXPERIMENT PARAMETERS

The package is located within the main body of the satellite, facing away from the Earth. The experiment weighs 6 lb, requires 2. 2 Watts of spacecraft power, and is 20 x 20 x 10 cm. The expected launch date is late 1968.

DOUGLAS MISSILE & SPACE SYSTEMS DIVISION
5301 Bolsa Avenue Huntington Beach, California 92646

MCDONNELL DOUGLAS
CORPORATION