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IMP Series Report/Bibliography

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NATIONAL SPACE SCIENCE DATA CENTER

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IMP SERIES REPORT/BIBLIOGRAPHY

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FOREWORD

The National Space Science Data Center (NSSDC) has been charged with the tasks of acquiring space science data from satellite experiments and of making the acquired data, along with adequate documentation, available to members of the space science community for further scientific study. In fulfilling these tasks, NSSDC has become an information center as well as a data center. This document, containing the scientific results of and information about the Interplanetary Monitoring Platform (IMP) spacecraft series, has been generated using the NSSDC information base and, particularly, the Technical Reference File (TRF) maintained at NSSDC. The TRF is a part of the NSSDC information base and contains references to published papers and unpublished reports related to space science experiments.

Some of the spacecraft-related information presented here was provided to NSSDC by IMP project personnel at Goddard Space Flight Center at the time of the generation of this document. For this we are grateful. We would also like to acknowledge the cooperation of personnel in the IMP Project Office and of those IMP experimenters who reviewed preliminary versions of the spacecraft and experiment descriptions and the bibliographic entries and abstracts in December of 1970.

It is anticipated that subsequent editions of this IMP report will be published as sufficiently more published papers using IMP data become available.

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I. INTRODUCTION

Through detailed measurements of the near interplanetary environment, the IMP series of spin-stabilized spacecraft has been highly successful in furthering our understanding of solar-terrestrial physics. Nearly continuous interplanetary measurements of magnetic fields, plasmas, and energetic solar and galactic particles have been obtained since November 1963; solar X-ray data have been obtained since July 1966. In addition, measurements taken in distant magnetospheric regions, the bow shock, the magnetosheath, the magnetopause, and the magnetotail have been crucial to our understanding of those regions.

It is the purpose of this document to summarize the main characteristics of the IMP spacecraft and experiments from a scientific rather than technological point of view and to present the scientific knowledge gained from this series of spacecraft in the form of abstracts of scientific papers using IMP data.

The document is divided into two parts. In the first part, spacecraft characteristics, including temporal and spatial coverages, are presented and are followed by a bibliography containing abstracts from spacecraft-related papers. In the second part, experiments on all IMPs (including prelaunch IMPs -H and -J) are described. Figures are presented showing the time histories, through the end of 1970, of magnetic field, plasma, and energetic particle experiments. A bibliography containing abstracts is presented for each experiment on each spacecraft from IMP A through IMP G. Wherever possible, the abstracts given here for spacecraft- and experiment-related papers are by the originating authors.

II. SPACECRAFT

Nomenclature

Because the entire IMP series of spacecraft is a subset of the Explorer series and because two of the IMPs were to have been anchored to a lunar orbit, the names of the IMP spacecraft may be somewhat confusing. For clarification, a list of names and launch dates is presented in Table 1.

Table 1 - IMP Spacecraft Names and Launch Dates

IMP	Explorer	IMP	AIMP	AIMP	Launch (UT)
A	18	1			11/27/63
B	21	2			10/04/64
C	28	3			05/29/65
D	33		D	1*	07/01/66
E	35		E	2**	07/19/67
F	34	4			05/24/67
G	41	5			06/21/69
I	43	6			03/13/71
H					planned 72
J					planned 73

*Lunar orbit intended but not achieved.
**Lunar orbit achieved.

Before launch, IMP spacecraft are known by their letter codes; after launch, an Explorer number and an IMP (or AIMP) number is assigned. In many cases, a spacecraft is referred to by its prelaunch designation even after launch. Because the prelaunch designations constitute the most continuous sequence of names in the IMP series, reference to individual spacecraft by their prelaunch designations is made throughout this report.

General Characteristics

The IMP spacecraft have been grouped here by their characteristics, with IMPs A, B, C, D, and E forming one group, IMPs F and G another, and IMPs I, -H, and -J a third.

IMPs A through E shared numerous characteristics. Each weighed about 62 kg and utilized about 38 w average power provided by solar cells and chemical batteries. Slight differences existed among individual spacecraft. Exclusive of appendages (antennas, experiment booms, etc.), each spacecraft was shaped as an octagonal drum 71 cm across; IMPs A through C were about 30.5 cm high, while IMPs D and E were only 18 cm high. Each spacecraft except IMP D carried seven active experiments; IMP D carried six active experiments. The PFM data telemetry bit rate was increased from about 10 bps on IMPs A, B, and C to about 28 bps on IMPs D and E. Of these spacecraft, IMP E continues to operate.

IMPs F and G were more complex than IMPs A through E, carrying 11 and 12 active experiments, respectively. Their configurations and their power consumptions were similar to those of the IMPs A through C. They weighed 74 and 80 kg, respectively, and the telemetry bit rate for both was 100 bps. IMP F entered the earth's atmosphere in May 1969; IMP G continues to operate.

IMP I represents the most significant increase in complexity in the IMP series. This spacecraft is a 16-sided drum, 135 cm across and 183 cm high. It weighs about 278 kg, uses about 110 w average power, and has a 1600-bps data telemetry rate. It carries 12 active experiments. IMPs -H and -J will be similar in configuration to IMP I.

Spacecraft Attitude

All IMP spacecraft were spin stabilized and used an optical aspect system for determining spin rate, spin phase, and spin axis direction. In addition, each spacecraft beginning with IMP D had a sun pulse generator to yield spin phase information required for the onboard sectoring of data on some experiments. The optical aspect systems and the sun pulse generators worked well throughout the useful life of each IMP, except on IMP F (failure occurred 2 months before spacecraft reentry).

The intended spin axis directions were achieved within reasonable limits for each IMP except IMP B. The spin axis of IMP D lay approximately in the ecliptic plane, while the spin axes of IMPs E, G, and I are approximately normal to the ecliptic plane, as was the spin axis of IMP F. Table 2 indicates the ranges, in degrees, over which the IMP spin axes have varied in the customary inertial earth-equatorial coordinate system. Also included in Table 2 are the corresponding angular ranges in inertial ecliptic coordinates. The two coordinate systems share a common X axis (i.e., from the earth to the sun at the time of the vernal equinox). Note that the declination angle, in ecliptic coordinates, measures the extent to which the spin vector lies outside of ecliptic plane. Table 2 also shows the approximate limits within which the IMP spin rates have varied over spacecraft lifetimes.

Table 2 - IMP Spacecraft Spin Directions and Rates

IMP	Right Ascension (equatorial) (deg)	Declination (equatorial) (deg)	Right Ascension (ecliptic) (deg)	Declination (ecliptic) (deg)	Spin Rate (rpm)
A	117 to 107	-24 to -31	111 to 125	-44 to -52	22.0 to 25.8
B	44 to 49	47 to 58	57 to 62	29 to 39	14.4 to 18.0
C	65 to 77	- 9 to -14	61 to 74	-32 to -36	17.4 to 27.5
D	215 to 246	-21 to -15	219 to 258	- 6 to 15	17.5 to 26.5
E	74 to 107	-55 to -73	0 to 360	-83 to -89	24.5 to 26.4
F	79 to 95	-62 to -69	0 to 360	-83 to -89	23.2 to 22.5
G	103 to 119	-61 to -68	156 to 206	-78 to -85	27.5 to 27.0
I*	90	-66	--	-90	5.4

*The angles are nominal initial values; the spin rate is as observed.

Time Coverage

The time intervals of principal data coverage for each launched IMP spacecraft are shown in Figure 1. Note the nearly continuous character of the IMP time coverage.

Spatial Coverage

IMPs A, B, C, F, G, and I were to have achieved highly eccentric earth orbits with apogee distances of a few 10's of earth radii. IMPs D and E were to have achieved lunar orbits, and IMPs -H and -J are scheduled for nearly circular earth orbits at 30 to 40 earth radii. Thus far, only IMPs B and D failed to achieve their intended orbits; however, these IMPs, like the others, have returned much useful data. The approximate limits within which selected orbital parameters have varied during spacecraft lifetimes are shown in Table 3. Because IMP D was subjected to significant lunar perturbations, many of its characteristics are shown separately in Figure 2. Note that the abscissa for this figure varies linearly with orbit number rather than with time. Detailed time histories of the standard orbit elements are available from NSSDC.

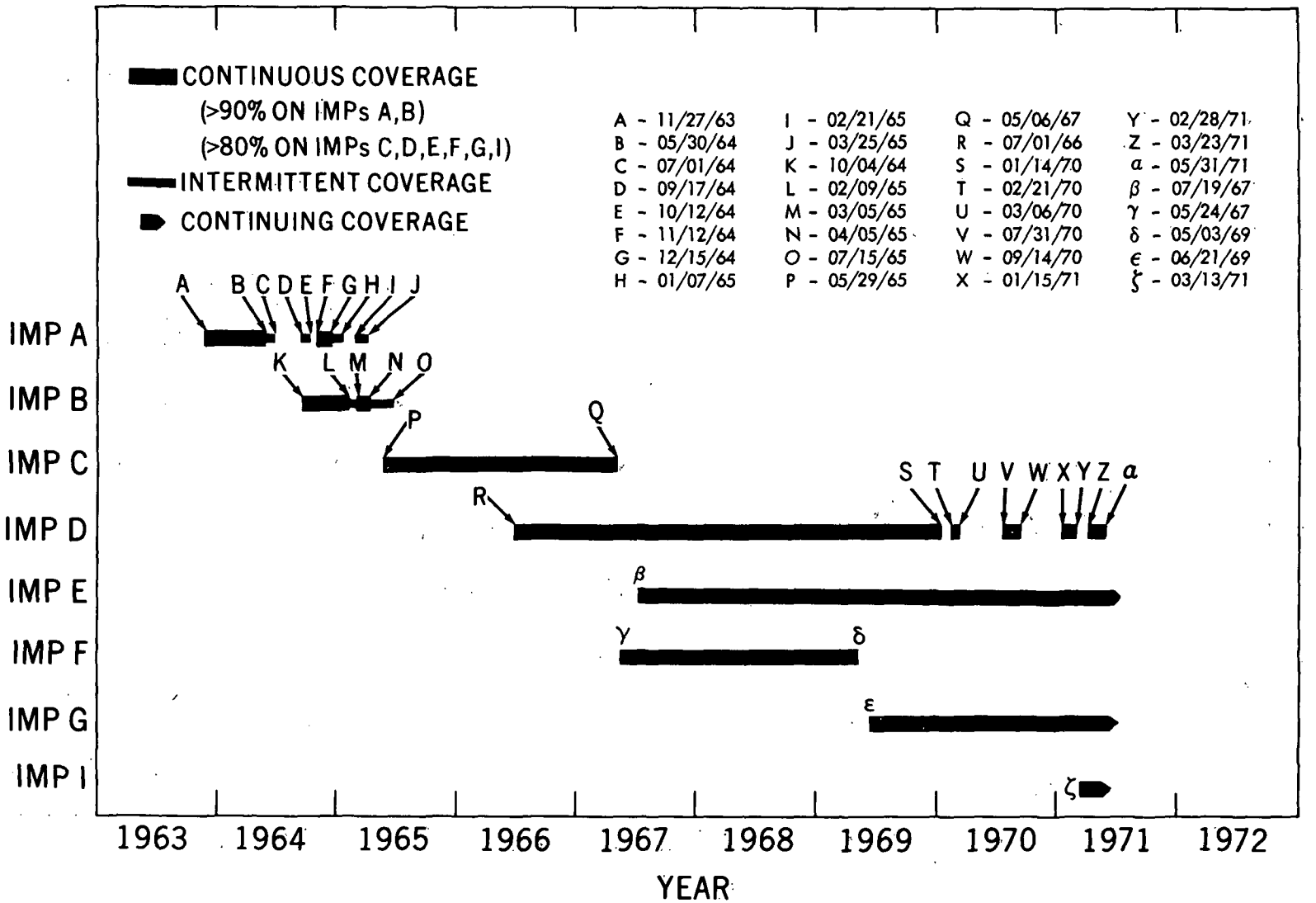

Figure 1 - IMP Spacecraft Data Coverage

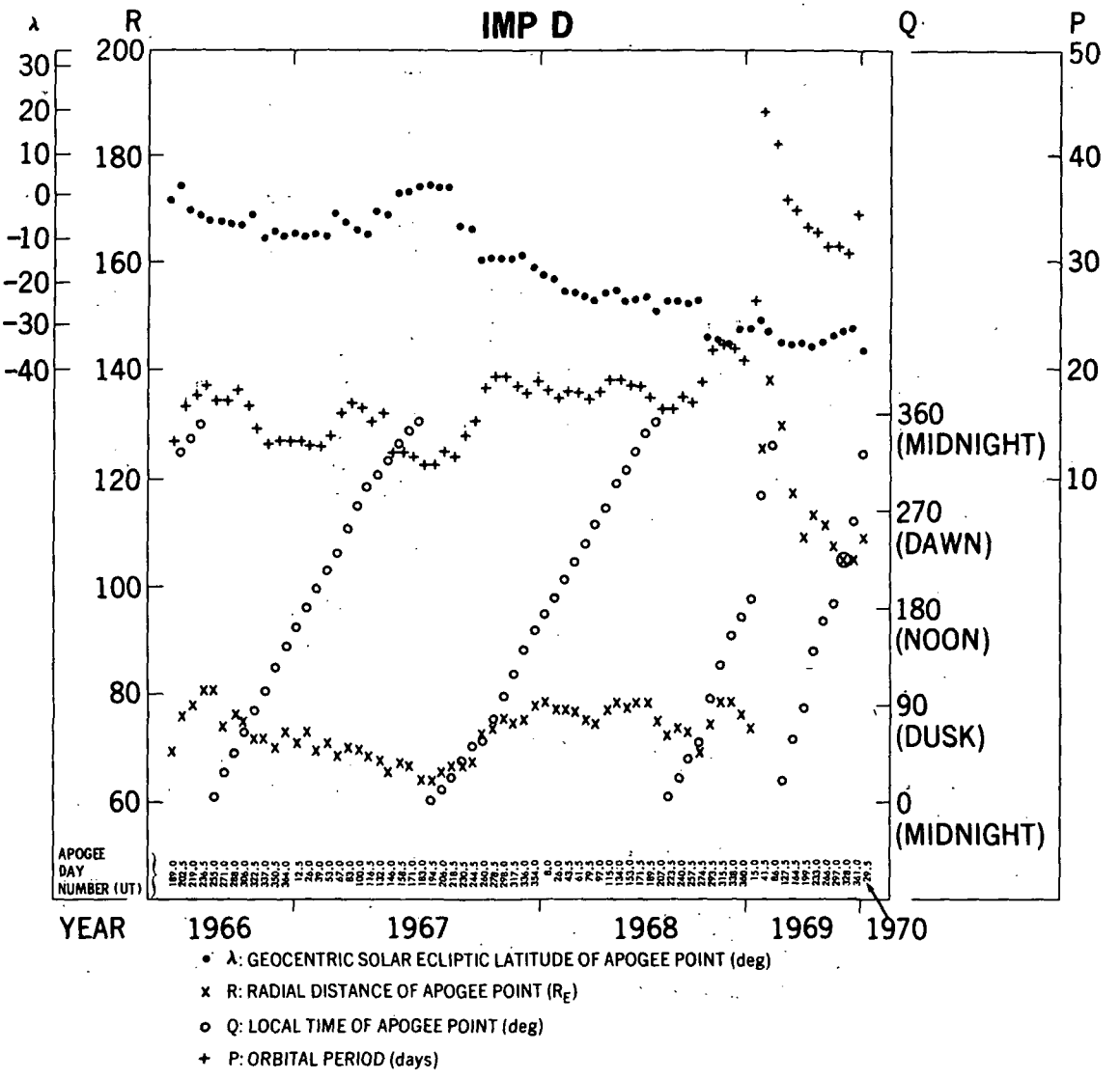

Figure 2 - IMP D Spacecraft Orbital Parameters

Table 3 - IMP Spacecraft Orbital Parameter Variations

IMP	Apogee Radial Distance (R_E)	Period (days)	I (deg)*	Eccentricity	Ψ (deg)**
A	31.4 to 31.6	3.8 to 3.9	46 to 50	.90 to .95	-8 to -5
B	15.8 to 15.9	1.4 to 1.5	48 to 53	.86 to .87	-20 to -9
C	36.5 to 41.8	5.8 to 5.9	68 to 72	.70 to .95	-20 to +10
D***	64 to 140	11.5 to 44	21 to 39	.48 to .82	-35 to +2.5
E+	1.5++; 61	0.48; 27.3	166; 5.1	.56; .05	11
F	33.4 to 34.0	4.3 to 4.4	89 to 93	.91 to .94	-5 to +8
G#	28.2 to 28.6	3.3 to 3.4	89 to 96	.90 to .93	-4 to 0
I##	32.1	4.1	45	.94	22

*Angle I is the inclination angle of the orbit plane with respect to the ecliptic plane.
**Angle Ψ is the angle that the line joining the earth's center and the spacecraft apogee point makes with the ecliptic plane.
***See Figure 2 for variation with time of some of these parameters.
+The first value in each pair is for the orbit of IMP E about the moon; the second value is for the moon's orbit about the earth.
++One earth radius = 3.7 lunar radii.
#These figures are for the first year of operation only.
##The figures are initial values.

The local times of apogee for the geocentric IMPs are shown in Figure 3. Since the apogee point of each of these IMPs appears to move around the earth once per year, it was possible to plot local time versus month of year without specifying a year. Due to lunar perturbations, the actual orbit of IMP D shows some deviations from the curve shown in Figure 3; for the correct local apogee time versus universal time for IMP D, refer to Figure 2.

The moon-IMP E system has noon local time (i.e., new moon phase) at universal times given by $t = Ai + B\ (n \pm 0.05)$ for integer values of

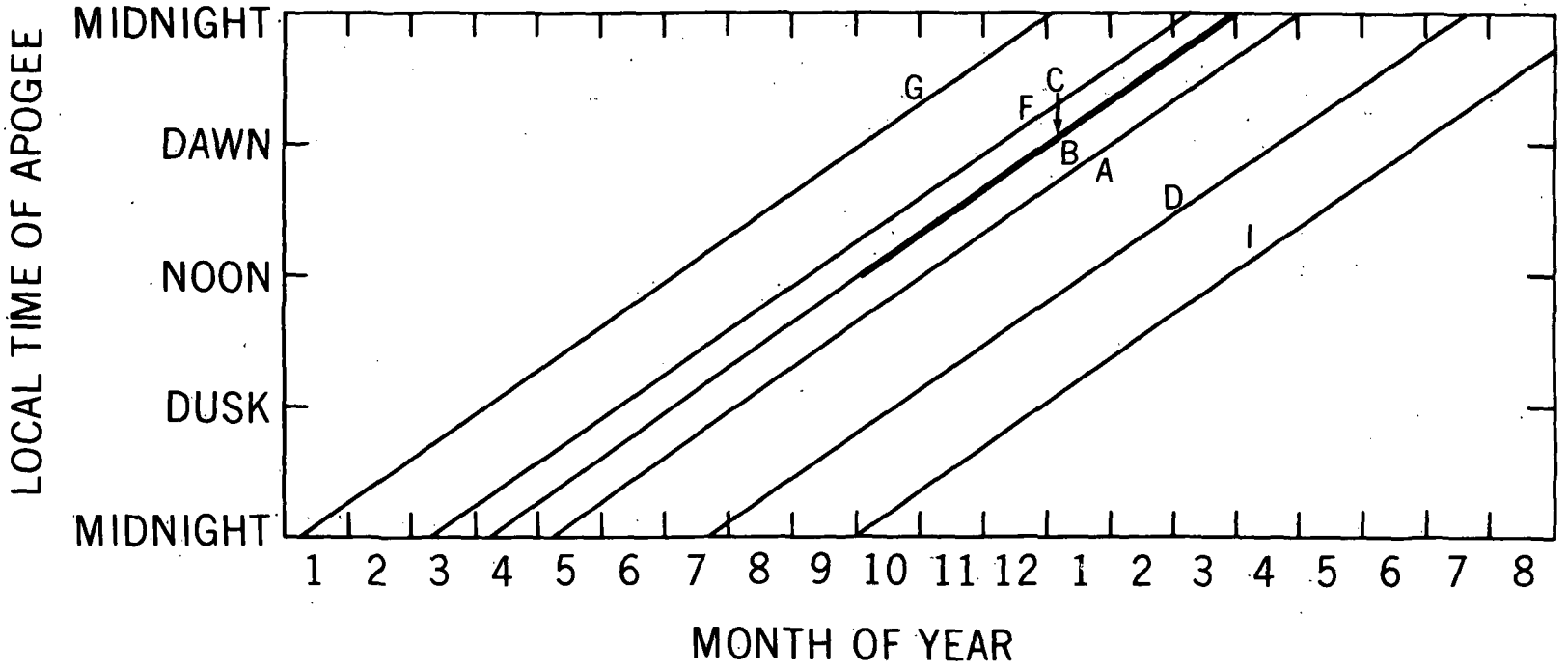

Figure 3 - IMP Spacecraft Local Time Apogee

n. Here Ai is the time of the first new moon for the ith year, as given below, and B is the synodic lunar orbital period, 29 days, 13 hours.

Year	Ai
1967	Jan. 10 hr 18
1968	Jan. 29 hr 16
1969	Jan. 18 hr 5
1970	Jan. 7 hr 22
1971	Jan. 26 hr 23

For studies of interplanetary events, it is important to know whether, for a given time, the spacecraft of interest is beyond the influence of the geomagnetic field. It is beyond the scope of this report to identify the individual time periods for which each IMP spacecraft was beyond a certain geocentric distance. However, using the equation given in the paragraph below and the information in Table 4, the approximate apogee times for the individual spacecraft can be determined. With this information, with the apogee distance information in Table 3, and with the apogee local time information in Figure 3, a reasonably accurate position for any one of the IMPs at any specific time may be determined.

The apogee times (day number of year and fraction of that day: January 1 day number = 1) of each of five IMP spacecraft are given by the equation $T = \alpha + \beta \cdot (n \pm 0.05)$ for the integer values of n. Table 4 gives values of α for each spacecraft and year and values of β for each spacecraft. Note that the apogee universal times of IMP D are listed in Figure 2.

Table 4 - IMP Spacecraft Values of α and β

IMP	A	B	C	F	G
		Values of α (days)			
Year					
1963	333.00				
1964	3.05	278.87			
1965		1.04	152.42		
1966			3.20		
1967			5.80	146.75	
1968				2.42	
1969				4.20	174.0
1970					4.20
		Values of β (days)			
	3.88	1.44	5.84	4.33	3.36

Bibliography and Abstracts for Spacecraft-Related Papers

Bibliographic references and original abstracts, where available, that relate to the IMP spacecraft are given on the following pages.

IMP A

A-01 Bridge, H.S., G.P. Serbu, N.F. Ness, J.A. Simpson, F. McDonald, K.A. Anderson, and J.H. Wolfe, "Initial Results from the First Interplanetary Monitoring Platform (IMP 1)," IG Bulletin No. 84, June 1964. (Reprinted in Transactions of the American Geophys. Union, 45, 501-520, 1964.

IMP 1 had an extremely eccentric orbit that put the spacecraft outside the magnetosphere two thirds of the time. Groups of detectors on IMP 1 monitored interplanetary magnetic fields, cosmic radiation, and the solar wind. One rubidium vapor magnetometer and two fluxgate magnetometers obtained measurements that indicated a spiral structure in space associated with the rotation of the sun and the efflux of solar plasma. A cosmic-ray telescope investigated the He component of galactic cosmic rays. Ion chambers and GM counters observed low-energy cosmic-ray protons, time variations of the total cosmic-ray intensity, and electrons in interplanetary space beyond the earth's influence. Plasma probes and a retarding potential analyzer gathered data that aided in defining the transition region between the magnetopause and the shock front. Data were also gathered on the structure, magnitude, and variations of magnetic fields in cislunar space beyond the magnetosphere, and on the energy, spectra, fluxes, velocities, variations, etc., of solar and galactic cosmic rays and the solar wind.

A-02 Carr, F.A., "Flight Report, Interplanetary Monitoring Platform, IMP-1 - Explorer 18," NASA, TN D-3352, Apr. 1966.

Following a successful launch, IMP-1 operated successfully for six months. Thereafter performance levels decreased and only limited data was provided during the next 12 months. A total of nearly 6000 hours of data were obtained. The elliptical orbit of IMP-1, reaching 106,000 nautical miles into cislunar space, provided the 9 scientific experiments with a unique opportunity to examine the outer limits of the Earth's magnetosphere, the transition region, and interplanetary space. The performance of the spacecraft system--telemetry, power, and thermal--was near nominal and is discussed based on telemetered performance parameter data. Some possible reasons for the degradation of the silver cadmium battery, which resulted in reduced operation, are discussed.

A-03 Carr, F.A., "Performance Parameter Measurements on the Interplanetary Monitoring Platform IMP 1," NASA-GSFC, X-672-63-238.

A-04 Ehrlich, E., "NASA Particles and Fields Spacecraft," American Institute of Aeronautics and Astronautics, AIAA Paper No. 64-337, Undated. (Paper presented at the 1st AIAA Annual Meeting, Washington, D.C., June 29 - July 2, 1964.)

A-05 "Interplanetary Monitoring Probe S-74," NASA-GSFC, Unnumbered, Feb. 1963.

A-06 Mish, W.H., "Timing Errors - Their Detection and Correction in the IMP Information Processing System," NASA-GSFC, X-612-64-328, Oct. 1964.

One of the major problems encountered by many experimenters in the analysis of data retrieved by experiments flown on board satellites has been that of obtaining correct universal time in conjunction with these data. This paper presents the scheme that was used by the IMP information processing system in the processing of the data from IMP-1, which provided a means of eliminating most of the timing errors before they reached the experimenter. In addition, this scheme proved valuable in the initial debugging of the IMP analog-to-digital line, and proved most significant in evaluating the stability of and providing a check on the IMP-1 spacecraft telemetry system.

A-07 Moore, H.D., "IMP Programmer," NASA-GSFC, X-632-63-111, June 1963.

This report presents to the IMP Project personnel a working document explaining the functions of the programmer in detail. Section I is an explanation in general terms of the overall basic relation of the programmer to the payload.

Section II, a documentation of the circuitry used in the IMP programmer, will be of value to those groups interested in a detailed technical description.

Section III is an interface document written specifically for those groups who have an electrical connection to the programmer. This section will also be of benefit to the Systems Integration Branch.

A-08 Parsons, C.L., and C.A. Harris, "IMP-1 Spacecraft Magnetic Test Program," NASA, TN D-3376, Apr. 1966.

The magnetic tests of the IMP-1 spacecraft (Explorer XVIII) include both individual component and integrated spacecraft test results. By having incorporated component testing in the early stages of the program, it was possible to obtain the following information: (1) individual component magnetic field disturbance magnitudes, (2) possible spacecraft field contribution due to assembled components, (3) to determine which components have excessive magnetic field, (4) a means by which excessive field could be reduced, and (5) possible results due to perming and ceperming effects. Based upon the magnetic test results and upon the telemetered in-flight data, the design goal (magnetic) for the IMP-1 was achieved.

A-09 Piazza, F.D., "Computer Analysis of Interplanetary Monitoring Platform (IMP) Spacecraft Performance," NASA, TN D-3340, Mar. 1966.

The significant features of this method of approach are described in detail, and their successful application to the prelaunch phase of the IMP spacecraft and of the scientific experiments assigned to the IMP missions are outlined. The effectiveness and advantages of this system are emphasized by the use of a compact general purpose computer to provide real-time telemetry data-processing for performance analysis. The analysis during prelaunch has been greatly improved by the system's flexibility, speed, and accuracy of operation compared with methods of analysis previously used. Also pointed out are the advantages of reduction in manpower needed for testing, and of mobility provided by housing the system in a van. The suitability of this system is evident for use with other types of spacecraft in the future, with minimal hardware modification. It is noted that more effective use of the present system depends on the development of more sophisticated software systems for relevant data-processing.

A-10 Rosenbaum, B., "Range Residuals in VHF Radar Tracking," NASA, TN D-3560, Aug. 1966.

The ionosphere imposes a large bias on the accuracy of tracking at VHF, while the irregularities in the ionospheric density add a fluctuating component to range tracking residuals which is about one percent of the principal range bias. The overall variation of these ionospheric effects is about two orders of magnitude during the diurnal cycle and the eleven-year solar cycle. The range residuals of samples of Imp-1 tracking data are examined to detect tracking noise having an ionospheric origin. The data show fluctuating residuals of about 15 meters rms and an anomalous, systematic variation on the order of 100 meters, which could be attributed to the tracking system. The negligible role of ionospheric irregularities observed in range residuals is consistent with the current epoch of the quiet sun.

A-11 Stonesifer, G.R., and E. Beard, "Quality Analysis of the Time and Data for Interplanetary Monitoring Platform Satellites A, B, and C," NASA-GSFC, X-564-66-227, May 1966.

There has been some discussion about the data quality and timing reliability of the first three Interplanetary Monitoring Platform Satellites. A statistical analysis was done on these topics of concern and this publication relates the pertinent information established. By comparing and contrasting the S-74, S-75, and S-76 satellites, various methods were employed to indicate their data quality, frequent tracking station malfunctions, and timing failures or irregularities. Several programs were written to expedite the tabulations needed and their use and development are explained in the appendices.

A-12 White, H.D., "Significance of the ET Flag in the S-74 (IMP) Information Processing System (Preliminary)," Unpublished Preliminary Report, Nov. 1963.

IMP B

B-01 Carr, F.A., "Flight Report Interplanetary Monitoring Platform IMP-2," NASA, TN D-3353, June 1966.

IMP II was launched on October 3, 1964 from Cape Kennedy, Florida, by the Delta 26 LAUNCH vehicle. The apogee achieved was 51,600 n.m., which was less than one-half of the planned altitude. This problem was attributed to the suspected failure of the igniter assembly of the third-stage motor, occurring after about 16 seconds of normal burning. The angle between the spacecraft spin-axis and the ecliptic plane was reduced by the third-stage malfunction, resulting in a wider range of incident sun-angles during the satellite lifetime. This caused low power output from the solar paddles and over-heating of the silver-cadmium battery. Spacecraft performance was satisfactory until the +50°C temperature environment (about two months after launch) caused the failure of the battery. Thereafter, the spacecraft operated only during periods of favorable incident sun-angles. In all, about five months of useful data was recorded. As of mid-1965, the spacecraft was operating itermittently with essentially no useful data being obtained. There is some possibility that perhaps as much as a month's more data might be obtained in the future.

B-02 Moe, K., D. Klein, G. Maled, and L. Tsang, "Density Scale Heights at Sunspot Maximum and Minimum from Satellite Data," Planetary Space Sci., 16, 409-417, 1968.

Density scale heights, $H\rho$, are derived by a new method, which utilizes the spin decay of paddlewheel satellites in highly eccentric orbits. The results are compared with $H\rho$ obtained by other satellite methods and with those given by the Harris and Priester 1964 Model Atmosphere. Equations are derived for the calculation of $H\rho$ from spin decay and X-ray absorption. The gradient of $H\rho$ is calculated for the first time from the drag on a single satellite (IMP 2). Although the trend with solar activity can be seen clearly in the best data, the most obvious conclusion is that it is, in general, very difficult to determine density scale heights accurately. The best method so far developed for obtaining annual averages is the method of King-Hele. The best method of obtaining averages over a few days is to use the spin decay of paddlewheel satellites in highly eccentric orbits. The accuracy of these two methods appears to be 5 to 10%, if the possible variation in drag coefficient is ignored.

B-03 Moore, H.D., "IMP Programmer," NASA-GSFC, X-632-63-111, June 1963.

See abstract under A-07.

B-04 Piazza, F.D., "Computer Analysis of Interplanetary Monitoring Platform (IMP) Spacecraft Performance," NASA, TN D-3340, Mar. 1966.

See abstract under A-09.

B-05 Stonesifer, G.R., and E. Beard, "Quality Analysis of the Time and Data for Interplanetary Monitoring Platform Satellites A, B, and C," NASA-GSFC, X-564-66-227, May 1966.

See abstract under A-11.

IMP C

C-01 Carr, F.A., "Interim Flight Report, Interplanetary Monitoring Platform IMP 3 - Explorer 28," NASA-GSFC, X-724-66-121, Mar. 1966.

The third IMP spacecraft, launched 29 May 1965, provided abundant scientific data on the magnetosphere, shock wave, and interplanetary space. The achieved orbit, apogee about 40 R_e, was satisfactory and the spacecraft performance was good although the failure of two of nine experiments compromises the solar plasma studies. The launch, orbit, spacecraft attitude, and performance are discussed based on the first six months of data. The spacecraft continued to operate past the 9-month mark.

C-02 Carr, F.A., "Interim Flight Report No. 2, Interplanetary Monitoring Platform IMP 3 - Explorer 28," NASA-GSFC, X-724-66-354, July 1966.

The spacecraft fulfilled the mission objective of a one-year lifetime, and at that time completed 62-1/2 orbits and some 10,000 hours of data (including overlapping coverage) were recorded. Operation of the primary spacecraft systems--telemetry, power and data handling--continue to be excellent. Experiment status continue unchanged: specifically, six of the nine are working properly, one partially, and two solar plasma experiments not providing any data.

C-03 Lowrey, B.E., "Decline and Fall of IMP 3, A Preliminary Report," NASA-GSFC, X-643-67-494, Sept. 1967.

Data from the IMP 3 satellite is used to establish an orbit which can be extrapolated until re-entry. The re-entry time is predicted to be the midnight between July 4 and 5, within 1/2 an hour. It is concluded that it is feasible to prepare experiments to observe the satellite re-entry in advance. Further work is in progress to establish a definitive orbit and to increase the accuracy of the decay trajectory.

C-04 Lowrey, B.E., "Decline and Fall of IMP 3, Second Report," NASA-GSFC, X-643-68-117, Feb. 1968.

C-05 Lowrey, B.E., "Ephemeris of a Highly Eccentric Orbit, Explorer 28," NASA-GSFC, X-643-70-177, May 1970.

C-06 Moore, H.D., "IMP Programmer," NASA-GSFC, X-632-63-111, June 1963.

See abstract under A-07.

C-07 Paddack, S.J., and B.E. Shute, "IMP-C Orbit and Launch Time Analysis," NASA-GSFC, X-643-65-40, Jan. 1965.

The purpose of this document is to show the time available for launch of the IMP-C satellite in order to obtain a successful mission. The analysis assumes that the rocket that places the satellite in orbit operates within acceptable tolerances. The launch time available is then dominated by the restraints imposed on the mission. In the case of the IMP-C, four restraints are considered: lifetime, two restraints on orientation in space, and the anticipated amount of time spent in the shadow of the earth or moon. Lifetime and one of the orientation restraints are mandatory, and the other two restraints are desired. The resulting time available for launch satisfying these conditions is shown. This time period (or periods) is defined as the launch window. The result is shown on a launch window map and also in tabular form. The analysis takes into account the anticipated dispersion on injection speed and also the high frequency perturbative effects of the moon. The successful use of an analog computer program is disclosed.

C-08 Piazza, F.D., "Computer Analysis of Interplanetary Monitoring Platform (IMP) Spacecraft Performance," NASA, TN D-3340, Mar. 1966.

See abstract under A-09.

C-09 Stonesifer, G.R., and E. Beard, "Quality Analysis of the Time and Data for Interplanetary Monitoring Platform Satellites A, B, and C," NASA-GSFC, X-564-66-227, May 1966.

See abstract under A-11.

IMP D

D-01 "AIMP (IMP-D) Technical Summary Description," NASA-GSFC, X-724-67-87, Mar. 1967.

D-02 Behannon, K.W., D.H. Fairfield, and N.F. Ness, "Trajectories of Explorers 33, 34 and 35 July 1966 - July 1968," NASA-GSFC, X-616-68-372, Sept. 1968.

Solar ecliptic plane projections are presented on the orbits of the Explorer 33, 34, and 35 satellites. Figures depict the Explorer 33 orbits from launch on July 1, 1966 through June 1967, and show orbit segments pertinent for near earth studies in the night side

magnetosphere. The approximate positions and orientations of the Explorer 34 orbits 1 to 50 from May 24 to December 26, 1967 are also depicted; the orbit period is 4 1/3 days. Apogee and perigee times for orbits 1 to 13 are listed for use in correlating the Explorer 34 position with that of Explorer 33 during May to July 1967. Also plotted are the orbit projections of all three spacecraft for successive periods of one month, collectively covering the period from July 1967 to June 1968.

D-03 Behannon, K.W., K.H. Schatten, D.H. Fairfield, and N.F. Ness, "Trajectories of Explorers 33, 34 and 35 July 1966 - April 1969," NASA-GSFC, X-692-70-64, Feb. 1970.

D-04 Madden, J.J., "AIMP Summary Description," NASA-GSFC, X-672-65-313, Aug. 1965.

Radiation experiments for energetic particles; passive experiments; and experiments for an Ames magnetometer, a GSFC magnetometer, meteorite flux, and solar-cell damage, all to be conducted with a lunar-anchored satellite, are described. The structure, stabilization, retromotor, thermal control, telemetry systems, power systems, tracking, and ground systems for the AIMP-D spacecraft are discussed. Also discussed are reliability, quality assurance, decontamination and clean-room assembly, testing, and the launch vehicle.

D-05 Madden, J.J., "Interim Flight Report Anchored Interplanetary Monitoring Platform AIMP 1 - Explorer 33," NASA-GSFC, X-724-66-588, Dec. 1966.

The first Anchored Interplanetary Monitoring Platform was launched on July 1, 1966, into a highly eccentric earth orbit alternate mission instead of the proposed lunar orbit. The alternate mission was chosen because the over performance of the vehicle precluded a captured lunar orbit. The orbital elements of the achieved orbit vary rapidly. In general, for the first six months the apogee will remain between 400, 000 km and 530,000 km and the perigee between 30,000 km and 100,000 km. The closest approach to the moon (35,000 km) occurred on the initial orbit. The launch operations, orbit, and spacecraft performance are discussed based on the first three months of data. Some predicted parameters are also included.

D-06 Madden, J.J., "Second Interim Flight Report AIMP-1 Explorer 33," NASA-GSFC, X-724-67-223, May 1967.

Data on the performance and orbital characteristics of the AIMP-I (Anchored Interplanetary Monitoring Platform) (Explorer XXXIII), which was launched on July 1, 1966, are presented. Cited are data for the period October 1966 through March 1967. Earlier data are included for comparison. The AIMP-I is in an orbit about the earth in which the perigee position varies from 26,000 km to 130,000 km and the apogee position from 400,000 to 530,000 km. On January 1, 1967 the AIMP-D

mission was declared a success, the spacecraft having passed its sixth month of active life. Discussed are the status of the spacecraft, battery failures, turn-on anomalies, spin axis/sun angle and spin rate, and performance parameters. Tabulated are a new set of predictions for use in determining orbital elements of the spacecraft.

D-07 Madden, J.J., and J.J. Brahm, "Explorer 35 First Interim Report and Explorer 33 Third Interim Report and the AIMP Project Bibliography," NASA-GSFC, X-724-68-45, Mar. 1968.

This report presents information on the launch and early spacecraft performance of Explorer XXXV (AIMP-E) along with remarks on the performance of Explorer XXXIII (AIMP-D). The data were obtained primarily in the second half of 1967. A bibliography of all the important documents produced during the AIMP project is included.

D-08 Marcotte, P.G., "IMP D and E Feasibility Study," NASA-GSFC, X-672-64-4, Jan. 1964.

D-09 Marcotte, P.G., J.J. Madden, and J.J. Brahm, "Anchored Interplanetary Monitoring Platform Summary Description for Explorer 33 AIMP-D and Explorer 35 AIMP-E," NASA-GSFC, X-724-68-82, Mar. 1968.

The Anchored Interplanetary Monitoring Platform (AIMP) program's purpose was to place a spacecraft into either a captured lunar orbit or a geocentric orbit with an apogee near or beyond the lunar distance to investigate the characteristics of the interplanetary plasma and magnetic fields. This document describes the spacecraft, the launch vehicle, the data-utilization systems, the experiments, and the orbital requirements.

D-10 Medlin, J.W., Jr., "Thermal Design Verification Testing of the Anchored Interplanetary Monitoring Platform 'D'," NASA, TN D-4112, Nov. 1967.

Major aspects of the thermal design performance test of the Anchored Interplanetary Monitoring Platform (AIMP-"D"-Lunar Orbiting) are presented herein. The severity of the test and the accuracy of the thermal predictions during the initial test phases are significant items. The test verified the assumptions made for the thermal model with minor exceptions. Thermal design was verified and the spacecraft successfully survived the 6.8-hour shadow simulation with only one experiment problem. Orbital thermal predictions and results are also presented. The orbital temperatures were generally within predicted values for most items with the exception of the solar paddles. The thermal test program was a success in closely duplicating the orbital thermal environment and in developing an excellent spacecraft thermal design. After completion of this report, orbital thermal data was received which exceeded predicted temperatures. Retro-motor exhaust contamination of the spacecraft top cover was determined by the thermal design engineer to be the cause of the thermal extremes.

D-11 Mootchnik, D.L., and J. Kork, "Lunar Orbit Mission Analysis for the Improved Delta Launch Vehicle and AIMP D Spacecraft," NASA, TN D-3911, May 1967.

A detailed analysis was conducted for the AIMP-D spacecraft mission to determine the launch conditions and trajectory shaping which would maximize the probability of attaining a lunar orbit with a lifetime in excess of six months. This study arose from the relatively large transfer orbit injection errors which are associated with the spin stabilized solid propellant injection motor. No mid-course correction is available; the only control parameter is the time of firing of the fixed-impulse lunar orbit injection motor. The large errors resulted in analysis and solutions peculiar to this mission trajectory. It was found that for the applicable vehicle errors, maximum lunar orbit probability was obtained for a 72-hour flight time and a high injection flight path angle. A circular parking orbit could not be used because of the flight path angle requirement, and the available launch times were thereby restricted. Analysis of the spacecraft and guidance constraints resulted in the selection of two launch periods, each of several days duration, occurring twice a year.

IMP E

E-01 Behannon, K.W., D.H. Fairfield, and N.F. Ness, "Trajectories of Explorers 33, 34 and 35 July 1966 - July 1968," NASA-GSFC, X-616-68-372, Sept. 1968.

See abstract under D-02.

E-02 Behannon, K.W., K.H. Schatten, D.H. Fairfield, and N.F. Ness, "Trajectories of Explorers 33, 34 and 35 July 1966 - April 1969," NASA-GSFC, X-692-70-64, Feb. 1970.

E-03 Fedor, J.V., T.W. Flatley, M.F. Federline, and J.R. Metzger, "Explorer 35 Attitude Control System," NASA, TN D-5187, June 1969.

This report deals with history, system description, system operation, maneuvering concept and theory, gas bearing testing, and preliminary flight performance of the attitude control system used on the AIMP E spacecraft (Explorer 35), launched July 19, 1967.

E-04 Madden, J.J., and J.J. Brahm, "Explorer 35 First Interim Report and Explorer 33 Third Interim Report and the AIMP Project Bibliography," NASA-GSFC, X-724-68-45, Mar. 1968.

See abstract under D-07.

E-05 Marcotte, P.G., "IMP D and E Feasibility Study," NASA-GSFC, X-672-64-4, Jan. 1964.

E-06 Marcotte, P.G., J.J. Madden, and J.J. Brahm, "Anchored Interplanetary Monitoring Platform Summary Description for Explorer 33 AIMP-D and Explorer 35 AIMP-E," NASA-GSFC, X-724-68-82, Mar. 1968.

See abstract under D-09.

E-07 Ness, N.F., "Lunar Explorer 35," Space Res. IX, 679-703, 1968.

The Lunar Explorer 35 experiment repertoire includes magnetometers, plasma probes, energetic particle and cosmic dust detectors. Bi-static radar measurements of the electromagnetic properties of the lunar surface have been studied by monitoring the transmitted and reflected RF signal. Results show that the moon is immersed in either interplanetary space or the geomagnetosheath-geomagnetotail formed by the solar wind interaction with the earth. In the geomagnetotail no evidence is found for a lunar magnetic field limiting the magnetic moment to 10^{20} cgs units. In the interplanetary medium no evidence is found for a bow shock wave due to supersonic solar wind flow. The moon does not accrete interplanetary magnetic field lines. A plasma shadow or cavity develops on the anti-solar side of the moon. Small magnetic field perturbations consist of penumbral increases and decreases but only umbral increases are observed due to the diamagnetic properties of the plasma. Diffusion of interplanetary field lines through the lunar body indicates a low electrical conductivity for the outer layers of the moon, less than 10^{-5} mhos/m., and correspondingly low body temperatures.

E-08 Taylor, H.E., "Aspect Determination in Lunar Shadow on Explorer 35," NASA, TN D-4544, May 1968.

The Explorer 35 spacecraft experiences a small, temporary secular decrease in spin period (approximately 2 parts in 1000) during every pass through the lunar shadow. Because of this, the pseudo-sun pulse, generated when the spacecraft is in the shadow, no longer accurately indicates the sunward direction. Details are given on an empirical method of fitting a spin period of the form $a + b \exp(-t/t_0)$ to the aspect information available before and after the optical shadow (t is time since the spacecraft entered the shadow, and a, b, and t_0 are constants to be determined). The resulting aspect information is estimated to be within $\pm$ 10 degrees of the true direction.

IMP F

F-01 Behannon, K.W., D.H. Fairfield, and N.F. Ness, "Trajectories of Explorers 33, 34 and 35 July 1966 - July 1968," NASA-GSFC, X-616-68-372, Sept. 1968.

See abstract under D-02.

F-02 Behannon, K.W., K.H. Schatten, D.H. Fairfield, and N.F. Ness, "Trajectories of Explorers 33, 34 and 35 July 1966 - April 1969," NASA-GSFC, X-692-70-64, Feb. 1970.

F-03 Cliff, R.A., "Application of the Stored-Program Computer to Small Scientific Spacecraft," NASA, TN D-3988, June 1967.

Stored-program computers have not yet been used in small scientific spacecraft. The evolution of spacecraft data systems indicates that inclusion of a computer is a logical next step. The computer would be used for four types of computation: buffering data, formatting data, redundancy removal, and parameter extraction. The most important advantage of using a computer is the flexibility obtained from using a stored program rather than a wired one.

F-04 Gurnett, D.A., "Reducing Radio Frequency-Interference from Spacecrafts in the Frequency Range from 20 Hz to 200 kHz, University of Iowa, UI 67-32, June 1967.

The performance of a satellite-borne radio noise experiment can be seriously degraded by radio-frequency-interference (RFI) generated by the spacecraft electrical system. This paper reviews the RFI program occurring in the range 20 Hz to 200 kHz and recommends methods for reducing the interference on the IMP-1 satellite. The problems encountered on Alouette 1, Injun 3, OGOs 1, 2, and 3, OV3-3, Injun 4, and IMP-F are summarized.

F-05 Narrow, B.G., "Effect on IMP-4 Telemetry Data Due to Range and Range Rate Operations," NASA-GSFC, X-564-69-213, May 1969.

F-06 Ness, N.F., "Magnetic Field Restraints for IMPs F and G," NASA-GSFC, X-672-64-197, July 1964.

To insure the success of magnetic field experiments on the IMP F and G spacecraft, it is necessary that contaminating magnetic fields associated with permanent and induced magnetization or circulating currents on the spacecraft be kept to an absolute minimum. This report outlines the acceptable magnetic testing procedures which are necessary for the spacecraft's success. Recommendations about fabrication of electronic structures and wiring of packages and solar cells that minimize the magnetic field noise levels associated with these individual problem areas are presented. These recommendations present state of the art techniques which proved successful in solving the spacecraft magnetic field contamination problems on IMPA.

F-07 Wolfgang, J.L., Jr., "Results from the Radiation Damage Effects on MOSFETs Experiment on Explorer 34 (IMP-F)," GSFC, Unnumbered, Undated.

IMP G

G-01 Ness, N.F., "Magnetic Field Restraints for IMPs F and G," NASA-GSFC, X-672-64-197, July 1964.

See abstract under F-06.

G-02 Paddack, S.J., "IMP-G Orbit and Launch Time," NASA-GSFC, X-724-69-252, June 1969.

The planned orbital parameters are listed for the high-eccentricity spacecraft IMP-G. The document includes a summary of the launch window analysis and times and the methods for mathematical determination of spin axis-ecliptic plane angle, spin axis-sun angle, and apogee-sun angle. Perigee height, eclipse time, vehicle error effects, and ground trace are discussed and illustrated.

III. EXPERIMENTS

General Information

The scientific experiments carried into space by the IMP spacecraft have measured magnetic fields, electric fields (IMPs I, -H and -J only), plasma, and energetic particles. (In the ambiguous region of energy overlap between plasma and energetic particles, energetic particle experiments are considered to be those which count individual incident particles.) Other experiments are the IMP E micrometeorite experiment, the IMP I radio astronomy experiment, and the IMP D and E passive lunar experiments.

Table 5 contains a complete list of experiments on IMPs A through -J grouped by phenomenon measured. Two-character codes have been assigned to individual experiments. The first character (alphabetic) is the letter designator of the IMP spacecraft on which the experiment was flown (or will fly). The second character (numeric) of the code has been sequenced, within each phenomenon-measured grouping for each spacecraft, alphabetically by the principal investigator's name. Figures and tables following Table 5 use these two-character codes to designate the various experiments. Table 6 contains a list of co-investigators.

A summary of some of the more important characteristics of the detectors flown on IMPs A through G is contained in Table 7. This presentation gives an overall view of the increasing complexity of the experiments carried on the IMP spacecraft. Scientific papers resulting from studies of the data from these experiments are referenced in the bibliography in this section.

Principal time periods between November 27, 1963 (IMP A launch), and December 31, 1970, during which good magnetic field and plasma data were obtained are shown in Figures 4 and 5.

Figure 6 exhibits time coverages of individual 1-kev to 1-Bev proton and electron counting modes of principal scientific interest, ordered by the energy threshold of the mode. No distinctions have been made between directional and omnidirectional modes, counting and energy deposition (e.g., ion chamber) modes, differential or integral energy window modes, or modes with and without energy spectral information (as by pulse height analysis). For such information, brief descriptions which follow Figure 6 must be consulted. Performance information on non-proton, non-electron counting modes can also be found in the brief descriptions. In Figure 6, protons and electrons are distinguished by solid and dashed lines, respectively.

Table 5 - IMP Experiments Grouped by Phenomenon Measured

Experiment Code	Principal Investigator	Investigator Affiliation
	Magnetic Field Experiments	
A1	N. F. Ness	NASA/Goddard Space Flight Center
B1	N. F. Ness	NASA/Goddard Space Flight Center
C1	N. F. Ness	NASA/Goddard Space Flight Center
D1	N. F. Ness	NASA/Goddard Space Flight Center
D2	C. P. Sonett	NASA/Ames Research Center
E1	N. F. Ness	NASA/Goddard Space Flight Center
E2	C. P. Sonett	NASA/Ames Research Center
F1	N. F. Ness	NASA/Goddard Space Flight Center
G1	N. F. Ness	NASA/Goddard Space Flight Center
I1*+	D. A. Gurnett	University of Iowa
I2	N. F. Ness	NASA/Goddard Space Flight Center
H1	N. F. Ness	NASA/Goddard Space Flight Center
H2*	F. L. Scarf	TRW Systems Group
J1*+	D. A. Gurnett	University of Iowa
J2	N. F. Ness	NASA/Goddard Space Flight Center
	Electric Field Measurements	
I3	T. L. Aggson	NASA/Goddard Space Flight Center
I1*+	D. A. Gurnett	University of Iowa
H2*	F. L. Scarf	TRW Systems Group
J3	T. L. Aggson	NASA/Goddard Space Flight Center
J1*+	D. A. Gurnett	University of Iowa
	Plasma Experiments**	
A2	H. S. Bridge	Massachusetts Institute of Technology
A3	G. P. Serbu	NASA/Goddard Space Flight Center
A4	J. H. Wolfe	NASA/Ames Research Center
B2	H. S. Bridge	Massachusetts Institute of Technology
B3	G. P. Serbu	NASA/Goddard Space Flight Center
B4	J. H. Wolfe	NASA/Ames Research Center

*Simultaneous ac electric and magnetic field measurements.

+Also P. J. Kellogg, University of Minnesota, and T. L. Aggson, NASA/GSFC.

**University of Iowa LEPEDEA experiments on IMPs F, G, I, -H, and -J are listed under energetic particle experiments.

Table 5 - IMP Experiments Grouped by Phenomenon Measured (continued)

Experiment Code	Principal Investigator	Investigator Affiliation
	Plasma Experiments (continued)	
C2	H. S. Bridge	Massachusetts Institute of Technology
C3	G. P. Serbu	NASA/Goddard Space Flight Center
C4	J. H. Wolfe	NASA/Ames Research Center
D3	H. S. Bridge	Massachusetts Institute of Technology
D4	G. P. Serbu	NASA/Goddard Space Flight Center
E3	H. S. Bridge	Massachusetts Institute of Technology
E4	G. P. Serbu	NASA/Goddard Space Flight Center
F2	F. B. Harrison	TRW Systems Group
F3	K. W. Ogilvie	NASA/Goddard Space Flight Center
G2	K. W. Ogilvie	NASA/Goddard Space Flight Center
I4	S. J. Bame	Los Alamos Scientific Laboratory
I5	K. W. Ogilvie	NASA/Goddard Space Flight Center
H3	S. J. Bame	Los Alamos Scientific Laboratory
H4	H. S. Bridge	Massachusetts Institute of Technology
H5	K. W. Ogilvie	NASA/Goddard Space Flight Center
J4	S. J. Bame	Los Alamos Scientific Laboratory
J5	H. S. Bridge	Massachusetts Institute of Technology
	Energetic Particle Experiments	
A5	K. A. Anderson	University of California at Berkeley
A6	F. B. McDonald	NASA/Goddard Space Flight Center
A7	J. A. Simpson	University of Chicago
B5	K. A. Anderson	University of California at Berkeley
B6	F. B. McDonald	NASA/Goddard Space Flight Center
B7	J. A. Simpson	University of Chicago
C5	K. A. Anderson	University of California at Berkeley
C6	F. B. McDonald	NASA/Goddard Space Flight Center
C7	J. A. Simpson	University of Chicago
D5	K. A. Anderson	University of California at Berkeley
D6	J. A. Van Allen	University of Iowa
E5	K. A. Anderson	University of California at Berkeley
E6	J. A. Van Allen	University of Iowa
F4	K. A. Anderson	University of California at Berkeley
F5	C. O. Bostrom	Johns Hopkins University/Applied Physics Laboratory
F6	W. L. Brown	Bell Telephone Laboratories
F7	J. A. Van Allen	University of Iowa

Table 5 - IMP Experiments Groupd by Phenomenon Measured (continued)

Experiment Code	Principal Investigator	Investigator Affiliation
	Energetic Particle Experiments (continued)	
F8	K. G. McCracken*	University of Texas at Dallas
F9	F. B. McDonald	NASA/Goddard Space Flight Center
F10	F. B. McDonald	NASA/Goddard Space Flight Center
F11	J. A. Simpson	University of Chicago
G3	R. P. Lin	University of California at Berkeley
G4	K. A. Anderson	University of California at Berkeley
G5	C. O. Bostrom	Johns Hopkins University/Applied Physics Laboratory
G6	W. L. Brown	Bell Telephone Laboratories
G7	J. A. Van Allen	University of Iowa
G8	L. A. Frank	University of Iowa
G9	K. G. McCracken*	University of Texas at Dallas
G10	F. B. McDonald	NASA/Goddard Space Flight Center
G11	F. B. McDonald	NASA/Goddard Space Flight Center
G12	J. A. Simpson	University of Chicago
I6	K. A. Anderson	University of California at Berkeley
I7	C. O. Bostrom	Johns Hopkins University/Applied Physics Laboratory
I8	T. L. Cline	NASA/Goddard Space Flight Center
I9	L. A. Frank	University of Iowa
I10	F. B. McDonald	NASA/Goddard Space Flight Center
I11	J. A. Simpson	University of Chicago
H6	T. L. Cline	NASA/Goddard Space Flight Center
H7	L. A. Frank	University of Iowa
H8	G. Gloeckler	University of Maryland
H9	S. M. Krimigis	Johns Hopkins University/Applied Physics Laboratory
H10	F. B. McDonald	NASA/Goddard Space Flight Center
H11	J. A. Simpson	University of Chicago
H12	E. C. Stone	California Institute of Technology
H13	D. J. Williams	NOAA/Space Environment Laboratory
J6	L. A. Frank	University of Iowa
J7	G. Gloeckler	University of Maryland
J8	S. M. Krimigis	Johns Hopkins University/Applied Physics Laboratory
J9	F. B. McDonald	NASA/Goddard Space Flight Center

*McCracken now at C.S.I.R.O., Port Melbourne, Victoria, Australia; University of Texas at Dallas--formerly the Southwest Center for Advanced Studies.

Table 5 - IMP Experiments Grouped by Phenomenon Measured (continued)

Experiment Code	Principal Investigator	Investigator Affiliation
	Energetic Particle Experiments (continued)	
J10	J. A. Simpson	University of Chicago
J11	E. C. Stone	California Institute of Technology
J12	D. J. Williams	NOAA/Space Environment Laboratory
	Other Experiments	
Selenodesy		
D7*+	W. M. Kaula	University of California at Los Angeles
E8*	W. M. Kaula	University of California at Los Angeles
RF Beacon		
D8*+	A. M. Peterson	Stanford University
E9*	A. M. Peterson	Stanford University
Micrometeorites		
E7	J. L. Bohn	Temple University
Radio Astronomy		
I12	W. C. Erickson	University of Maryland

*Passive experiments.
+No results due to failure of IMP D to achieve lunar orbit.

Table 6 - Co-Investigators for IMP Experiments

This list was provided (except where noted) by the Space Science Steering Committee of NASA in November 1971. The absence of an experiment indicates that no co-investigators have been identified.

Experiment Code and Principal Investigator	Co-Investigators and Current Affiliations
IMP A • IMP B • IMP C	
A3 B3 C3 G.P. Serbu	R. Bourdeau, NASA/GSFC
A7 B7 C7 J.A. Simpson	C.Y. Fan,* U. of Arizona G. Gloeckler,* U. of Maryland
IMP D • IMP E	
D1 E1 N.F. Ness	K. Behannon, NASA/GSFC
D2 E2 C.P. Sonett	W.J. Kerwin, NASA/ARC R.W. Silva, NASA/ARC J.H. Wolfe, NASA/ARC
D3 E3 H.S. Bridge	A.J. Lazarus, MIT E.F. Lyon, MIT
D4 E4 G.P. Serbu	E.J.R. Maier, NASA/GSFC
E7 J.L. Bohn	O.E. Berg, NASA/GSFC W.M. Alexander, Baylor U.
D8 E9 A.M. Peterson	B.B. Lusignan, Stanford U. V.R. Eshleman, Stanford U. O.K. Garriott, Stanford U. R.L. Leadabrand, Stanford U.
IMP F • IMP G	
F1 G1 N.F. Ness	D.H. Fairfield, NASA/GSFC
F2 F.B. Harrison	J.L. Vogl, TRW
F3 G2 K.W. Ogilvie	T.D. Wilkerson, U. of Maryland
G3 R.P. Lin	K.A. Anderson, U. of California at Berkeley
F4 G4 K.A. Anderson	R.P. Lin, U. of California at Berkeley
F5 G5 C.O. Bostrom	D.E. Hagge, NASA/MSC F.B. McDonald, NASA/GSFC D.J. Williams, NOAA
F6 G6 W.L. Brown	G.L. Miller, Bell Telephone Lab. C.S. Roberts, Bell Telephone Lab.
F7 G7 J.A. Van Allen	L.A. Frank, U. of Iowa W.A. Whelpley, U. of Iowa
F8 G9 K.G. McCracken	W.C. Bartley, U. of Texas, Dallas U.R. Rao, U. of Texas, Dallas
F9 G10 F.B. McDonald	G.H. Ludwig, NASA/GSFC
F10 G11 F.B. McDonald	G.H. Ludwig, NASA/GSFC
F11 G12 J.A. Simpson	M. Garcia-Munoz, U. of Chicago

Experiment Code and Principal Investigator	Co-Investigators and Current Affiliations
IMP I	
I1 D.A. Gurnett	T.L. Aggson, NASA/GSFC J.P. Heppner, NASA/GSFC P. Kellog, U. of Minnesota
I2 N.F. Ness	J. Seek, NASA/GSFC D.H. Fairfield, NASA/GSFC
I3 T.L. Aggson	J.P. Heppner, NASA/GSFC
I4 S.J. Bame	J.R. Asbridge, Los Alamos Scientific Laboratory
I7 C.O. Bostrom	D.L. Beall, Johns Hopkins U. - Applied Physics Lab. D.J. Williams, NOAA
I8 T.L. Cline	K.A. Brunstein, U. of Denver
I10 F.B. McDonald	D. Hagge, NASA/MSC B. Teegarden, NASA/GSFC
I11 J.A. Simpson	M. Garcia-Munoz, U. of Chicago G.M. Mason, U. of Chicago
I12 W.C. Erickson	F.T. Haddock, U. of Michigan R.G. Stone, NASA/GSFC
IMP H • IMP J	
H1 J2 N.F. Ness	C. Scearce, NASA/GSFC J. Seek, NASA/GSFC R. Lepping,** NASA/GSFC
J1 D.A. Gurnett	T.L. Aggson, NASA/GSFC G.W. Pfeiffer, U. of Iowa
H2 F.L. Scarf	G.M. Crook, TRW R.W. Fredricks, TRW J.M. Green, TRW
J3 T.L. Aggson	J.P. Heppner, NASA/GSFC
H3 J4 S.J. Bame	J.R. Asbridge, Los Alamos Scientific Laboratory
H4 J5 H.S. Bridge	J.H. Binsack, MIT A.J. Lazarus, MIT E.F. Lyon, MIT
H6 T.L. Cline	K.A. Brunstein, U. of Denver
H8 J7 G. Gloeckler	C.Y. Fan, U. of Arizona D. Hovestadt, Max-Planck Inst.
H9 J8 S.M. Krimigis	T.P. Armstrong, U. of Kansas J.A. Van Allen, U. of Iowa
H10 J9 F.B. McDonald	D. Hagge, NASA/MSC B. Teegarden, NASA/GSFC
H11 J10 J.A. Simpson	M. Garcia-Munoz, U. of Chicago G.M. Mason, U. of Chicago
H12 J11 E.C. Stone	R.E. Vogt, California Institute of Technology
H13 J12 D.J. Williams	J.C. Armstrong, Johns Hopkins U. - Applied Physics Lab. C.O. Bostrom, Johns Hopkins U. - Applied Physics Lab. J.H. Trainor, NASA/GSFC

*According to the Project Development Plan, December 1967.
**Provided by the Principal Investigator.

Table 7 - IMPs A - G Experiment Summary

IMP A • IMP B • IMP C	
A1 B1 C1 Ness, N. F.	BIAXIAL FLUXGATE MAGNETOMETER: range per sensor = ± 40 γ ; digitization uncertainty = 1% of full range.
A2 B2 C2 Bridge, H. S.	FARADAY CUP: ions 40 - 5400 v in five intervals; electrons 65 - 210 v (A2) or 130 - 265 v (B2, C2).
A3 B3 C3 Serbu, G. P.	FARADAY CUP: ions and electrons 0 - ±28 v (A3), 0 - ±100 v (A3), ∓5 - ±15 v (B3, C3), ∓5 - ±45 v (B3, C3) in 15 steps each.
A4 B4 C4 Wolfe, J. H.	ELECTROSTATIC ANALYZER: protons 25 ev - 16 kev in 14 steps (A4) or 0.7 - 8 kev in 12 steps (B4, C4).
A5 B5 C5 Anderson, K. A.	ION CHAMBER: electrons ≥ 1 Mev plus protons ≥17 Mev. GM TUBES: electrons ≥ 45 kev. Protons ≥500 kev (B5, C5 only).
A6 B6 C6 McDonald, F. B.	SCINTILLATOR TELESCOPE: protons and alphas 18.7 - 81.6 Mev/nucleon; electrons 3 - 12 Mev. GM TELESCOPES: protons ≥ 65 Mev; electrons ≥6 Mev.
A7 B7 C7 Simpson, J. A.	SOLID-STATE TELESCOPE: nuclei (1 ≤ Z ≤ 6) 0.9 - 190, 6.5 - 19 (190 on A7), 19 - 90 (190 on A7), 90 - 190 Mev/nucleon.

IMP D • IMP E	
D1 E1 Ness, N. F.	TRIAXIAL FLUXGATE MAGNETOMETER: range per sensor = ±24 γ (E1 only), 64 γ ; digitization uncertainty = 0.4% of full range.
D2 E2 Sonett, C. P.	TRIAXIAL FLUXGATE MAGNETOMETER: range per sensor = ±20, ±60, ±200 γ; digitization uncertainty = ±1% of full range.
D3 E3 Bridge, H. S.	FARADAY CUP: ions and electrons 50 - 5400 v in eight steps.
D4 E4 Serbu, G. P.	FARADAY CUP: ions and electrons 0 - 45 v (D4) or 0 - 500 v (E4).
D5 E5 Anderson, K. A.	ION CHAMBER: electrons ≥ 0.7 Mev plus protons ≥12 Mev. GM TUBES: electrons ≥ 45 kev and ≥ 22 kev; protons ≥ 300 kev.
D6 E6 Van Allen, J. A.	GM TUBES: electrons ≥ 45 kev; protons ≥730 kev; X rays 2 - 12 A. SOLID-STATE SENSOR: protons 0.31 - 10 Mev in three nested ranges (D6) or 0.32 - 6.3 Mev in two nested ranges (E6); alphas 0.6 - 225 Mev in four nested ranges (D6) or 2 - 10 Mev (E6); nuclei 3 ≤ Z ≤ 8 (E6).
E7 Bohn, J. L.	MICRO-METEORITE DETECTORS.
D7 E8 Kaula, W. M.	PASSIVE SELENODETIC EXPERIMENT
D8 E9 Peterson, A. M.	PASSIVE BEACON EXPERIMENT FOR LUNAR IONOSPHERE

IMP F • IMP G	
F1 G1 Ness, N. F.	TRIAXIAL FLUXGATE MAGNETOMETER: range per sensor = ±32, ±128 γ (F1) or ± 40, ± 200 γ (G1); accuracies = ±0.25% full range.
F2 Harrison, F. B.	ELECTRO-STATIC ANALYZER: electrons, protons, and alphas <10 kev.
F3 G2 Ogilvie, K. W.	ELECTROSTATIC ANALYZER: protons and alphas 0.31 - 5.1 kev in 14 steps.
G3 Lin, R. P.	CHANNEL-TRON: electrons 2.5 - 12.5 kev in two intervals.
F4 G4 Anderson, K. A.	ION CHAMBER: electrons ≥ 0.7 Mev plus protons ≥ 12 Mev. GM TUBES: electrons ≥ 45 kev; electrons ≥ 22 kev and protons ≥ 300 kev; electrons ≥ 80 kev and protons ≥ 1.5 Mev (G4 only); electrons ≥ 160 kev and protons > 400 kev (G4 only).
F5 G5 Bostrom, C. O.	SOLID-STATE DETECTORS: protons 1 - 10, ≥10, ≥ 30, ≥ 60 Mev.
F6 G6 Brown, W. L	SOLID-STATE TELESCOPE: protons 0.6 - 18 Mev in five intervals; alphas 1.7 - 80 Mev in four intervals; electrons 0.3 - 3 Mev.
F7 G7 Van Allen, J. A.	LEPEDEA: protons 25 ev - 47 kev; electrons 33 ev - 57 kev in 15 intervals each. GM TUBE: electrons ≥ 40 kev.
G8 Frank, L. A.	LEPDEA: protons 90 ev - 12 kev in 32 intervals.
F8 G9 McCracken, K. G.	SOLID-STATE SCINTILLATOR TELESCOPE: protons 0.8 - 7, 7 - 35, 35 - 110 Mev. PROPORTIONAL COUNTER: electrons ≥70 kev; X rays ≥ 2 kev.
F9 G10 McDonald, F. B.	SOLID-STATE TELESCOPE: protons and alphas 4.2 - 19.1 Mev/nucleon; protons ≥ 1.1 Mev (F9), ≥0.6 Mev (G10). SOLID-STATE SENSORS: protons 83 - 200 kev (G10 only).
F10 G11 McDonald, F. B.	SCINTILLATOR TELESCOPE: protons and alphas 18.7 - 81.6 Mev/nucleon; electrons 0.3 - 0.9, 3 - 12 Mev.
F11 G12 Simpson, J. A.	SOLID-STATE TELESCOPES: nuclei (1 ≤ Z ≤ 14) 0.8 - 9, 9 - 19, 30 - 95, 95 - 119 (G12 only), >119 (G12), > 170 (F11) Mev/nucleon; electrons 85 - 135 kev (F11), 160 - 370 kev (F11).

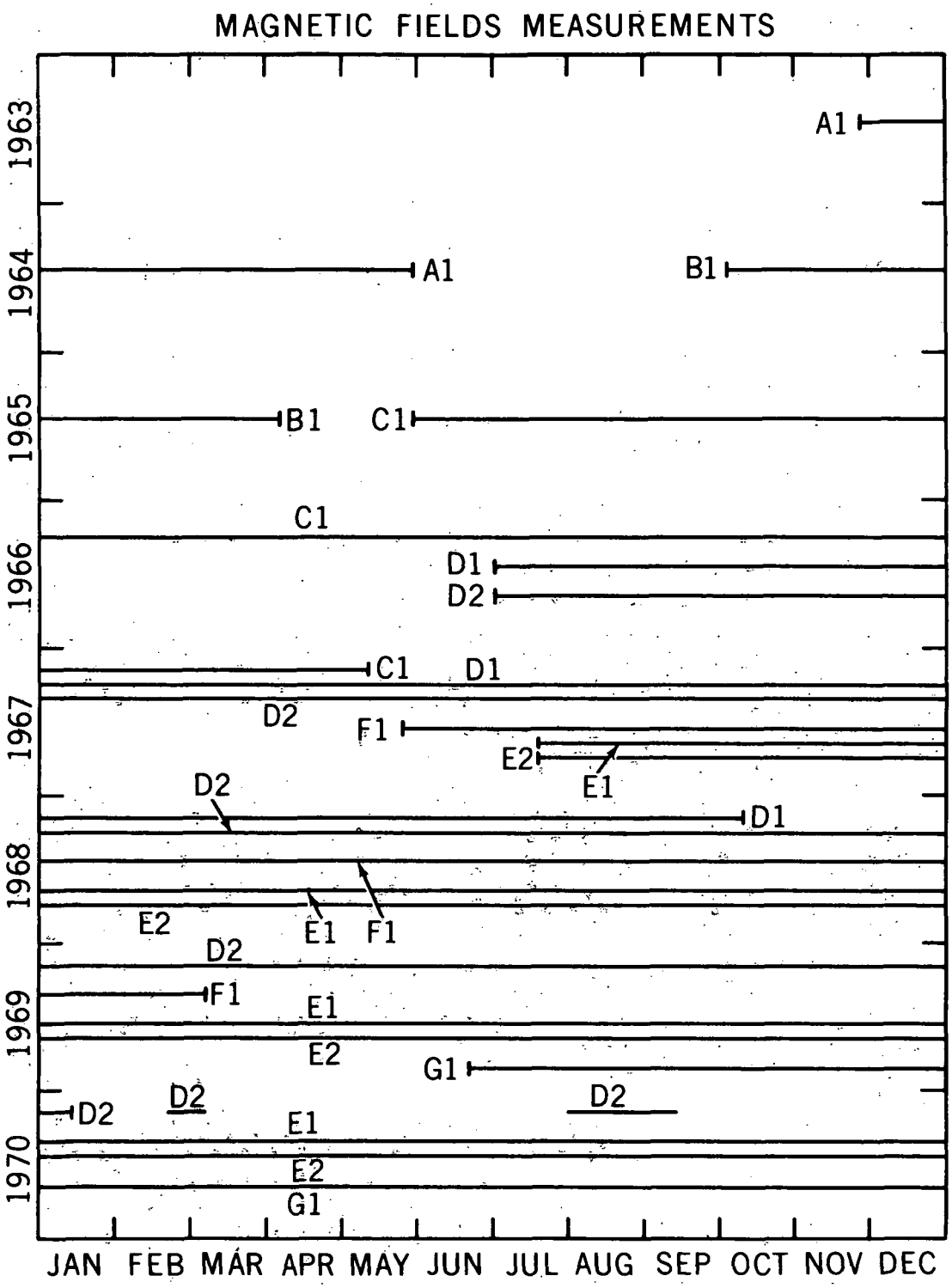

Figure 4 - IMPs A - G Magnetic Field Data Coverage

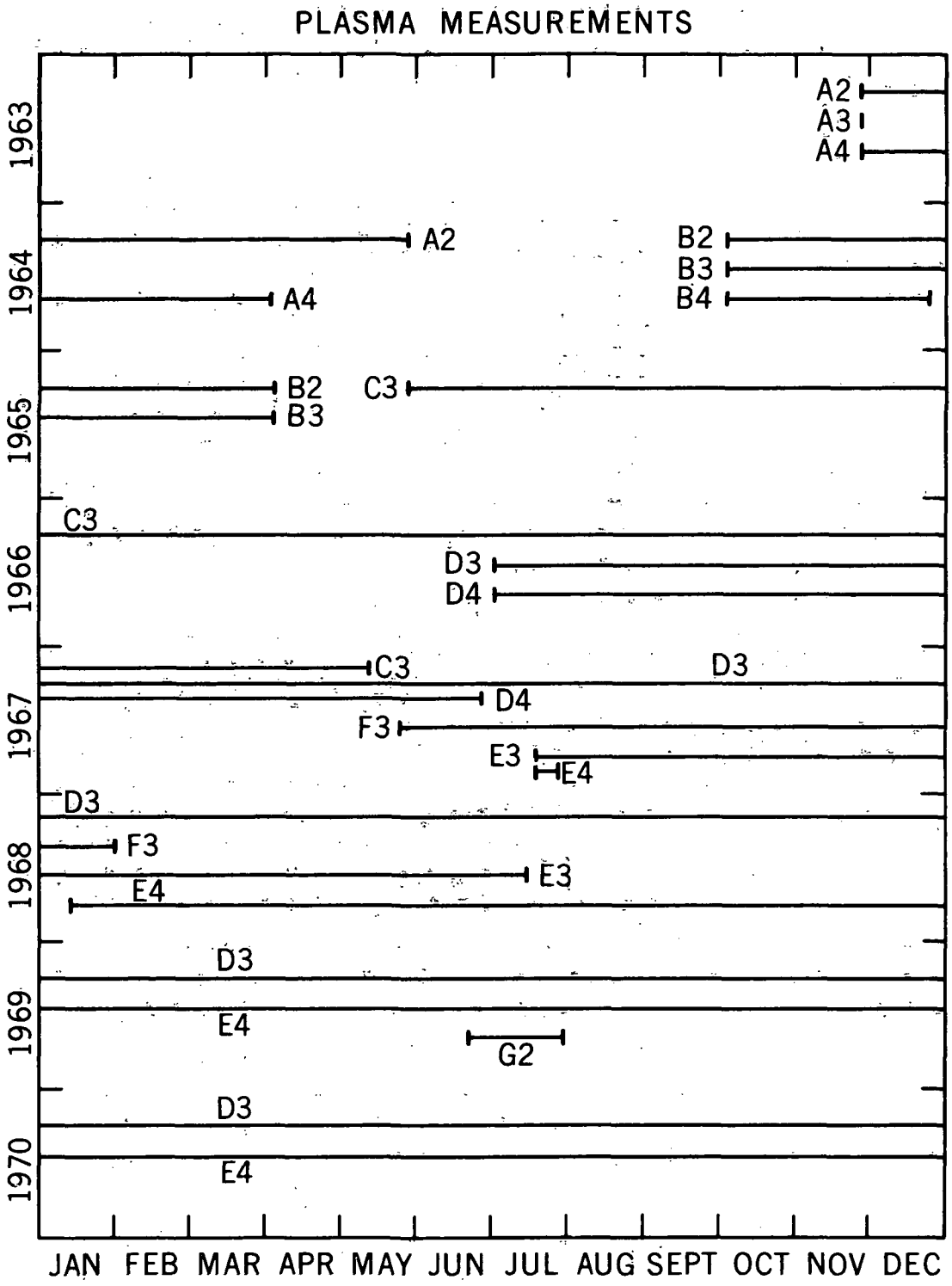

Figure 5 - IMPs A - G Plasma Data Coverage

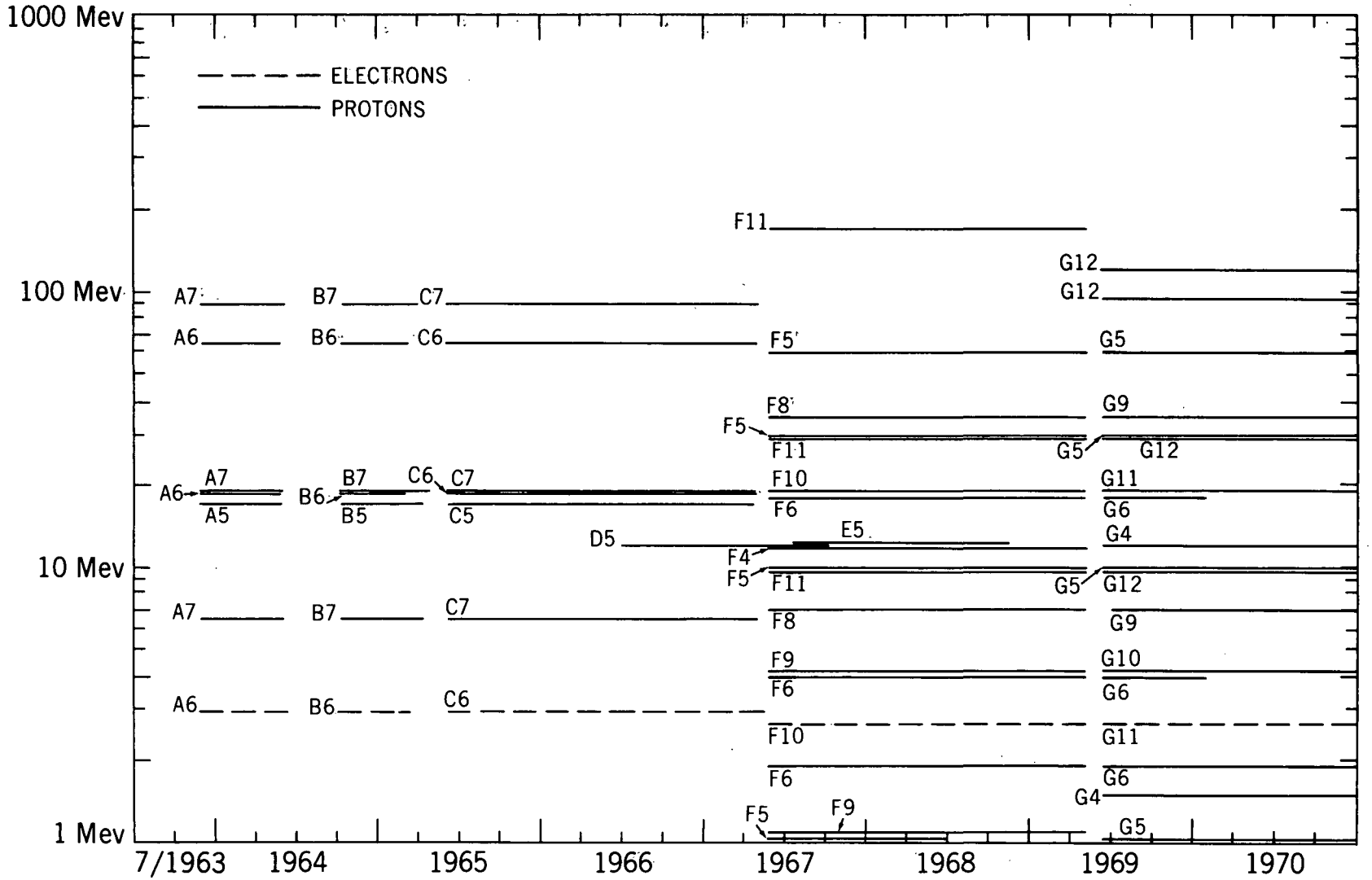

Figure 6 - IMPs A - G Proton and Electron Count Rate Data Coverage

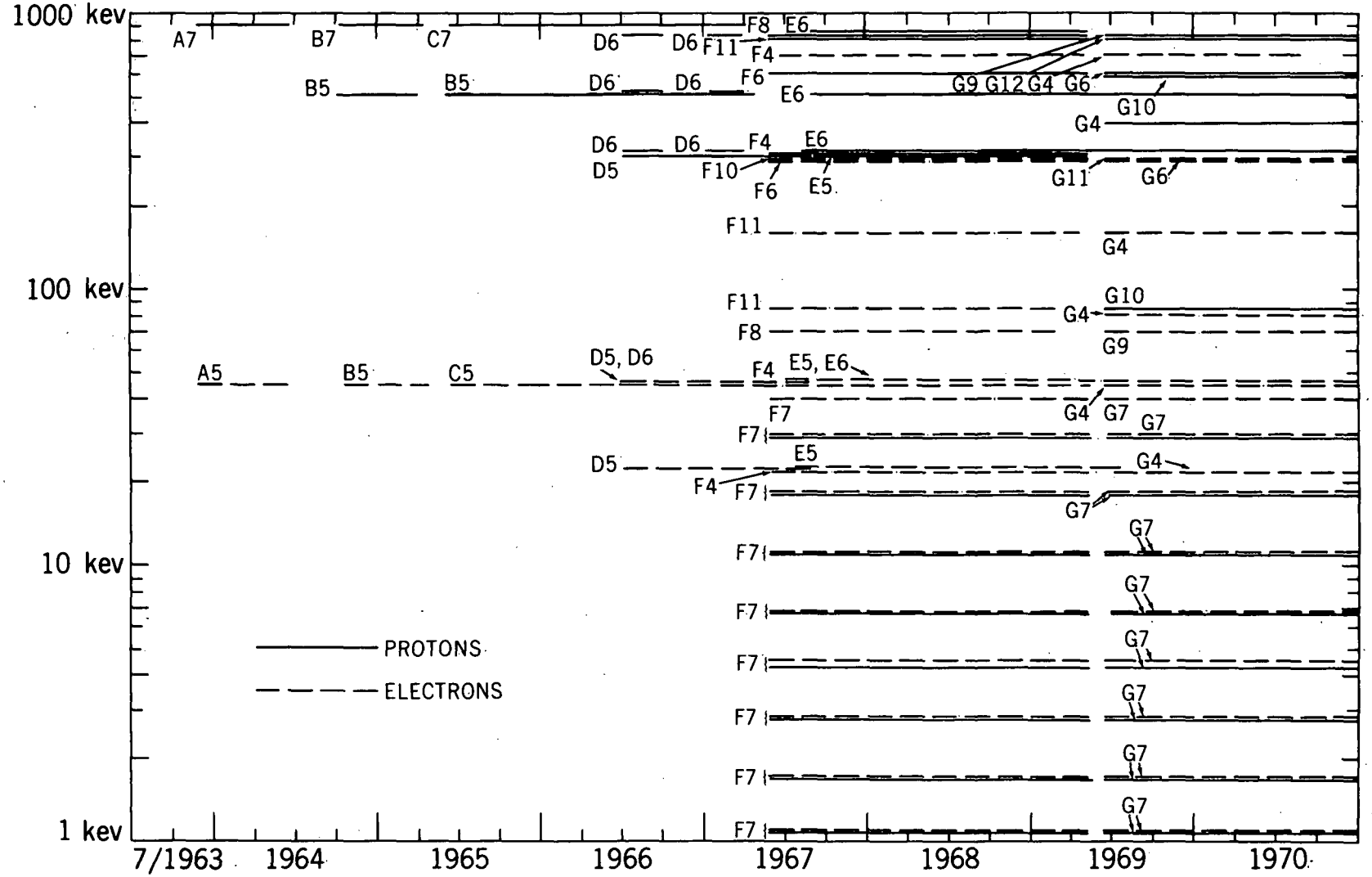

Figure 6 - (continued)

Brief Descriptions of IMP Experiments

In the following pages, brief descriptions of the IMP experiments are presented in the sequence in which they appear in Table 5. The brief descriptions have been taken from the automated information files of the National Space Science Data Center.

Magnetic Field Experiments

A1 Magnetometer

N.F. Ness NASA/Goddard Space Flight Center

Each of two uniaxial fluxgate magnetometers, having dynamic ranges of ±40γ, sampled the magnetic field 30 times within each of six 4.8-sec intervals, every 5.46 min. Detector sensitivites were ±0.25γ, and digitization uncertainty was ±0.40γ. A rubidium vapor magnetometer was used to calibrate the fluxgates but did not produce an independently useful data set. The fluxgates functioned normally throughout the useful life of the satellite and provided usable data through May 30, 1964.

B1 Magnetometer

N.F. Ness NASA/Goddard Space Flight Center

Each of two uniaxial fluxgate magnetometers, having dynamic ranges of ±40γ, sampled the magnetic field 30 times within each of six 4.8-sec intervals every 5.46 min. Detector sensitivities were ±0.25γ, and digitization uncertainty was ±0.40γ. A rubidium vapor magnetometer was used to calibrate the fluxgates but did not produce an independently useful data set. The fluxgates functioned normally throughout the useful life of the satellite, and provided usable data through April 5, 1965.

C1 Magnetometer

N.F. Ness NASA/Goddard Space Flight Center

Each of two uniaxial fluxgate magnetometers had a dynamic range of ±40γ and a sensitivity of ±0.25γ. One fluxgate failed at launch, but the other performed normally, sampling the magnetic field 30 times within each of six 4.8-sec intervals every 5.46-min. Uncertainties in data values are ±1.0γ. Useful fluxgate data were transmitted until May 11, 1967. A rubidium vapor magnetometer was included in the experiment package, but it produced no useful data.

D1

GSFC Magnetometer

N.F. Ness NASA/Goddard Space Flight Center

The instrumentation for this experiment consisted of a boom-mounted triaxial fluxgate magnetometer. Each of the three sensors had a range of ±64γ and a digitization resolution of ±0.25γ. Zero-level drift was checked by periodic reorientation of the sensors. Spacecraft fields at the sensors were not greater than the digitization uncertainty. One vector measurement was obtained each 5.12 sec. The bandpass of the magnetometer was 0 to 5 Hz, with a 20-db per decade falloff for higher frequencies. The detector functioned well between launch and October 10, 1968, but it provided no useful data after that date.

D2

Ames Magnetometer

C.P. Sonnett NASA/Ames Research Center

The Ames magnetometer experiment consisted of a boom-mounted triaxial fluxgate magnetometer and an electronics package. The sensors were orthogonally mounted with one sensor oriented along the spin axis of the spacecraft. A motor interchanged a sensor in the spin plane with the sensor along the spin axis every 24 hr, allowing inflight calibration. The instrument package included a circuit for spin demodulating the outputs from the sensors in the spin plane. The noise threshold was <0.4γ. The instrument had three ranges covering ±20, ±60, and ±200γ full scale for each vector component. The digitization accuracy was 1% of the entire range covered for each range. The magnetic field vector was measured instantaneously, and the instrument range was changed after each measurement. A period of 2.05 sec elapsed between adjacent measurements and 6.14 sec between measurements using the same range. The instrument performance was normal until the final spacecraft transmission on May 31, 1971.

E1

GSFC Magnetometer

N.F. Ness NASA/Goddard Space Flight Center

The experiment consisted of a boom-mounted triaxial fluxgate magnetometer. Each sensor had dual ranges of ±24γ and ±64γ, with digitization resolutions of ±0.94γ and ±0.25γ, respectively. Zero level drift was checked, until May 20, 1969, by periodic reorientation of the sensors. Spacecraft interference was <0.125γ. One vector measurement was obtained each 5.12 sec. The bandpass of the magnetometer was 0 to 5 Hz, with a 20-db per decade falloff for higher frequencies. The experiment has functioned normally from launch to the present (March 12, 1971).

E2

Ames Magnetometer

C.P. Sonett NASA/Ames Research Center

The Ames magnetometer experiment consisted of a boom-mounted triaxial fluxgate magnetometer and an electronics package. The

sensors were orthogonally mounted, with one sensor oriented along the spin axis of the spacecraft. A motor interchanged a sensor in the spin plane with the sensor along the spin axis every 24 hr, allowing inflight calibration. The instrument package included a circuit for spin demodulating the outputs from the sensors in the spin plane. The noise threshold was <0.4γ. The instrument had three ranges covering ±20, ±60, and ±200γ for each vector component. The digitization accuracy was 1% of the entire range covered for each range. The magnetic field vector was measured instantaneously, and the instrument range was changed after each measurement. A period of 2.05 sec elapsed between adjacent measurements and 6.14 sec between measurements using the same range. The instrument performance has been normal as of December 1970.

F1 Magnetometer

N.F. Ness — NASA/Goddard Space Flight Center

This experiment consisted of a triaxial fluxgate magnetometer. Each sensor had dual ranges of ±32γ and ±128γ, and digitization errors of ±0.16γ and ±0.64γ, respectively. Automatic range selection was included. The sensor parallel to the spin axis was on a 6-ft boom and was flipped every 3.9 days to check the zero level. The other two sensors were on a separate boom. Vector measurements were returned each 2.56 sec. An on board autocorrelation computer was included. Autocorrelation data based on 240 samplings were returned on alternate components each 20.45 sec. The experiment worked well until May 3, 1969 (spacecraft reentry date).

G1 Magnetometer

N.F. Ness — NASA/Goddard Space Flight Center

A boom-mounted triaxial fluxgate magnetometer measured magnetic fields in the interplanetary medium, in the magnetosheath, and in the geomagnetic tail. The magnetometer had dynamic ranges of ±40 γ and ±200 γ with respective sensitivities of ±0.2 γ and ±1.0 γ. Automatic onboard range selection was included. Measurement of the energy spectra of magnetic field fluctuations will be accomplished through a computation of the autocorrelation function in an onboard digital processor. The detector has functioned well to date (March 1971).

I1 AC Electric and Magnetic Fields*

D.A. Gurnett — University of Iowa

Three orthogonal search coils and the three orthogonal nearly balanced dipoles utilized in the DC electric field experiment were used to gain simultaneous E and B field data in 16 logarithmically equispaced narrow channels from 20 Hz to 200 kHz. The spectral

***This experiment operates in various modes. Data from the differing modes will be studied for differing physical effects by three investigator groups. Therefore, three brief descriptions are presented.**

frequency resolution was about 30%. Each E-B channel was sampled every 5.12 sec. A short back-up dipole antenna (about 1 m tip to tip) was also utilized to detect very short wavelength plasma phenomena. Analog B or E data from 0 to 30 kHz in three segments were also telemetered on the special purpose analog channel. This experiment was designed to be used in conjunction with the Low Energy Proton and Electron Differential Energy Analyzer (LEPEDEA). Initial experiment performance was normal.

P.S. Kellogg — University of Minnesota

This experiment was designed to determine the polarization, direction of propagation, poynting flux, and direction of the wave normal surface for plasma waves. The time-averaged correlation at one channel frequency from any combination of the six antenna elements (three each orthogonal E and B) could be simultaneously calculated by six onboard analog computers. Three were 64 logarithmically equispaced frequency channels centered from 23 Hz to 200 kHz with a 15% bandwidth at 3 db. Averaging time was 2.5 sec. The combinations of elements and the sequence of frequencies measured were controlled either by an onboard computer or from the ground. Initial experiment performance was normal.

T.L. Aggson — NASA/Goddard Space Flight Center

AC electric field intensity in 12 narrow channels was measured from 0.1 to 100 Hz. The experiment had an optimum noise threshold of 10 microvolts per meter. Each channel was sampled once every 5.12 sec at the high bit rate. The antennas used in the DC field experiment were also utilized in this experiment. Initial experiment performance was normal.

I2 Fluxgate Magnetometer

N.F. Ness — NASA/Goddard Space Flight Center

This experiment was designed to accurately measure the vector magnetic field in the interplanetary medium and in the earth's magnetosphere, magnetotail, and magnetosheath. The detector was a boom-mounted triaxial fluxgate magnetometer with four ranges: ∓ 16, ∓ 48, ∓ 144, and ∓ 432 γ, respectively. Corresponding sensitivities are ± 0.06, ± 0.19, ± 0.56, and ± 1.69 γ. Automatic range selection capability was included. A flipping mechanism permitted inflight calibration of the three sensor zero levels. The vector sampling rate is 12.5 samples per sec. Initial experiment performance was normal.

H1 Fluxgate Magnetometer

N.F. Ness — NASA/Goddard Space Flight Center

This experiment consists of a boom-mounted triaxial fluxgate magnetometer designed to study the interplanetary and geomagnetic tail magnetic fields. Each sensor has three dynamic ranges: ± 12 γ, ± 36 γ, and ± 108 γ. With the aid of a bit compaction scheme (delta modulation), there will be 25 vector measurements made and telemetered per second.

H2 Electric and Magnetic Fields

F.L. Scarf TRW Systems Group

Electric field components perpendicular to the spacecraft spin axis and the magnetic field component parallel to that axis will be measured by an electric dipole antenna and a search coil magnetometer. Both sensors will be mounted on a 3.05-m boom. Data will be obtained in eight narrow frequency channels from 10 Hz to 100 kHz in either the normal mode or the snapshot mode. In the normal mode, the antenna is first sampled in a given frequency channel many times during a given measurement period (comparable to spacecraft spin period). During the next period, the search coil is sampled many times in the same frequency channel. Next, the antenna is sampled in the next frequency channel, followed by the search coil in that channel. The frequency channels are incremented, and the sampled sensors alternated, until a full set of data is obtained in 16 measurement periods (20 sec). In the snapshot mode, only electric field data are transmitted in the following manner. The antenna is first sampled in a given frequency channel many times during a given measurement period. In the next period, the antenna is sampled in two sequences of eight frequency channels. This two-period measurement is executed eight times, incrementing the frequency channel studied in every other period by one each time. Thus, a full set of data again requires 16 measurement periods. In addition, an analog mode sampling the antenna and search coil from 10 Hz to 100 Hz is used in conjunction with the special purpose analog telemetry channel test to be conducted. The electric and magnetic thresholds are 10 μv/m and 3 mγ.

J1 AC Electric and Magnetic Fields

D.A. Gurnett University of Iowa
P.S. Kellogg University of Minnesota
T.L. Aggson NASA/Goddard Space Flight Center

A wide-band receiver will be used to observe high-resolution frequency-time spectra, and a six-channel narrow-band receiver with a variable center frequency will be used to observe wave characteristics. The receivers will operate from three antenna systems. The first system will contain a pair of long dipole antennas (one normal to the spacecraft spin axis (extendable to 400 ft) and the other antenna along the spin axis (extendable to 20 ft). The second system will contain a boom-mounted triad of orthogonal loop antennas. The third system will consist of a boom-mounted 20-in. spin axis dipole. The magnetic and electric field intensities and frequency spectra, polarization, and direction of arrival of naturally occurring radio noise in the magnetosphere will be observed. Phenomena to be studied are the time-space distribution, origin, propagation, dispersion, and other characteristics of radio noises occurring across and on either side of the magnetospheric boundary region. The frequency range for electric fields is 0.3 Hz to 200 kHz and for magnetic fields is 20 Hz to 200 kHz.

J2 Fluxgate Magnetometer

N.F. Ness NASA/Goddard Space Flight Center

This experiment consists of a boom-mounted triaxial fluxgate magnetometer designed to study the interplanetary and geomagnetic tail magnetic fields. Each sensor has three dynamic ranges: ±12 γ, ±36 γ, and ±108 γ. With the aid of a bit compaction scheme (delta modulation), there will be 25 vector measurements made and telemetered per second.

Electric Field Measurements

I3 DC Electric Fields

T.L. Aggson NASA/Goddard Space Flight Center

Two dipole antennas were mounted orthogonally in the spin plane of the spacecraft while a third dipole antenna was mounted along the spacecraft spin axis. Antenna element lengths were: -X, 27.6 m; +X, 24.4 m; -Y and +Y, 45.5 m; -Z and +Z (spin axis), 2.9 m. Electrometers measured the analog potential difference between the elements in each pair of antennas simultaneously every 5.12 sec. The potential differences were sampled digitally through a 14-bit analog/digital converter every .64 sec. DC sensitivity was 100 microvolts per meter. Initial experiment performance was normal.

I1 AC Electric and Magnetic Fields

D.A. Gurnett University of Iowa
P.S. Kellogg University of Minnesota
T.L. Aggson NASA/Goddard Space Flight Center

See brief descriptions under Magnetic Field Experiments.

H2 Electric and Magnetic Fields

F.L. Scarf TRW Systems Group

See brief description under Magnetic Field Experiments.

J3 DC Electric Fields

T.L. Aggson NASA/Goddard Space Flight Center

A biaxial antenna system, with electrometers to measure the potential difference between the two halves of each antenna, will determine the vector electrostatic field with a sensitivity of 0.1 μv/m. One antenna lies along the spacecraft spin axis and the other is normal to this axis. Measurements will be made in the solar wind, in the transition region, and in the geomagnetic tail.

J1 AC Electric and Magnetic Fields

D.A. Gurnett University of Iowa
P.S. Kellogg University of Minnesota
T.L. Aggson NASA/Goddard Space Flight Center

See brief description under Magnetic Field Experiments.

Plasma Experiments

A2 MIT Faraday Cup

H.S. Bridge Massachusetts Institute of Technology

A five-element split collector Faraday cup was used to measure solar wind particles in the following sequence: positive ions from 45 to 105 ev, positive ions from 95 to 235 ev, positive ions from 220 to 640 ev, positive ions from 560 to 1800 ev, electrons from 65 to 210 ev, and positive ions from 1700 to 5400 ev. (The split plane of the collector was in the spin equatorial plane of the spacecraft.) Measurements consisted of 22 instantaneous current samples, each separated by 0.16 sec (spanning more than one satellite rotation). These measurements represented the sum of the current to the split collector, the maximum difference current encountered during spacecraft rotation, and which half collector was maximum. The entire sequence required 2.8 min and was repeated every 5.5 min. The entrance cone for this Faraday cup had a half-angle of about 80°. Interference was encountered from refracted particles (with the most pronounced effect at about 70° incidence to cup normal), from secondary electrons, and from ultraviolet radiation. Useful data were obtained from launch until January 13, 1965. However, there was poor data coverage during the last 7 months because of intermittent satellite transmission.

A3 GSFC Faraday Cup

G.P. Serbu NASA/Goddard Space Flight Center

The retarding potential analyzer was a three-element planar Faraday cup. It was mounted normal to the spacecraft spin axis and had an effective look angle of 5 ster. Coarse and fine resolution modes were programmed for both ions and electrons. These modes consisted of 15 steps each for retarding voltages of 0 to 28 and 0 to 100 v. The entire ion and electron sequence was repeated once every 10.92 min, and each 15-step spectrum analysis required 5.4 sec. The experiment operated from launch for about 20 hr when failure of a mechanical programmer switch terminated operations. The data were adversely affected by secondary electrons.

A4 Electrostatic Analyzer

J.H. Wolfe NASA/Ames Research Center

A quadrispherical electrostatic analyzer with a current collector and an electrometer amplifier was used to detect and analyze the positive ion component of the incident plasma and to study its gross flow characteristics. Protons were analyzed in 14 energy channels between 0.025 and 16 kev. The instrument was mounted on the satellite equatorial plane and had a view angle of 15° in this plane and of 90° in the plane containing the spin axis. The satellite's equatorial plane was divided into three contiguous sectors (111.8°, 111.8°, and 136.4°) by use of an optical aspect sensor. The peak flux in one sector was recorded at one analyzer plate potential per revolution of the satellite. (No information as to the position within the sector in which the peak flux occurred was retained.) After 14 revolutions, all energy channels had been scanned, and the process was repeated for the next sector. A complete scan in energy and sector was repeated every 5.46 min. No data were obtained for the brief periods when the satellite was in the magnetosphere. The instrument operated well until April 1964 when it started operating intermittently. Its operation continued to degrade thereafter.

B2 MIT Faraday Cup

H.S. Bridge Massachusetts Institute of Technology

This five-element Faraday cup measured electrons between 130 and 265 ev and ions in the following five energy windows: 40 to 90, 95 to 230, 260 to 650, 700 to 2000, and 1700 to 5400 ev. For each 5.46-min interval, 22 usable instantaneous current samples were recorded for each energy window, separated by 0.16 sec each. Two collector plates were used to yield information about the angular variation out of the satellite spin plane. The sum and difference of the currents on the two plates and the direction with maximum current were telemetered. The effect of secondary electrons has not been eliminated. This effect could be very significant within the earth's plasmapause. The instrument produced data throughout the operational life of the spacecraft, and provided essentially continuous data through April 5, 1965.

B3 GSFC Faraday Cup

G.P. Serbu NASA/Goddard Space Flight Center

The retarding potential analyzer was a four-element Faraday cup. It was mounted normal to the spacecraft spin axis and had an effective look angle of 5 ster. The experiment operated for 5.2 sec in each of four modes once every 648 sec. In two modes, 15-step spectra for ions were determined for retarding potentials in the ranges -5 v to +15 v and -5 v to +45 v. In the other two modes similar information for electrons was obtained by changing the signs of the potentials. The instrument experienced secondary electron contamination but returned essentially continuous data until April 5, 1965.

B4 Electrostatic Analyzer

J.H. Wolfe NASA/Ames Research Center

A quadrispherical electrostatic analyzer with a current collector and an electrometer amplifier was intended to detect and analyze the positive ion component of the incident plasma and to study its gross flow characteristics. The planned monitoring of the interplanetary medium was not accomplished because the apogee that the satellite achieved was lower than expected. Protons were analyzed in 12 energy channels between 0.7 and 8 kev. The instrument was mounted on the satellite's equatorial plane and had a view angle of 15° in this plane and of 90° in the plane containing the spin axis. The satellite's equatorial plane was divided into three contiguous sectors (61°, 95°, and 204°) by use of an optical aspect sensor. The peak flux in one sector was recorded at one analyzer plate potential per revolution of the satellite. (No information as to the position within the sector in which the peak flux occurred was retained.) After 12 revolutions, all the energy channels had been scanned, and the process was repeated for the next sector. A complete scan in energy and sector was repeated every 5.46 min. Because the instrument was not capable of observing magnetospheric plasma, no data were obtained for the time when the satellite was in the magnetosphere. The instrument operated well during the time when data could be recorded.

C2 MIT Faraday Cup

H.S. Bridge Massachusetts Institute of Technology

The Faraday cup was a multi-element split collector instrument intended to make differential energy spectrum measurements of interplanetary and magnetospheric ions and electrons. The experiment failed at launch.

C3 GSFC Faraday Cup

G.P. Serbu NASA/Goddard Space Flight Center

The retarding potential analyzer was a four-element Faraday cup. It was mounted normal to the spacecraft spin axis and had an effective look angle of 5 ster. The experiment operated for 5.2 sec in each of six modes once every 648 sec. In two modes, 15-step spectra for ions were determined for retarding potentials in the ranges -5 v to +15 v and -5 v to +45 v. In two modes, similar information for electrons was obtained by changing the signs of the potentials. The remaining two modes were net current modes with zero potential applied to all elements for 15 measurements. The instrument experienced secondary electron contamination, but operated without degradation during the spacecraft lifetime (i.e., until May 11, 1967).

C4 Electrostatic Analyzer

J.H. Wolfe NASA/Ames Research Center

A quadrispherical electrostatic analyzer with a current collector and an electrometer amplifier was intended to detect and analyze the positive ion component of the incident plasma and to study its gross flow characteristics as a function of radial distance from the earth. The instrument failed at launch and thus produced no useful data.

D3 MIT Faraday Cup

H.S. Bridge Massachusetts Institute of Technology

A split-collector Faraday cup mounted on the spacecraft equator was used to study the directional intensity of solar wind ions and electrons. The following 25-sec sequence was executed three times for ions and once for electrons each 328 sec. Twenty-seven directional current samples from the two collectors were taken in the energy per charge window from 80 to 2850 v. The currents in the two collectors were then sampled in eight energy per charge windows between 50 and 5400 v at the azimuth at which peak current appeared in the previous 27 measurements. Due to telemetry limitations, only the following data were returned to earth every 328 sec: for ions, the sums of currents measured on the two collector plates twice and the difference once; for electrons, the sums once. The experiment worked well from launch until final spacecraft data transmission on May 31, 1971.

D4 GSFC Faraday Cup

G.P. Serbu NASA/Goddard Space Flight Center

A wide-aperture multi-grid potential analyzer was used to observe the intensity of the electron and ion components of the low-energy plasma in interplanetary space and near earth. Integral spectra were obtained for both ions and electrons in the energy ranges from 0 to 45 ev (15 steps) and 0 to 15 ev (15 steps). Complete spectra for protons and electrons were obtained every 80 sec. The experiment operated until June 29, 1967.

E3 MIT Faraday Cup

H.S. Bridge Massachusetts Institute of Technology

A multi-grid, split-collector Faraday cup mounted on the equator of the spacecraft was used to study the directional intensity of solar wind positive ions and electrons with particular emphasis on the interaction of the solar wind with the moon. Twenty-seven integral current samples (requiring about 4.3 sec) were taken in an energy per charge window from 80 to 2850 v. Then the current was sampled in eight differential energy per charge windows between 50 and 5400 v at the azimuth where the peak current appeared in the previous series of the integral measurements. These measurements (integral and differential) took about 25 sec. Both the sum and difference of collector currents

were obtained for positive ions. Only the sum was obtained for electrons. A complete set of measurements (two collector plate sums and one difference for protons and one collector plate sum for electrons) required 328 sec. The experiment worked well from launch until its failure in July 1968.

E4 GSFC Faraday Cup

G.P. Serbu — NASA/Goddard Space Flight Center

A planar multi-grid sensor programmed as a retarding potential analyzer was used to observe the intensity of the electron and ion components of the low-energy plasma near the moon. Integral spectra were obtained for both ions and electrons in the energy range from 0 to 500 ev. A complete spectrum was obtained every 80 sec. Except for the period July 25, 1967, to January 12, 1968, the experiment has worked well (as of March 1971).

F2 TRW Electrostatic Analyzer

F.B. Harrison — TRW Systems Group

This experiment used a spherical electrostatic analyzer with an electron multiplier to study the directional properties, absolute intensity, time variations, and energy spectrum of protons, electrons, and alpha particles in the energy range <10 kev. At launch, it was questionable whether the door on the experiment had opened. Within a week (and before the question of the door had been resolved), the experiment failed.

F3 GSFC Electrostatic Analyzer

K.W. Ogilvie — NASA/Goddard Space Flight Center

An electrostatic analyzer and an E x B velocity selector normal to the spacecraft spin axis were used to separately determine proton and alpha particle spectra in the solar wind. For each species, measurements in the energy per charge range 310 to 5100 ev were made at 14 points logarithmically equispaced in energy. During individual spacecraft rotations, counts were obtained in each of sixteen 22.5-deg sectors for a given species and energy. The sum of these counts, the sum of the squares of these counts, and the sector number of maximum counting were telemetered to earth. After successive 61.44-sec spectral determinations for protons and alpha particles, 15 consecutive readings for protons at 1408 ev were obtained. A period of 3.07 min separated two spectra of the same species. The instrument operated normally until January 30, 1968. At that time it was turned off since it was spending all its time in the magnetosphere. Later, attempts to reactivate the sensor failed.

G2 Electrostatic Analyzer

K.W. Ogilvie NASA/Goddard Space Flight Center

An electrostatic analyzer and an E x B velocity selector normal to the spacecraft spin axis were used to separately determine proton and alpha particle spectra in the solar wind. For each species, measurements in the energy per charge range 310 to 5100 ev were made at 14 points logarithmically equispaced in energy. During individual spacecraft rotations, counts were obtained in each of sixteen 22.5° sectors for a given species and energy. The sum of these counts, the sum of the squares of these counts, and the sector number of maximum counting were telemetered to earth. After successive 61.44-sec spectral determinations for protons and alpha particles, 15 consecutive readings for protons at 1408 ev were obtained. A period of 3.07 min separated two spectra of the same species. The instrument operated intermittently until July 31, 1969, and provided no data beyond that date.

I4 LASL Electrostatic Analyzer

S.J. Bame Los Alamos Scientific Laboratory

A hemispherical electrostatic analyzer was used to extend description of the particle (electron and positive ion) populations in the solar wind, magnetosheath, and magnetotail. Energy spectral analysis was accomplished by charging the plates to known voltage levels and allowing them to discharge with known RC time constants. The analyzer has four commandable modes. The first mode was designed for the measurement of solar wind protons and alpha particles. During eight spacecraft revolutions, 32-level energy spectra were obtained in eight angular ranges centered on the sun. The energy levels extend from 100 ev to 8 kev. The second mode was designed for the measurement of solar wind heavy ions. This cycle was the same as the first except that the energy per charge levels were limited to 900 v to 8 kv and the efficiency of counting heavy ions was increased relative to protons and alpha particles. The third mode was designed for the measurement of solar wind and magnetosheath electrons and magnetosheath positive ions. This was a combination cycle in which electron and positive ion spectral sweeps were alternated. During a cycle of nine spacecraft revolutions, eight electron spectra and eight positive ion spectra were obtained. The combined data for electrons in this mode consisted of 16-level energy spectra taken in 32 evenly spaced angular ranges. The spectra extended from 4 to 1000 ev. The data for positive ions consisted of 32-level spectra taken in the same 32 angular ranges. The energy per charge spectra extended from 100 v to 8 kv. The fourth mode was designed for magnetotail electrons and positive ions. Electrons and positive ions were studied with 16-level spectra in 32 evenly spaced angular ranges for both electrons and positive ions. The energy per charge ranges were 6 v to 24 kv for electrons and 45 v to 34 kv for positive ions. Initial experiment performance was normal.

I5 GSFC Electrostatic Analyzer

K.W. Ogilvie NASA/Goddard Space Flight Center

This experiment consisted of two oppositely directed plasma detectors, both of which were normal to the spacecraft spin axis. An elec-

trostatic analyzer measured protons and alpha particles with deflection voltages between 170 and 6400 v. An electrostatic analyzer and velocity selector measured only alpha particles with deflection voltages between 640 and 7200 v. During successive spacecraft revolutions, each of the two electrostatic analyzer deflection voltages was advanced through one of 20 logarithmically equispaced steps in the above stated intervals. Complete spectra are thus obtained in 240 sec. During each revolution, directional measurements were taken by each detector in 16 contiguous 2.5° sectors centered on the satellite sun line and in six contiguous 11.25° sectors on either side of the first sector. No measurements were taken in the antisun hemisphere. The sum and the sum of squares of counts in the 28 angular sectors were telemetered in both telemetry modes. In addition, in the high bit rate, counts in the middle twelve 2.5° sectors were telemetered, while in the low bit rate, the highest count rate in a 2.5° sector and the sector number were telemetered. Initial experiment performance was normal for the first month. After one month, difficulty was encountered. Current operational status is unknown (June 22, 1971).

H3 LASL Electrostatic Analyzer

S.J. Bame Los Alamos Scientific Laboratory

A hemispherical electrostatic analyzer will be used to study the directional intensity of positive ions and electrons in the solar wind, magnetosheath, and magnetotail. Ions as heavy as oxygen will be resolved when the solar wind temperature is low. Energy analysis will be accomplished by charging the plates to known voltage levels and allowing them to discharge with known rc time constants. In the solar wind, positive ions from 200 ev to 5 kev (15% spacing, 3% resolution) and electrons from 5 ev to 1 kev (30% spacing, 15% resolution) will be studied. In the magnetosheath, positive ions from 200 ev to 5 kev (15% spacing, 3% resolution) and from 200 ev to 2 kev (30% spacing, 15% resolution) and electrons from 5 ev to 1 kev (30% spacing, 15% resolution) will be studied. In the magnetotail, positive ions from 200 ev to 20 kev (30% spacing, 15% resolution) and electrons from 5 ev to 1 kev (30% spacing, 15% resolution) and from 100 ev to 20 kev (15% resolution) will be studied.

H4 Faraday Cup

H.S. Bridge Massachusetts Institute of Technology

A modulated split-collector Faraday cup which looks perpendicular to the spacecraft spin axis will be used to study the directional intensity of positive ions and electrons in the solar wind, transition region, and magnetotail. Electrons will be studied in eight logarithmically equal energy channels between 17 ev and 7 kev. Positive ions are to be studied in eight energy channels between 50 ev and 7 kev. A spectrum will be obtained every eight spacecraft revolutions. Angular information will be obtained in either 15 equally spaced intervals during a 360° revolution of the satellite or more closely about the spacecraft sun line.

H5 GSFC Electrostatic Analyzer

K.W. Ogilvie NASA/Goddard Space Flight Center

An electrostatic analyzer and Wein type velocity selector will be used to gain exploratory data on heavy ion composition in the solar wind. Bulk velocities of 4 He^{++}, 4 He^{+}, 3 He^{++}, and O (isotopes indistinguishable) ions will be separately studied. During 30 successive spacecraft spin periods, ions of a given species will be studied in 30 logarithmically equispaced bulk velocity channels from 200 to 600 km/sec. A complete set of measurements requires about 10 minutes and consists of 30 one-step sequences for 4 He^{++} ions and five 30 step sequences for each of the other three species.

J4 Electrostatic Analyzer

S.J. Bame Los Alamos Scientific Laboratory

A hemispherical electrostatic analyzer will be used to study the directional intensity of positive ions and electrons in the solar wind, magnetosheath, and magnetotail. Ions as heavy as oxygen will be resolved when the solar wind temperature is low. Energy analysis will be accomplished by charging the plates to known voltage levels and allowing them to discharge with known RC time constants. In the solar wind, positive ions from 200 ev to 5 kev (15% spacing, 3% resolution) and electrons from 5 ev to 1 kev (30% spacing, 15% resolution) will be studied. In the magnetosheath, positive ions from 200 ev to 5 kev (15% spacing, 3% resolution) and from 200 ev to 20 kev (30% spacing, 15% resolution) and electrons from 5 ev to 1 kev (30% spacing, 15% resolution) will be studied. In the magnetotail, positive ions from 200 ev to 20 kev (30% spacing, 15% resolution) and electrons from 5 ev to 1 kev (30% spacing, 15% resolution) and from 100 ev to 20 kev (15% resolution) will be studied.

J5 Faraday Cup

H.S. Bridge Massachusetts Institute of Technology

A modulated split-collector Faraday cup which looks perpendicular to the spacecraft spin axis will be used to study the directional intensity of positive ions and electrons in the solar wind, transition region, and magnetotail. Electrons will be studied in eight logarithmically equal energy channels between 17 ev and 7 kev. Positive ions will be studied in eight channels between 50 ev and 7 kev. A spectrum will be obtained every eight spacecraft revolutions. Angular information will be obtained in either 15 equally spaced intervals during a 360° revolution of the satellite or more closely about the spacecraft sun line.

Energetic Particle Experiments

A5 Ion Chamber and GM Counters

K.A. Anderson University of California at Berkeley

The instrumentation for this experiment, designed to measure fluxes of geomagnetically trapped particles, consisted of a 3-in.-diameter Neher type ionization chamber and two Anton 223 Geiger-Mueller tubes. The ion chamber responded to electrons and protons with E > 1 and 17 Mev, respectively. Both GM tubes were mounted parallel to the spacecraft spin axis. GM tube A detected electrons with E > 45 kev scattered off a gold foil. The acceptance cone for these electrons had a 61° full angle, and its axis of symmetry made an angle of 59.5° with the spacecraft spin axis. GM tube A responded omnidirectionally to electrons and protons with E > 6 and 52 Mev, respectively. GM tube B had no direct access to the space environment and omnidirectionally responded to background electrons and protons with E > 6 and 52 Mev, respectively. Pulses from the ion chamber were accumulated for 326.08 sec and read out once every 327.68 sec. Counts from GM tube A were accumulated for 39.36 sec and read out six times every 327.68 sec. Counts from GM tube B were accumulated for 39.36 sec and read out five times every 327.68 sec. This experiment performed normally from launch through May 10, 1965.

A6 Scintillator and GM Telescopes

F.B. McDonald NASA/Goddard Space Flight Center

This experiment consisted of two detector systems. The first was a dE/dx vs E telescope with thin and thick CSI scintillators (one each) and an anticoincidence plastic scintillation counter. The telescope axis was normal to the spacecraft spin axis. Counts of particles penetrating the thin CsI scintillator and stopping in the thick CsI scintillator were accumulated during one 39.36-sec interval every 5.46 min. The relative contribution to the count rate of various species (electrons between 3 and 12 Mev, ions with charge = 1, 2, atomic mass ≐ 1, 2, 3, 4, and energy between 18.7 and 81.6 Mev/nucleon) and energy spectral information were determined by 512-channel pulse height analysis performed simultaneously on the output of both CsI scintillators six times every 5.46 min. The second detector system consisted of two Geiger-Mueller tube telescopes oriented parallel and perpendicular to the spacecraft spin axis. Each telescope consisted of two colinear GM tubes. The parallel and perpendicular telescopes measured the sum of counts due to protons with E > 70 Mev and electrons with E > 6.5 Mev and the sum of counts due to protons with E > 65 Mev and electrons with E > 6 Mev, respectively. Counts registered in any one of the four GM tubes were also accumulated. These omnidirectional counts were due to protons with E > 50 Mev plus electrons with E > 4 Mev. The parallel, perpendicular, and omnidirectional count rates were obtained for one 40-sec accumulation interval during successive normal 81.9-sec telemetry sequences. Thus, any one count rate was measured for 40 sec once each 5.46 min. Both detector systems worked well from launch until May 8, 1964.

A7 Solid-State Telescope

J.A. Simpson University of Chicago

A charged particle solid-state telescope was used to measure range and energy loss of galactic and solar cosmic rays. The experiment was designed to study particle energies (energy range is proportional to Z^2/A; for protons: 0.9 to 190 Mev, 6.5 to 190 Mev, 19 to 190 Mev, and 90 to 190 Mev) and charge spectra ($Z \leq 6$). The detector was oriented normal to the spacecraft spin axis. The detector accumulators for each energy interval were telemetered six times every 5.46 min. Each accumulation was about 40 sec long (initial spacecraft spin period was about 2 sec). The output from two 128-channel pulse height analyzers was obtained for one incident particle every 41 sec and read out along with the detector accumulations. From launch until October 15, 1964, a malfunction limited alpha studies to particles of $E > 30$ Mev. No useful information was received after October 15, 1964.

B5 Ion Chamber and GM Counters

K.A. Anderson University of California at Berkeley

This experiment, designed to measure fluxes of geomagnetically trapped particles, consisted of a 7.6-cm-diameter Neher type ionization chamber and two Anton 223 Geiger-Mueller tubes. The ion chamber responded to electrons and protons with $E > 1$ and 17 Mev, respectively. Both GM tubes were mounted parallel to the spacecraft spin axis. GM tube A detected electrons with $E > 45$ kev scattered off a gold foil. The acceptance cone for these electrons had a full angle of 61°, and its axis of symmetry made an angle of 59.5° with the spacecraft spin axis. GM tube A responded omnidirectionally to electrons and protons with $E > 6$ and 52 Mev, respectively. GM tube B looked directly into space through a hole in the spacecraft skin. The acceptance cone for GM tube B had a full angle of 38°, and its axis of symmetry was parallel to the spacecraft spin axis. Omnidirectionally, GM tube B responded to electrons and protons with $E > 6$ and 52 Mev, respectively. Directionally, GM tube B responded to electrons and protons with $E > 40$ and 500 kev, respectively. Pulses from the ion chamber were accumulated for 326.08 sec and read out once every 327.68 sec. Counts from GM tube A were accumulated for 39.36 sec and read out six times every 327.68 sec. Counts from GM tube B were accumulated for 39.36 sec and read out five times every 327.68 sec. This experiment performed normally from launch through October 13, 1965, the date of the last data transmission.

B6 Scintillator and GM Telescopes

F.B. McDonald NASA/Goddard Space Flight Center

This experiment consisted of two detector systems. The first was a dE/dx vs E telescope with thin and thick CsI scintillators (one each) and an anticoincidence plastic scintillation counter. The telescope axis was normal to the spacecraft spin axis. Counts of particles penetrating the thin CsI scintillator and stopping in the thick CsI scintillator were accumulated during one 39.36-sec interval every 5.46 min. The relative contribution to the count rate of various species (electrons between 3 and 12 Mev, ions with charge = 1, 2, atomic mass = 1, 2, 3, 4, and energy between 18.7 and 81.6 Mev/nucleon) and energy spectral infor-

mation were determined by 512-channel pulse height analysis performed simultaneously on the output of both CsI scintillators six times every 5.46 min. The second detector system consisted of two Geiger-Mueller tube telescopes oriented parallel and perpendicular to the spacecraft spin axis. Each telescope consisted of two colinear GM tubes. The parallel and perpendicular telescopes measured the sum of counts due to protons with E > 70 Mev and electrons with E > 65 Mev and the sum of counts due to protons with E > 65 Mev in electrons with E > 6 Mev, respectively. Counts registered in any one of the four GM tubes were also accumulated. These omnidirectional counts were due to protons with E > 50 Mev plus electrons with E > 4 Mev. The parallel, perpendicular, and omnidirectional count rates were obtained for one 40-sec accumulation interval during successive normal 81.9-sec telemetry sequences. Thus, any one count rate was measured for 40 sec once each 5.46 min. Both detector systems worked well from launch until March 2, 1965.

B7 Solid-State Telescope

J.A. Simpson University of Chicago

A charged particle solid-state telescope was used to measure range and energy loss of galactic and solar cosmic rays. The experiment was designed to study particle energies (energy range is proportional to Z^2/A; for protons: 0.9 to 190 Mev, 6.5 to 19 Mev, 19 to 90 Mev, and 90 to 190 Mev) and charge spectra ($Z \leq 6$). The detector was oriented normal to the spacecraft spin axis. The detector accumulators for each energy interval were telemetered six times every 5.46 min. Each accumulation was about 40 sec long (initial spacecraft spin period was about 4.1 sec). The output from two 128-channel pulse height analyzers was obtained for one incident particle every 41 sec and read out along with the detector accumulations. Useful data were obtained from launch until April 5, 1965. Data coverage was intermittent throughout the life of the spacecraft due to frequent spacecraft shutoffs and sporadic failure of some detectors.

C5 Ion Chamber and GM Counters

K.A. Anderson University of California at Berkeley

This experiment, designed to measure fluxes of geomagnetically trapped particles, consisted of a 7.6-cm-diameter Neher type ionization chamber and two Anton 223 Geiger-Mueller tubes. The ion chamber responded to electrons and protons with E > 1 and 17 Mev, respectively. Both GM tubes were mounted parallel to the spacecraft spin axis. GM tube A detected electrons with E > 45 kev scattered off a gold foil. The acceptance cone for these electrons had a full angle of 61°, and its spin axis of symmetry made an angle of 59.5° with the spacecraft spin axis. GM tube A responded omnidirectionally to electrons and protons with E > 6 and 52 Mev, respectively. GM tube B looked directly into space through a hole in the spacecraft skin. The acceptance cone for GM tube B had a full angle of 38°, and its axis of symmetry was parallel to the spacecraft spin axis. Omnidirectionally, GM tube B responded to electrons and protons with E > 6 and 52 Mev, respectively. Directionally, GM tube B responded to electrons and protons with E > 40 and 500 kev, respectively. Pulses from the ion chamber were accumulated for 326.08 sec and read out once every 327.68 sec. Counts

from GM tube A were accumulated for 39.36 sec and read out six times every 327.68 sec. Counts from GM tube B were accumulated for 39.36 sec and read out five times every 327.68 sec. This experiment performed normally from launch through May 11, 1967, the date of the last useful data transmission.

C6 Scintillator and GM Telescopes

F.B. McDonald NASA/Goddard Space Flight Center

This experiment consisted of two detector systems. The first was a dE/dx, E telescope with thin and thick CsI scintillators (one each) and an anticoincidence plastic scintillator counter. The telescope axis was normal to the spacecraft spin axis. Counts of particles penetrating the thin CsI scintillator and stopping in the thick CsI scintillator were accumulated during one 39.36-sec interval every 5.46 min. The relative contribution to the count rate of various species (electrons between 3 and 12 Mev, ions with charge = 1, 2, atomic mass = 1, 2, 3, 4, and energy between 18.7 and 81.6 Mev/nucleon) and energy spectral information were determined by 512-channel pulse height analysis performed simultaneously on the output of both CsI scintillators six times every 5.46 min. The second detector system consisted of two Geiger-Mueller tube telescopes oriented parallel and perpendicular to the spacecraft spin axis. Each telescope consisted of two colinear GM tubes. The parallel and perpendicular telescopes measured the sum of counts due to protons with E > 70 Mev and electrons with E > 6.5 Mev and the sum of counts due to protons with E > 65 Mev and electrons with E > 6 Mev, respectively. Counts registered in any one of the four GM tubes were also accumulated. These omnidirectional counts were due to protons with E > 50 Mev plus electrons with E > 4 Mev. The parallel, perpendicular, and omnidirectional count rates were obtained for one 40-sec accumulation interval during successive normal 81.9-sec telemetry sequences. Thus, any one count rate was measured for 40 sec once each 5.46 min. Both detector systems worked well from launch until May 11, 1967.

C7 Solid-State Telescope

J.A. Simpson University of Chicago

A charged particle solid-state telescope was used to measure range and energy loss of galactic and solar cosmic rays. The experiment was designed to study particle energies (energy range is proportional to Z^2/A; for protons: 0.9 to 190 Mev, 6.5 to 19 Mev, 19 to 90 Mev, and 90 to 190 Mev) and charge spectra ($Z \leq 6$). The detector was oriented normal to the spacecraft spin axis. The detector accumulators for each energy interval were telemetered six times every 5.46 min. Each accumulation was about 40 sec long (initial spacecraft spin period was about 3.3 sec). The output from two 128-channel pulse height analyzers was obtained for one incident particle every 41 sec and was read out along with the detector accumulations. The experiment performed normally until April 21, 1966, after which several problems with the instrumentation developed, causing spikes in the count rate data, especially in the lowest energy channel. The date of transmission of the last useful information was April 29, 1967.

D5 Ion Chamber and GM Counters

K.A. Anderson University of California at Berkeley

This experiment consisted of a 10.2-cm Neher type ionization chamber and two Geiger-Mueller tubes. The ion chamber responded omnidirectionally to electrons with E > 0.7 Mev and protons with E > 12 Mev. Both GM tubes were mounted perpendicular to the spacecraft spin axis. GM tube A detected electrons with E > 45 kev which were scattered off a gold foil. The acceptance cone for these electrons had a full angle of 61° and axis of symmetry which was perpendicular to the spacecraft spin axis. GM tube B responded to electrons and protons with E > 22 and 300 kev, respectively, in an acceptance cone of 45° full angle with axis of symmetry perpendicular to the spacecraft spin axis. Both GM tubes responded omnidirectionally to electrons and protons with E > 2.5 and 35 Mev, respectively. Pulses from the ion chamber and counts from each GM tube were accumulated for 39.72 sec and read out every 40.96 sec. In addition, the time between the first two ion chamber pulses in an accumulation period was telemetered. On August 1, 1967, GM tube B began to behave erratically and on August 9, 1967, it stopped counting. GM tube A stopped counting a few days later. The ion chamber operated normally from launch through September 2, 1966. Between September 2, 1966, and October 20, 1967, the date of last usable data, the ion chamber operated at a lower threshold voltage.

D6 Solid-State and GM Counters

J.A. Van Allen University of Iowa

Three EON type 6213 Geiger-Mueller tubes (GM1, GM2, and GM3) and a silicon solid-state detector (SSD) provided measurements of solar X rays (GM tubes only, between 2 and 12 A) and of solar, galactic, and magnetospheric charged particles. The GM tubes measured electrons of E > 45 to 50 kev and protons of E > 730 to 830 kev. The SSD output was discriminated at four thresholds: (1) pn1, which detected protons with $.31 \leq E \leq 10$ Mev and alphas with $.59 \leq E \leq 225$ Mev; (2) pn2, which detected protons with $.50 \leq E \leq 4$ Mev and alphas with $.78 \leq E \leq 98$ Mev; (3) pn3, which detected protons with $.82 \leq E \leq 1.9$ Mev and alphas with $1.13 \leq E \leq 46$ Mev; and (4) pn4, which detected alphas with $2.1 \leq E \leq 17$ Mev. GM1 and the SSD were oriented perpendicular to the spacecraft spin axis, GM2 was oriented parallel to the spin axis, and GM3 was oriented antiparallel to the spin axis. Data from GM1 and pn1 were divided into data from quadrants oriented with respect to the sun (sectors I, II, III, and IV centered 180°, 270°, 0°, and 90° from the sun, respectively). Data were read out in either 82- or 164-sec intervals. An intermittent, recognizable electronic failure occurred in the SSD starting about September 15, 1966. Accumulator failures occurred on July 21, 1967, and September 24, 1967. A limited amount of usable data was collected through the date of final spacecraft transmission (May 31, 1971).

E5 Ion Chamber and GM Counters

K.A. Anderson University of California at Berkeley

This experiment consisted of a 10.2-cm Neher type ionization chamber and two Geiger-Mueller tubes. The ion chamber responded omni-

directionally to electrons with E > 0.7 Mev and protons with E > 12 Mev. Both GM tubes were mounted parallel to the spacecraft spin axis. GM tube A detected electrons with E > 45 kev which were scattered off a gold foil. The acceptance cone for these electrons had a 70° full angle and axis of symmetry which was 20° off the spacecraft spin axis. GM tube B responded to electrons and protons with E > 22 and 300 kev respectively, in an acceptance cone of 70° full angle centered at the spacecraft spin axis. Both GM tubes responded omnidirectionally to electrons and protons of energies with E > 2.5 and 50 Mev, respectively. Pulses from the ion chamber and counts from each GM tube were accumulated for 39.72 sec and read out every 40.96 sec. In addition, the time between the first two ion chamber pulses in an accumulation period was telemetered. This experiment performed well initially. On November 20, 1968, the ion chamber failed. On May 9, 1969, GM tube B failed. GM tube A is still operating normally and returning usable information (February 22, 1971).

E6 Solid-State and GM Counters

J.A. Van Allen University of Iowa

Three EON type 6213 Geiger-Mueller tubes (GM1, GM2, and GM3) and a silicon solid-state detector (SSD) provided measurements of solar X rays (GM1 only, between 2 and 12 A) and charged particles in the vicinity of the moon. GM1 and GM3 measured electrons of E > 48 to 50 kev and protons of E > 740 to 820 kev, while GM2 was shielded by a cap approximately 1 g/cm^2 thick (limiting its response to protons of E ≥ 30 Mev). The SSD output was discriminated at four thresholds: (1) pn1, which detected protons with .32 ≤ E ≤ 6.3 Mev, (2) pn2, which detected protons with .48 ≤ E ≤ 3.0 Mev, (3) pn4, which detected alphas with 2 ≤ E ≤ 10.2 Mev, and (4) pn3, which was sensitive to particles of Z > 3, carbon 12 with .58 ≤ E ≤ 9.5 Mev/nucleon, nitrogen 14 with .514 ≤ E ≤ 13.9 Mev/nucleon, and oxygen 16 with .466 ≤ E ≤ 18.8 Mev/nucleon. GM1 the SSD were oriented perpendicular to the spacecraft spin axis, GM2 was oriented parallel to the spin axis, and GM3 was oriented antiparallel to the spin axis. Data from GM1, pn1, and pn4 were divided into data from quadrants oriented with respect to the sun (sectors I, II, III, and IV centered 180°, 270°, 0°, and 90° away from the sun, respectively). Data were read out every 82 or 164 sec, and the experiment performance was normal as of April 1971.

F4 Ion Chamber and GM Counters

K.A. Anderson University of California at Berkeley

The instrumentation for this experiment consisted of a 10.2-cm Neher type ionization chamber and two Geiger-Mueller tubes. The ion chamber responded omnidirectionally to electrons with E > 0.7 Mev and protons with E > 12 Mev. Both GM tubes were mounted parallel to the spacecraft spin axis. GM tube A detected electrons with E > 45 kev that were scattered off a gold foil. The acceptance cone for these electrons had a 70° full angle and an axis of symmetry that was 20° off the spacecraft spin axis. GM tube B responded to electrons and protons with E > 22 and 300 kev, respectively, in an acceptance cone of 70° full angle centered at the spin direction. Both GM tubes responded omnidirectionally to electrons and protons of E > 2.5 and 50 Mev, respectively. Pulses from the ion chamber

and counts from each GM tube were accumulated for 9.92 sec and read out every 10.24 sec. The time between the first two ion chamber pulses in an accumulation period was also telemetered. This experiment performed normally from launch through May 3, 1969, when IMP F reenter-the earth's atmosphere.

F5 Solar Proton Monitor

C.O. Bostrom — Johns Hopkins University/Applied Physics Laboratory

The solar proton monitoring experiment utilized four separate detectors, each of which used one or more solid-state sensors. Three detectors measured the omnidirectional fluxes of protons and alpha particles with energy per nucleon values above 10, 30, and 60 Mev. Alpha particle contributions to the total count rates were generally less than 10%. The 10-Mev channel was sampled for two 19.2-sec intervals every 163.8 sec, and the 30- and 60-Mev channels were sampled for one 19.2-sec interval every 163.8 sec. Resultant hourly averaged fluxes have been published in Solar-Geophysical Data (NOAA, Boulder) on a rapid basis. The fourth detector had a 60° full angle normal to the spacecraft spin axis. Each of two discrimination levels was sampled for two 19.2-sec intervals every 163.8 sec. Fluxes of 1- to 10-Mev protons were measured in the lower discrimination state, and fluxes of particles depositing more than 3.6 Mev were measured in the upper discrimination state. Data were obtained from the first three detectors between launch and May 3, 1969. Data from the fourth detector were obtained between launch and June 12, 1968.

F6 Low Energy Solid-State Telescope

W.L. Brown — Bell Telephone Laboratories

A four-element solid-state telescope with an acceptance cone half angle of 20° was mounted normal to the spacecraft spin axis. During each 2.73-min interval, 9.82-sec accumulations were obtained in each of 16 distinct counting modes. These modes involved protons in five energy intervals covering 0.6 to 18 Mev, alpha particles in four intervals covering 1.7 to 80 Mev, and electrons, deuterons, tritons, and helium-3 nuclei in the intervals 0.3 to 3, 5 to 20, 5.5 to 25, and 11 to 72 Mev, respectively. Onboard calibration checks were performed every 6 hr. The experiment performed normally from launch to the spacecraft reentry date, May 3, 1969.

F7 Low Energy Proton and Electron Differential Energy Analyzer

J.A. Van Allen — University of Iowa

This experiment was designed to measure low-energy electron and proton intensities separately inside the magnetosphere and in the interplanetary region. The detector system consisted of a curved plate, cylindrical, electrostatic analyzer (LEPEDEA - Low Energy Proton and Electron Differential Energy Analyzer) and Bendix continuous channel multiplier (Channeltron) array, and in addition, an Anton 213 GM tube

designed to survey the intensities of electrons with E > 40 kev in the outer magnetosphere. The electrostatic analyzer was capable of measuring the angular distributions and differential energy spectra of proton (25 ev to 47 kev) and electron (33 ev to 57 kev) intensities, separately, within 15 contiguous energy intervals. The analyzer accumulators were read out four times every 20.48 sec. Each accumulation was about 480 msec long (spacecraft spin period was initially 2.6 sec). A complete scan of the spectrum for four directions in a plane perpendicular to the spacecraft spin axis required 307.2 sec. For each energy interval, the detector response for four approximately 60° segments of the angular distribution were telemetered. The instruments performed normally from launch until the satellite decayed on May 3, 1969.

F8 Cosmic Ray Anisotropy

K.G. McCracken University of Texas at Dallas

The experiment was designed to study solar particle anisotropy and its variation with time. A telescope, consisting of three aligned detectors (A - solid state, B - plastic scintillator, C - CsI scintillator) and a plastic scintillator anticoincidence shield (D), was used to measure protons from 0.8 to 7.0 Mev (counts in A but not in B) and from 35 to 110 Mev (coincident counts in B (dE/dx) and C (total E) but not in D). Pulse height analysis yielded six-point spectra within each of these two energy intervals. In addition, a proportional counter provided directional measurements of X rays with E > 2 kev and electrons with E > 70 kev. Counts in each particle counting mode were obtained in each of eight sectors in the ecliptic plane. X-ray counts were obtained in the solar sector. A complete set of count rates and spectral data was obtained every 81.9 sec. The proportional counter and telescope worked well from launch until March 1968 and May 3, 1969 (spacecraft reentry date), respectively.

F9 GSFC Solid-State Telescope

F.B. McDonald NASA/Goddard Space Flight Center

This experiment used a dE/dx vs E telescope with one thin and two thick surface barrier solid-state detectors and an anticoincidence plastic scintillator counter. The two thick detectors acted together as one detector. The telescope axis was perpendicular to the spacecraft spin axis. Counts of particles penetrating the thin detector and stopping in a thick detector were accumulated for two 4.48-sec intervals every 2.73 min. The relative contributions to the count rate of protons and alpha particles with $4.2 \leq E \leq 19.1$ Mev/nucleon and energy spectral information were determined by 1024-channel pulse height analysis, which was performed simultaneously on the output of the solid-state detectors eight times every 2.73 min. Separation of counting rates into two modes (proton and alpha particle), distinguished by the amount of energy deposited in the thin detector, was not achieved as planned. Protons stopping in the thin detector (and particles penetrating it) were measured by passing the output signal through an eight-level energy threshold discriminator. The eight corresponding proton energies ran from 1.1 Mev to about 4 Mev. Data from any one level were transmitted once every 2.73 min. The anticoincidence scintillator failed in March 1968. This resulted in somewhat higher background count rates, which rendered isotopic (but not charge) sepa-

ration more difficult. Except as already noted, the experiment performed well from launch until May 3, 1969 (spacecraft reentry date).

F10 Scintillator Telescope

F.B. McDonald — NASA/Goddard Space Flight Center

This experiment used a dE/dx vs E telescope with thin and thick CsI scintillators (one each) and an anticoincidence plastic scintillation counter. The telescope axis was parallel to the spacecraft spin axis. Counts of particles penetrating the thin CsI scintillator and stopping in the thick CsI scintillator were accumulated for a 4.48-sec interval twice every 2.73 min. The relative contribution to the count rate of various species (electrons with $2.7 \leq E \leq 21.5$ Mev, nuclei with charge = 1, 2, atomic mass = 1, 2, 3, 4, and with $18.7 \leq E \leq 81.6$ Mev/nucleon) and energy spectral information were determined by 1024-channel pulse height analysis performed simultaneously on the output of both CsI scintillators 16 times every 2.73 min. Separation of counting rates into two modes (proton and alpha particle) distinguished by the amount of energy deposited in the thin detector was not achieved as planned. Counts of electrons with $0.3 \leq E \leq 0.9$ Mev stopping in the thin scintillator were also obtained once each 2.73 min. Except as noted above, the experiment performed well from launch to May 3, 1967 (spacecraft reentry date).

F11 Chicago Solid-State Telescope

J.A. Simpson — University of Chicago

The experiment was designed to measure separately the contributions of solar nuclei and of galactic nuclei ($Z \leq 14$) using a solid-state cosmic-ray telescope designed for energy loss vs range or total energy measurements. The particle energy range was proportional to Z^2/A; for protons: 0.8 to 9.6 Mev, 9.6 to 18.8 Mev, 29.5 to 94.2 Mev, and 94.2 to 170 Mev and above. The detector viewing angle was perpendicular to the satellite spin axis. A second, smaller, solid-state telescope mounted parallel to the spacecraft spin axis was used to direct electrons in the range 80 to 130 kev and 175 to 390 kev. The electron detector was designed to provide information concerning the shape and intensity of the magnetospheric electon spectra. The detector accumulators for each energy interval were telemetered four times every 20.48 sec. Each accumulation was 4.8 sec long (spacecraft initial spin period was about 2.6 sec). The output from three 256-channel nuclear particle telescope pulse height analyzers was obtained for one incident particle every 5.12 sec and was telemetered along with the detector accumulators. Except for the failure of the electron detector 6 days after launch, the experiment performed normally until the satellite decayed on May 3, 1969.

G3 Channeltron

R.P. Lin — University of California at Berkeley

The instrumentation for this experiment consisted of a parallel plate electric-field analyzer and two funnel-shaped channel multipliers. The parallel plate analyzer was used as a discriminatory device. One

of the channel multipliers responded to electrons with $2.5 \leq E \leq 7.5$ kev, and the other responded to electrons with $7.5 \leq E \leq 12.5$ kev. The acceptance cones for the channel multipliers had full angles of approximately 30° with axes of symmetry 60° off the spacecraft spin axis. Due to high background count rates, only data of low quality were obtained. On December 2, 1969, the experiment was turned off.

G4 Ion Chamber and GM Tubes

K.A. Anderson University of California at Berkeley

The instrumentation for this experiment consisted of a 10.2-cm Nether type ionization chamber and three pairs of Geiger-Mueller tubes, the members of which were perpendicular and parallel to the spacecraft spin axis. The ion chamber responded omnidirectionally to electrons and protons with $E > 1$ and 15 Mev, respectively. The members of one pair of GM tubes had 45° acceptance cones and responded to electrons with $E > 80$ kev and protons with $E > 1.5$ Mev. The members of another pair also had 45° acceptance cones and measured electrons with $E > 20$ kev (parallel) or 160 kev (perpendicular) and protons with $E > 400$ kev. The members of the third pair with 60° acceptance cones responded to electrons with $E > 40$ kev scattered off a gold foil. The axes of these acceptance cones were 0° and 90° with respect to the spacecraft spin axis. Omnidirectionally, all of the GM tubes responded to electrons with $E > 3$ Mev and protons with $E > 30$ Mev. Pulses from the ion chamber and counts from each of the GM tubes were accumulated for 9.92 sec and read out four times each 40.96 sec. In addition, the time between the first two ion chamber pulses in an accumulation period was also telemetered. This experiment has performed normally from launch to the present (March 1971) except for the ionization chambers, which intermittently stopped.

G5 Solar Proton Monitor

C.O. Bostrom Johns Hopkins University/Applied Physics Laboratory

The solar proton monitoring experiment utilized four separate detectors, each of which used one or more solid-state sensors. Three detectors measured the omnidirectional fluxes of protons and alpha particles with energy per nucleon values with $E > 10$, 30, and 60 Mev. Alpha particle contributions to the total count rates were generally less than 10%. The 10-Mev channel was sampled for two 19.2-sec intervals every 163.8 sec, and the 30- and 60-Mev channels for one 19.2-sec interval every 163.8 sec. Resultant hourly averaged fluxes are published in Solar-Geophysical Data (NOAA, Boulder) on a rapid basis. The fourth detector had a 60° full look angle normal to the spacecraft spin axis. Each of two discrimination levels was sampled for two 19.2-sec intervals every 163.8 sec. Fluxes of 1- to 10-Mev protons were measured in the lower discrimination state, and fluxes of particles depositing more than 3.6 Mev were measured in the upper discrimination state. All detectors have functioned normally from launch to the present (April 1971).

G6 Low Energy Solid-State Telescope

W.L. Brown Bell Telephone Laboratories

A four-element solid-state telescope with an acceptance cone half angle of 20° was mounted normal to the spacecraft spin axis. During each 2.73-min interval, 9.82-sec accumulations were obtained in each of 16 distinct counting modes. These modes involved protons in five energy intervals covering 0.6 to 18 Mev, alpha particles in four intervals covering 1.7 to 80 Mev, and electrons, deuterons, tritons, and helium-3 nuclei in the intervals 0.3 to 3, 5 to 20, 5.5 to 25, and 11 to 72 Mev, respectively. Onboard calibration checks were performed every 6 hr. The experiment performed normally until January 30, 1970, when a GSFC power supply failure limited useful data gathered to low energy protons, electrons, and alphas. Information on these particles is not available after that date. The instrument is still about 30% operational (April 1971).

G7 Low Energy Proton and Electron Differential Energy Analyzer

J.A. Van Allen University of Iowa

This experiment, which was similar to the University of Iowa experiment on IMP F, was designed to separately measure low-energy electron and proton intensities inside the magnetosphere and in the interplanetary region. The detector system consisted of a curved plate, cylindrical, electrostatic analyzer (LEPEDEA detector) and Bendix continuous channel multiplier (Channeltron) array, and an Anton 213 GM tube designed to survey the intensities of electrons with E > 40 kev in the outer magnetosphere. The electrostatic analyzer was capable of measuring the angular distributions and differential energy spectra of proton and electron intensities, separately, within 15 contiguous energy intervals over the energy ranges 25 ev to 47 kev and 33 ev to 57 kev. The analyzer accumulators were read out four times every 20.48 sec. Each accumulation was about 480 msec long (spacecraft spin period was initially 2.6 sec). A complete scan of the spectrum for four directions in a plane perpendicular to the spacecraft spin axis required 307.2 sec. For each energy interval, the detector response for four approximately 60° segments of the angular distribution was telemetered. The instruments were performing normally as of March 1971.

G8 Low Energy Proton Differential Energy Analyzer

L.A. Frank University of Iowa

This experiment was designed to observe positive ion intensities in the solar wind, within the magnetosheath, and in the geomagnetic tail using a modified low energy proton and electron differential energy analyzer (LEPEDEA detector). The detector, which was composed of curved plate electrostatic analyzers and continuous channel multipliers (channeltrons), was designed to measure differential energy spectra and angular distributions of low energy positive ions over the energy range 90 ev to 12 kev. The detector was an analog device and, therefore, was read continuously during the flight. Energy measurements were obtained within 32 individual energy intervals over the proposed range and at 16 sun-referenced azimuthal directions perpendicular to

the spacecraft spin axis for each energy interval. The experiment performed normally for about two and one half months from launch when the experiment power supply failed.

G9 Cosmic Ray Anisotropy

K.G. McCracken University of Texas at Dallas

This experiment was designed to study solar particle anisotropy and its variations with time. A telescope, consisting of three aligned detectors (A - solid state, B - plastic scintillator, C - CsI scintillator) and a plastic scintillator anticoincidence shield (D), was used to measure protons from 0.8 to 7.0 Mev (counts in A but not in B) and from 35 to 110 Mev (coincident counts in B (dE/dx) and C (total E) but not in D). Pulse height analysis yielded six-point spectra within each of these two energy intervals. In addition, a proportional counter provided directional measurements of X rays with E > 2 kev and electrons with E > 70 kev. Counts in each particle counting mode were obtained in each of eight sectors in the ecliptic plane. X-ray counts were obtained in the solar sector. A complete set of count rates and spectral data was obtained every 81.9 sec. The experiment was functioning normally as of March 1971.

G10 Solid-State Detectors

F.B. McDonald NASA/Goddard Space Flight Center

This experiment used a dE/dx vs E telescope with one thin and two thick surface barrier solid-state detectors and an anticoincidence plastic scintillator counter. The two thick detectors acted together as one detector. The telescope axis was perpendicular to the spacecraft spin axis. Counts of particles penetrating the thin detector and stopping in a thick detector were accumulated for a 4.48-sec interval once each 2.73 min for each of two counting modes. (Counting modes are defined with respect to the energy deposited in the thin dE/dx detector. Good separation of protons and alpha particles was achieved by this mode distinction.) The relative contribution of each count rate of protons and alpha particles with $4.2 \leq E \leq 19.1$ Mev/nucleon and energy spectral information were determined by 1024-channel pulse height analysis performed simultaneously on the output of the solid-state detectors four times every 2.73 min for each of the two threshold modes. Protons stopping in the thin detector (and particles penetrating it) were measured by passing the output signal through an eight-level energy threshold discriminator. The eight corresponding proton energies ran from 0.6 Mev to about 4 Mev. Data from any one level were transmitted once every 2.73 min. There were also two solid-state detectors that looked along the spacecraft spin axis and that were identical except for differing covering foil thicknesses. Both responded to electrons in the 80- to 200-kev range. One responded to protons with 83 kev $\leq E \leq$ 2 Mev and the other to protons with 200 kev $\leq E \leq$ 2 Mev. Spectral information was gathered by subjecting the output signals from each detector to eight-level energy threshold discrimination. Data from each of the eight levels and each of the two detectors were transmitted once each 5.46 min. Except for a 2-week period in March 1970 when the telescope data were noisy, all the detectors have functioned normally from launch to the present (March 1971).

G11 Scintillator Telescope

F.B. McDonald NASA/Goddard Space Flight Center

This experiment used a dE/dx vs E telescope with thin and thick CsI scintillators (one each) and an anticoincidence plastic scintillation counter. The telescope axis was parallel to the spacecraft spin axis. Counts of particles penetrating the thin CsI scintillator and stopping in the thick CsI scintillator were accumulated for two 4.48-sec intervals each 2.73 min. The relative contribution to the count rate of various species (electrons with $2.7 \leq E \leq 21.5$ Mev, nuclei with charge = 1 and 2, atomic mass = 1, 2, 3, and 4, and with $18.7 \leq E \leq 81.6$ Mev/nucleon) and energy spectral information were determined by 1024-channel pulse height analysis performed simultaneously on the output of both CsI scintillators 16 times every 2.73 min. In addition, counts of electrons with $0.3 \leq E \leq 0.9$ Mev stopping in the thin scintillator were also obtained once each 2.73 min. The experiment was functioning normally as of March 1971.

G12 Solid-State Telescope

J.A. Simpson University of Chicago

This experiment was designed to measure separately the contributions of solar nuclei and of galactic nuclei ($Z \leq 14$) using a combination solid-state and Cerenkov counter cosmic-ray telescope detector. The detector was designed for energy loss vs range or total energy measurements for protons (differential measurements between 0.8 to 119 Mev and an integral measurement between 119 Mev and 1 Bev). Similar differential energy measurements of HE and higher Z nuclei were made between 3 Mev/nucleon and 1 Bev/nucleon. The detector was oriented perpendicular to the satellite spin axis. The detector accumulators were telemetered four times every 20.48 sec. Each accumulation was 4.8 sec long (spacecraft initial spin period was about 2.2 sec). The output from the three 256-channel pulse height analyzers was obtained for one incident particle every 5.12 sec and was telemetered along with the detector accumulators. The experiment was functioning normally as of March 1971.

I6 Solid-State and GM Detectors

K.A. Anderson University of California at Berkeley

This experiment, which was designed to study the acceleration of electrons at the sun and their ejection into interplanetary space, consisted of four detectors. Two of these were GM tubes with viewing directions anti-parallel to the spacecraft spin axis. Data from each GM tube were accumulated for one spin period and were read out once every 20.48 sec. One tube responded to electrons with $E > 15$ kev that were backscattered off a gold foil. The other GM tube directly observed electrons and protons with $E > 15$ and 150 kev, respectively. The third detector was a telescope consisting of three semiconductors that had a viewing direction of 165° with respect to the spacecraft spin axis. This detector responded to electrons and protons in the energy intervals 20 to 400 kev and 0.2 to 2 Mev, respectively. Data from this detector were accumulated for one spin period and were read out once each 20.48

sec. The last detector consisted of two semiconductors with a viewing direction perpendicular to the spacecraft spin axis. This detector responded to electrons with $40 \leq E \leq 200$ kev that were backscattered off a gold foil. Data from each of 16 sectors were accumulated for 1/16 of a spin period and telemetered once each 20.48 sec. Initial experiment performance was normal.

I7 Solar Proton Monitor

C.O. Bostrom — Johns Hopkins University/Applied Physics Laboratory

The solar proton monitoring experiment consisted of five separate detectors, each using one or more solid-state detector elements. Three detectors, each with a 2π ster field of view and a 20.48-sec accumulation time, measured protons with $E > 10$, 30, and 60 Mev. Resultant hourly averaged fluxes will be published on a rapid basis in Solar-Geophysical Data. The fourth detector measured directional fluxes of protons in three energy intervals between 0.21 Mev and 7.5 Mev. The fifth detector measured directional fluxes of electrons with $E > 10$ kev. For the last two detectors, counts were obtained in 45° sectors as the spacecraft spun. Onboard calibration capability for the first four detectors was included. Initial experiment performance was normal.

I8 Crystal Scintillator

T.L. Cline — NASA/Goddard Space Flight Center

This experiment was designed to study galactic and solar electrons and positrons in the kinetic energy range 50 kev to 2 Mev. Information on protons with $0.5 \leq E \leq 4.0$ Mev was also obtained. A collimated Stilbene crystal scintillator looking perpendicular to the spacecraft spin axis was the principal detector. A similar, fully shielded crystal served to determine the contribution to the principal detector count rate of electrons and protons generated within the principal detector by gamma rays and neutrons, respectively. A fully shielded CsI crystal served as a gamma-ray spectrometer and was used in coincidence with the principal detector to distinguish electrons from positrons. Count rates from each detector obtained in eight angular sectors per revolution were telemetered. In addition, the amplitude and shape of the pulse generated in the principal detector by the first stopping particle in each appropriate telemetry frame were studied. Pulse amplitude and shape yielded energy (10% resolution) and particle species information. Initial experiment performance was normal.

I9 Low Energy Proton and Electron Differential Energy Analyzer

L.A. Frank — University of Iowa

This experiment was designed to conduct comprehensive observations of the differential energy spectra; the angular distribution, and spatial distributions and temporal variations of electrons and protons over the geocentric radial distance range 1.03 to 30 R_E. Two arrays of curved-plate cylindrical electrostatic analyzers and continuous channel multipliers were used for this purpose. One analyzer, the LEPEDEA (Low

Energy Proton and Electron Differential Energy Analyzer), was included to measure protons and electrons separately in the energy range 24 ev to 50 kev (16 energy intervals). The other analyzer LEPDEA (Low Energy Proton Differential Energy Analyzer) was included to measure the energy spectra and angular distributions of protons in the energy range 1.7 ev to 550 ev (eight energy intervals). An EON type 213 GM counter, whose collimated field of view of 15° half angle was oriented approximately parallel to that of the LEPEDEA, was used to measure the intensity of electrons with E > 45 kev and protons with E > 500 kev and to provide background measurements for the LEPEDEA. Initial experiment performance was normal.

I10 Solid-State and Scintillator Telescopes

F.B. McDonald NASA/Goddard Space Flight Center

The GSFC cosmic-ray experiment was designed to measure energy spectra, composition, and angular distributions of solar and galactic electrons, protons, and heavier nuclei up to Z = 30. Three distinct detector systems were used. The first system consisted of four essentially identical solid-state telescopes. Two were perpendicular and two were parallel to the spacecraft spin axis. Because the telescopes differed in their absorbing thickness, some discrimination between electrons and protons was possible. Each detector responded to particles between 50 kev and 2 Mev. A seven-level integral analyzer was included for spectral information. The second detector system was a solid-state dE/dx vs E telescope that looked perpendicular to the spin axis. This telescope measured Z = 1 to 16 nuclei with $4 \leq E \leq 20$ Mev/nucleon. Counts of particles in the 0.5 to 4 Mev/nucleon range, with no charge resolution, were obtained as counts in the dE/dx, but not in the E sensor. The third detector system was a three-element CsI scintillator telescope whose axis made an angle of 39° with respect to the spin axis. The instrument responded to electrons with $2 \leq E \leq 12$ Mev and to Z = 1 to 30 nuclei in the energy range 20 to 500 Mev/nucleon. For particles below 80 Mev this instrument acted as a dE/dx detector. Above 80 Mev, it acted as a bidirectional triple dE/dx detector. By use of a combination of pulse height analysis and gain switching, the output of each sensor of the second and third detector systems was sorted into one of 1000 and 1200 energy channels, respectively. Flux directionality information was obtained by dividing certain portions of the data from each detector into eight angular sectors. Initial experiment performance was normal.

I11 Solid-State Telescopes

J.A. Simpson University of Chicago

This experiment was designed to measure the energy spectra of nuclei over a wide dynamic range of fluxes (at least 100,000). Emphasis has been placed on high charge resolution extending from Z = 1 to Z = 30, and high isotopic resolution for H, He, and Li. The experiment was also designed to measure electrons with E > 2 Mev. The instrumentation included two particle telescopes (a composition telescope and a low energy telescope) protected by anticoincidence shields, an electron current detector, and a fission cell. The composition telescope was composed of four solid-state detectors and a Cerenkov counter, and the low energy telescope was composed of five solid-state and two

scintillation detectors. Both telescopes were to be calibrated periodically in flight by programmed pulse generators. The output of sensors D1, D4, and the Cerenkov counter of the composition telescope were pulse height analyzed by three 512-channel pulse height analyzers, and the output of D2 was analyzed by a 1024-channel pulse height analyzer. Use of the various count rate modes provided a differential energy spectrum (three intervals) of nuclei up to about Z = 30 in the energy range from 0.5 to 1200 Mev/nucleon. The Cerenkov counter allowed measurement of nuclei from 1.2 to about 2 Bev/nucleon before saturating. Similarly, the outputs of sensors D1, D2, and D5 of the low energy telescope were pulse height analyzed using two 256-channel analyzers. Sensors D1 and D5 shared one analyzer; i.e., when an event had sufficient energy to trigger D5, then the analyzer was automatically switched from D1 to D5. The differential energy spectrum (two intervals) of nuclei up to about Z = 30 was obtained from about 0.5 to about 800 Mev/nucleon. The electron current detector (ECD) and the fission cell carried out measurements in the earth's radiation belts. The ECD detected extremely high intensities (> 1,000,000 particles/cm sq-sec) of electrons with E > 2 Mev by measuring the current generated in a solid-state detector by the ionization loss of large numbers of electrons. The fission cell was designed to detect proton fluxes (E > 50 Mev) by sandwiching a thin foil of Th232 between two solid-state detectors which responded only to large pulses left by slow moving fragments from proton induced fission of the thorium. The composition telescope failed within a day after launch, but the performance of the other experiment systems has been normal.

H6 Crystal Scintillator

T.L. Cline NASA/Goddard Space Flight Center

This experiment is designed to study galactic and solar electrons and positrons in the kinetic energy range 50 kev to 2 Mev. Information on protons between 0.5 and 4.0 Mev will also be obtained. A collimated Stilbene crystal scintillator looking perpendicular to the spacecraft spin axis is the principal detector. A similar, fully shielded crystal will serve to determine the contribution to the principal detector count rate of electrons and protons generated within the principal detector by gamma rays and neutrons, respectively. A fully shielded CsI crystal will serve as a gamma-ray spectrometer and will be used in coincidence with the principal detector to distinguish electrons from positrons. Count rates from each detector obtained in eight angular sectors per revolution will be telemetered. In addition, the amplitude and shape of the pulse generated in the principal detector by the first stopping particle in each appropriate telemetry frame will be studied. Pulse amplitude and shape will yield energy (10% resolution) and particle species information.

H7 Low Energy Proton and Electron Differential Energy Analyzer

L.A. Frank University of Iowa

This experiment is designed to measure the energy spectra of low energy electrons and protons in the geocentric range 30 to 40 R_E in order to further understand geomagnetic storms, aurora, tail and neutral sheet, and other magnetospheric phenomena. The detector is a dual-channel curved plate electrostatic analyzer (LEPEDEA- Low

Energy Proton and Electron Differential Energy Analyzer) with 16 energy intervals between 5 ev and 50 kev. It has an angular field of view of 9° x 25°. The detector may be operated in one of two modes, (1) one providing good angular resolution (16 directions for each particle energy band) once each 272 sec and (2) one providing good temporal resolution in which the entire energy range in four directions is measured every 68 sec.

H8 University of Maryland Solid-State Detectors

G. Gloeckler University of Maryland

This experiment is to determine the composition and energy spectra of low energy particles observed during solar flares and 27-day recurrent events. The detectors to be used are (1) an electrostatic analyzer (to select particles of the desired energy/charge) combined with an array of windowless solid-state detectors (to measure the energy loss) and surrounded by an anticoincidence shielding and (2) a two-element solid-state particle telescope. The experiment is to measure particles with energies from 0.1 to 2 Mev/charge in 12 bands and to uniquely identify positrons, electrons, and nuclei with Z between 1 and 8 (no charge resolution for Z greater than 8). Two 1000-channel pulse height analyzers are included in the experiment, one for each detector system.

H9 Solid-State and GM Detectors

S.M. Krimigis Johns Hopkins University/Applied Physics Laboratory

Three solid-state detectors in an anticoincidence plastic scintillator will observe electrons between 0.2 and 2.5 Mev, protons between 0.3 and 500 Mev, alpha particles between 2.0 and 200 Mev, heavy particles with Z values ranging from 2 to 5 with E > 8 Mev, heavy particles with Z values ranging between 6 and 8 E > 32 Mev, and integral protons and alphas of E > 50 Mev/nucleon, all with dynamic ranges of 1 to one million (per square cm-sec-ster). Five thin window Geiger-Mueller tubes will observe electrons of E > 15 kev, protons of E > 250 kev, and X rays with wavelengths between 2 and 10 A, all with a dynamic range of 10 to 100 million (per square cm-sec-ster). Particles and X rays primarily of solar origin will be studied, but the dynamic range and resolution of the instrument permit cosmic rays and magnetotail particles to be observed as well.

H10 Solid-State and Scintillator Telescopes

F.B. McDonald NASA/Goddard Space Flight Center

The GSFC cosmic-ray experiment is designed to measure energy spectra, composition, and angular distributions of solar and galactic electrons, protons, and heavier nuclei up to Z = 30. Three distinct detector systems will be used. The first system consists of a pair of solid-state telescopes which measure integral fluxes of electrons above 150, 350, and 700 kev and of protons above .05, .15, .50, .70, 1.0, 1.2, 2.0, 2.5, 5.0, 15, and 25 Mev. Except for the .05 Mev proton mode, all

counting modes have unique species identification. The second detector system is a solid-state dE/dx vs E telescope that looks perpendicular to the spin axis. This telescope measures Z = 1 to 16 nuclei with energies between 4 and 20 Mev/nucleon. Counts of particles in the 0.5 to 4 Mev/nucleon range, with no charge resolution, will be obtained as counts in the dE/dx, but not in the E sensor. The third detector system is a three-element CsI scintillator telescope whose axis makes an angle of 39° with respect to the spin axis. The instrument will respond to electrons between 2 and 12 Mev and to Z = 1 to 30 nuclei in the energy range 20 to 500 Mev/nucleon. For particles below 80 Mev this instrument acts as a dE/dx detector. Above 80 Mev, it acts as a bidirectional triple dE/dx detector. Flux directionability information will be obtained by dividing certain portions of the data from each detector system into eight angular sectors.

H11 Chicago Solid-State Telescopes

J.A. Simpson — University of Chicago

The experiment is designed to increase the understanding of solar flare particle acceleration and particle containment in magnetic fields in the vicinity of the sun. The detector is to point along the spacecraft spin axis. It is a windowless dE/dx vs E telescope with anticoincidence shielding and can be operated in either of two modes: (1) high Z - low E mode having an energy range from 0.5 to 50 Mev/nucleon and a charge range Z from 5 to 50 and (2) low Z mode having an energy range 6 to 1200 Mev/nucleon (isotopes - hydrogen, deuterium, tritium, helium-3, helium-4). The energy range for electrons is primarily 0.3 to 10 Mev. The acceptance angle of the detector is to be 50° full angle.

H12 C.I.T. Solid-State Telescope

E.C. Stone — California Institute of Technology

This experiment is to study (via differential energy spectra) local acceleration of particles, acceleration processes of solar particles, storage in the interplanetary medium, and solar modulation of particles in the interplanetary medium. The detector to be used is a multi-element, totally depleted solid-state telescope with anticoincidence shielding and is to be operated in any of three modes: (1) the energy range mode, (2) the electron mode (150 kev to 2.8 Mev), and (3) the hydrogen and helium isotopes mode (0.5 to 40 Mev/nucleon). The detector has an angular resolution of ±22°.

H13 NOAA Solid-State Detectors

D.J. Williams — NOAA/Space Environment Laboratory

This experiment will consist of a three-element telescope configuration employing solid-state detectors and a magnetic field to deflect electrons. Two side-mounted detectors will be used to detect the electrons deflected by the magnet. Two additional solid-state detectors will be used to detect very low energy (>15 kev) particles, alpha particles, and Z > 2 charged particles. This experiment is

designed to measure proton fluxes from 30 kev to 8.6 Mev in six ranges, electron fluxes from 30 kev to >450 kev in three ranges, charged particles with E > 15 kev, alpha particles with E > 0.5 Mev, > 1.6 Mev, 2.2 to 8.8 Mev, 8.8 to 35 Mev, and Z > 2 charged particles at E > 5 Mev.

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L.A. Frank — University of Iowa

This experiment is designed to measure the energy spectra of low energy electrons and protons in the geocentric range 30 to 40 R_E in order to further understand geomagnetic storms, aurora, tail and neutral sheet, and other magnetospheric phenomena. The detector is a dual-channel curved plate electrostatic analyzer (LEPEDEA - Low Energy Proton and Electron Differential Energy Analyzer) with 16 energy intervals between 5 ev and 50 kev. It has an angular field of view of 9° x 25°. The detector may be operated in one of two modes: (1) one providing good angular resolution (16 directions for each particle energy band) once each 272 sec, and (2) one providing good temporal resolution in which the entire energy range in four directions is measured every 68 sec.

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This experiment is designed to determine the composition and energy spectra of low energy particles observed during solar flares and 27-day recurrent events. The detectors to be used are (1) an electrostatic analyzer (to select particles of the desired energy/charge) combined with an array of windowless solid-state detectors (to measure the energy loss) and surrounded by an anticoincidence shielding and (2) a two element solid-state particle telescope. The experiment is to measure particles with energies from 0.1 to 2 Mev/charge in 12 bands and to uniquely identify positrons, electrons, and nuclei with Z between 1 and 8 (no charge resolution above Z = 8). Two 1000-channel pulse height analyzers are included in the experiment, one for each detector system.

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J9 Solid-State and Scintillator Telescopes

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The GSFC cosmic-ray experiment is designed to measure energy spectra, composition, and angular distributions of solar and galactic electrons, protons, and heavier nuclei up to Z = 30. Three distinct detector systems are to be used. The first system will consist of a pair of solid-state telescopes which measure integral fluxes of electrons above 150, 350, and 700 kev and of protons above .05, .15, .50, .70, 1.0, 1.2, 2.0, 2.5, 5.0, 15, and 25 Mev. Except for the .05 Mev proton mode, all counting modes will have unique species identification. The second detector system is a solid-state dE/dx vs E telescope that looks perpendicular to the spin axis. This telescope measures Z = 1 to 16 nuclei with energies between 4 and 20 Mev/nucleon. Counts of particles in the 0.5 to 4 Mev/nucleon range, with no charge resolution, will be obtained as counts in the dE/dx but not in the E sensor. The third detector system is a three-element telescope whose axis makes an angle of 39° with respect to the spin axis. The middle element is a CsI scintillator while the other two elements are solid-state sensors. The instrument will respond to electrons between 2 and 12 Mev and to Z = 1 to 30 nuclei in the energy range 20 to 500 Mev/nucleon. For particles below 80 Mev, this instrument well act as a dE/dx detector. Above 80 Mev, it will act as a bidirectional triple dE/dx detector. Flux directionability information will be obtained by dividing certain portions of the data from each detector into eight angular sectors.

J10 Chicago Solid-State Telescopes

J.A. Simpson University of Chicago

This experiment is designed to increase the understanding of solar flare particle acceleration and particle containment in magnetic fields in the vicinity of the sun. The detector is to point along the spacecraft spin axis. It is a windowless dE/dx vs E telescope with anticoincidence shielding and can be operated in either of two modes: (1) high Z - low E mode having an energy range from 0.5 to 50 Mev/nucleon and a charge range Z from 5 to 50 and (2) low Z mode having an energy range 6 to 1200 Mev/nucleon (isotopes: hydrogen, deuterium, tritium, helium-3, helium-4). The energy range for electrons is primarily 0.3 to 10 Mev. The acceptance angle of the detector is to be 50° full angle.

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This experiment consists of a three-element telescope configuration employing solid-state detectors and a magnetic field to deflect electrons. Two side-mounted detectors will be used to detect the electrons deflected by the magnet. Two additional solid-state detectors will be used to detect very low energy (> 15 kev) particles, alpha particles, and Z > 2 charged particles. This experiment is designed to measure proton fluxes from 30 kev to > 8.6 Mev in 6 ranges, electron fluxes from 30 kev to > 450 kev in 3 ranges, charged particles > 15 kev, alpha particles > 0.5 Mev, > 1.6 Mev, 2.2 to 8.8 Mev, 8.8 to 35 Mev, and Z > 2 charged particles at E > 5 Mev.

Other Experiments

D7 Selenodetic Studies

W.M. Kaula — University of California at Los Angeles

Range and range-rate tracking data was to be used to obtain selenodetic information. However, because IMP D did not achieve lunar orbit, the experiment could not be performed.

E8 Selenodetic Studies

W.M. Kaula — University of California at Los Angeles

Range and range-rate tracking data have been used to obtain selenodetic information.

D8 Cislunar RF Beacon

A.M. Peterson — Stanford University

The purpose of this experiment was to study the electromagnetic reflective properties of the lunar surface. However, because IMP D did not achieve lunar orbit, the experiment could not be performed.

E9 Cislunar RF Beacon

A.M. Peterson Stanford University

The purpose of this experiment was to study the electromagnetic reflective properties of the lunar surface. The 136.10-Hz (2.2 m) telemetry transmissions from the spacecraft were scattered from the lunar surface and then recorded by use of the 150-ft Stanford dish antenna. The reflected signal intensity depended upon the lunar reflectivity, the spacecraft altitude above the lunar surface, and the mean curvature of the moon. The returned signal bandwidth was proportional to RMS lunar surface slopes. Occultation phenomena permitted a determination of the scattering properties of the lunar limb. The dielectric constant of the lunar subsurface in the scattering region below a depth of about 25 cm was then determined from a profile of reflectivity values vs the angle of incidence on the moon. The mean lunar slope over each area from which signals were reflected has also been inferred. The observations were located within about 10° of the lunar equator. Experiment operation was normal as of March 1971.

E7 Micrometeorite Flux

J.L. Bohn Temple University

This experiment was designed to measure the ionization, momentum, speed, and direction of micrometeorites, using thin film charged detectors, induction devices, and microphones. The experiment continues to operate normally (March 1971).

I12 Radio Astronomy Experiment*

W.C. Erickson University of Maryland
F.T. Haddock University of Michigan

The objective of this experiment was to study the spectra of the galaxy, the sun, and Jupiter with high flux resolution (about 1%). A radiometer, operating in either a stepping mode (eight frequencies) or at a single frequency, was connected to a 91-m dipole antenna (also used in the electric field experiments). The frequency range covered was 0.05 to 3.5 MHz. Initial experiment performance was normal.

W.C. Erickson University of Maryland
R.G. Stone NASA/Goddard Space Flight Center

This experiment was designed to study the radio spectra of the galaxy, the sun, and Jupiter with relatively high time resolution. Two stepped-frequency radiometers, attached to a single 91-m dipole antenna (also used in the electric field experiments), stepped through the frequency range of 30 kHz to 2 MHz in 32 steps. Initial experiment performance was normal.

*This experiment operates in two modes. Data from these modes will be studied by two separate investigator groups. Therefore, two brief descriptions are presented.

Bibliography and Abstracts for Experiment-Related Papers

In the following pages, the publications, with abstracts where available, which have resulted from studies of the data from the experiments flown on IMPs A through G are listed. The experiments that have related scientific publications are sequenced as in Table 5. For a given experiment, the brief description previously given is repeated before the actual listing of publications. Each publication is then alphabetized by author within one of the following five categories.

- Major paper authored or co-authored by the principal investigator or by a member of his group and published in one of the principal space science archival journals.
- Paper authored or co-authored by the principal investigator or by a member of his group, presented at a scientific conference, and found in the published proceedings of that conference.
- Any other papers authored or co-authored by the principal investigator or his group.
- Paper not authored or co-authored by the principal investigator or anyone in his group but published in one of the principal space science archival journals.
- Other publications of note that are not described by the above categories.

Magnetic Field Experiments

A1 Magnetometer

N.F. Ness NASA/Goddard Space Flight Center

Each of two uniaxial fluxgate magnetometers, having dynamic ranges of ±40γ, sampled the magnetic field 30 times within each of six 4.8-sec intervals, every 5.46 min. Detector sensitivites were ±0.25γ, and digitization uncertainty was ±0.40γ. A rubidium vapor magnetometer was used to calibrate the fluxgates but did not produce an independently useful data set. The fluxgates functioned normally throughout the useful life of the satellite and provided usable data through May 30, 1964.

- Principal Investigator Group/Major Journals

A1-01 Anderson, K.A., and N.F. Ness, "Correlation of Magnetic Fields and Energetic Electrons on the IMP 1 Satellite," J. Geophys. Res., 71, 3705-3727, 1966.

A study of simultaneous magnetic field and energetic particle records from the IMP 1 satellite on the dark side of the earth has shown several distinct correlations that can be understood as diamagnetic effects of charged particle populations. Depression of the magnetic field in the closed magnetic field line configuration of the particle cusp region is observed on most orbits. A small but significant portion of this effect can be attributed to the diamagnetic effects of electrons >45 kev. In the geomagnetic tail region, large depressions of the magnetic field having radial extent ~10 R_E are observed when the satellite approaches the neutral sheet to within ~5 R_E. Energetic electron fluxes appear throughout this volume and show no strong preference to occur immediately adjacent to the neutral sheet. In this region, less than 1% of the diamagnetic effect is due to electrons >45 kev. Finally, there are examples of intense, energetic electron fluxes closely associated with reduction of the magnetic field magnitude. In one case, an electron flux of 3×10^6 cm^{-2} sec^{-1} >45 kev was associated with a field change from 20 γ to 8 γ.

A1-02 Behannon, K.W., and N.F. Ness, "Magnetic Storms in the Earth's Magnetic Tail," J. Geophys. Res., 71, 2327-2351, 1966.

Detailed measurements of the earth's magnetic field at distances between 7 and 31.4 R_E were obtained by the IMP 1 satellite between Nov. 27, 1963, and May 30, 1964. The interaction of the solar wind with the geomagnetic field compresses it on the sunlit hemisphere but extends the field to form a magnetic tail in the antisolar direction with a median magnitude of 16 gammas. From March 15 to June 3, 1964, the satellite was imbedded well within the magnetic tail and for 19+ orbits (29-48) it measured principally the temporal variation and spatial structure of this tail field. The experimental data reveal the development of a magnetically neutral sheet in the tail separating fields of opposite direction that are aligned parallel to the earth-sun line. A total of five magnetic storms were observed terrestrially that are correlated with satellite data and discussed in this paper. Three storms of an M-region sequence, presumed to be associated with the sector structure within the corotating interplanetary medium are presented and discussed in detail, as well as two other magnetic storms. Both positive and negative correlations with worldwide H-component terrestrial data are observed. The former is interpreted to be due to large-scale compression of the entire magnetosphere and tail. Anti-correlation of the H component with the tail field magnitude is shown to be due to an increased number of lines of force being carried into the tail by the enhanced solar plasma flow. This occurs simultaneously with the main phase decrease and thus supports geomagnetic storm theories invoking such a tail field mechanism. Positive correlations of an increased tail field magnitude with the planetary magnetic index K_p are also obtained.

A1-03 Fairfield, D.H., "Average and Unusual Locations of the Earth's Magnetopause and Bow Shock," NASA-GSFC, X-692-70-452, Dec. 1970. (Accepted for publication in J. Geophys. Res.)

A best fit ellipse and hyperbola have been calculated to represent several hundred magnetopause and bow shock positions observed by six IMP spacecraft. Average geocentric distances to the magnetopause and bow shock near the ecliptic plane are 11.0 R_E and 14.6 R_E in the sunward direction, 15.1 R_E and 22.8 R_E in the dawn meridian and 15.8 and 27.6 R_E in the dusk meridian. The bow shock hyperbola is oriented in a direction consistent with that expected considering aberration of a radial solar wind. Observed magnetopause crossings agree well with theoretical predictions in the noon meridian plane but fall outside the theoretical boundaries in the dawn-dusk meridian planes. IMP 4 plasma data are used to demonstrate that the solar wind momentum flux is the prime factor controlling the orbit-to-orbit changes in the boundary positions. Data suggest that the interplanetary field orientation also affects the distance to the magnetopause boundary with more earthward crossings corresponding to southward fields. Six unusual bow shock locations up to 22 R_E beyond the average position are found to be due to an enhanced standoff distance associated with a low Alfven Mach number. The possibility is raised that the solar wind may have become sub-Alfvenic on July 31, 1967.

A1-04 Fairfield, D.H., "Average Magnetic Field Configuration of the Outer Magnetosphere," J. Geophys. Res., 73, 7329-7338, 1968.

Over 1500 hours of data from the satellites IMP 1, 2, and 3 have been used to study the configuration of the magnetic field in the outer magnetosphere between 5 and 18 R_e. Hourly average field vectors were projected in the solar magnetic equatorial plane and in 24 meridian sections corresponding to each hour of local time. The plots show the sweeping back of the field toward the tail and the dawn and dusk transition from compressed dayside field lines to extended nightside field lines. Constant B contours in the equatorial plane were constructed, and flux conservation was used to establish a quantitative relationship between the equatorial crossing point of an outer magnetosphere field line and the latitude of its earth intersection. A contour diagram in the equatorial plane designating the latitude of field line origin permits the mapping of low-altitude phenomena to the equatorial plane and vice versa. Auroral oval field lines are found to come from the region of the magnetopause in the daylight hemisphere but from well within the magnetosphere in the night hemisphere. The outermost closed field line is found to come from approximately 78° throughout the dayside hemisphere.

A1-05 Fairfield, D.H., "Ordered Magnetic Field of the Magnetosheath, J. Geophys. Res., 72, 5865-5877, 1967.

Simultaneous data from the IMP 1 and 2 satellites in interplanetary space have revealed that magnetic field discontinuities seen at one satellite are subsequently seen at the other satellite after delay times that are consistent with the idea that magnetic fields frozen into the solar wind are convected away from the sun with the solar wind velocity. A one-to-one correspondence of discontinuities at the two satellites persists even when one of the satellites is in the magnetosheath fields and their relation to simultaneously measured inter-

planetary fields shows that as magnetosheath fields are convected around the magnetopause by the solar plasma they undergo distortion from their interplanetary directions until they are aligned tangent to the magnetopause. Results are consistent with a gas-dynamic model where interplanetary field lines frozen in the solar plasma are convected through the earth's bow shock and draped around the magnetosphere with the sense of the magnetosheath field being determined by the incoming interplanetary field.

A1-06 Ness, N.F., "Earth's Magnetic Tail," J. Geophys. Res., 70, 2989-3005, 1965.

Measurements of the magnetic field of Earth at distances greater than approximately 7 R_e (Earth Radii) were performed. The geomagnetic field is observed to trail out far behind the earth in the antisolar direction, forming a magnetic tail. Magnetic field strengths of approximately 10 to 30 gammas are observed out to satellite apogee. The diameter of the magnetosphere at a distance of 30 R_e behind the Earth is approximately 40 R_e. The direction of the field is parallel to the Earth-Sun line and in the antisolar direction below the solar magnetospheric equatorial plane and in the solar direction above this plane. A neutral surface separating antisolar directed fields in the southern hemisphere from solar directed fields in the northern hemisphere has been detected over a large extent in area. No termination of the magnetic tail is detected or suggested by the data.

A1-07 Ness, N.F., "Geomagnetic Tail," Reviews of Geophysics, 7, 97-128, 1969.

An overview is presented on the experimental investigations of the earth's magnetic tail and imbedded neutral sheet which established its permanent existence as an extension of the magnetosphere with lines of force closely paralleling the earth-sun line. Physical properties and dynamics of the geomagnetic tail are defined, and a figure is included to depict both the geometry of the tail and the earth's bow shock in cislunar space, as well as the orbits of the satellites used in the experiments. Among the data reported are: (1) The plasma sheet surrounding the neutral sheet appears to be thicker in the center of the tail, flaring to approximately twice that near the dusk and dawn magnetopause boundaries. (2) The tail is still well-defined out to radial distances of 80 R_E although at distances of 500 and 1000 R_E it appears to have broken up into separate filaments. (3) Multiple correlation and regression analysis show that the field magnitude decreases from approximately 16 gammas at 20 R_E to 7 gammas at 80 R_E.

A1-08 Ness, N.F., "Magnetohydrodynamic Wake of the Moon," J. Geophys. Res., 70, 517-534, 1965.

The possible detection of the lee wake of the magnetohydrodynamic interaction of the solar wind with the moon as observed by the Imp 1 satellite is discussed. The interplanetary magnetic field was found to fluctuate very rapidly and reach anomalously large values when the satellite was approximately eclipsed by the moon in December 1963. Later data on the interplanetary field in February 1964 suggest that a detached lunar shock wave analogous to that observed by Imp 1 associated

with the earth may not be a permanent feature of the lunar environment. The approximate length of the wake region behind the moon is 150 lunar radii; at this distance the diameter of the region is about 70 lunar radii. Related studies on 29.5-day periodicities in K_p are reviewed. The solar wind interaction with the geomagnetic field extends the magnetosphere far behind the earth. Hence lunar synodic periodicities in K_p may reflect the interaction of the moon with the earth's magnetic tail rather than the moon's wake with the earth.

A1-09 Ness, N.F., C.S. Scearce, and J.B. Seek, "Initial Results of the IMP 1 Magnetic Field Experiment," J. Geophys. Res., 69, 3531-3569, 1964.

Presentation of measurements of the interplanetary magnetic field and the interaction of the solar wind with the geomagnetic field, obtained from the interplanetary monitoring platform Imp 1 or Explorer 18 (1963-46A). The strength of the interplanetary magnetic field is found to vary between 4 and 7γ, with extreme values as low as 1, and as high as 10γ. The magnitude, however, is extremely stable over times of hours, although changes of direction are significant. The average direction of the interplanetary magnetic field is slightly below the plane of the ecliptic and approximately along the streaming angle predicted for a steady-state solar wind. A significant feature of the magnetic field measurements is said to be the discovery of fields pointed diametrically opposite the streaming angle, indicating the filamentary structure of the interplanetary field. The complex interaction of the solar wind and the geomagnetic field shows a variety of magnetic field fluctuations and transition characteristics. It is noted that the detection of the collisionless magnetohydrodynamic shock wave at 13.4 R_e at the stagnation point associated with super-Alfvenic flow of solar plasma is one of the major results of this experiment.

A1-10 Ness, N.F., and J.M. Wilcox, "Extension of the Photospheric Magnetic Field into Interplanetary Space," Astrophys. J., 143, 23-31, 1966.

Observations of the nearby interplanetary magnetic field by the magnetometer experiment on the artificial Earth satellite IMP-1 have been compared with observations of the photospheric magnetic field obtained with the solar magnetograph at the Mt. Wilson Observatory. A good correlation has been found between the large scale pattern of the direction (into or out of the sun) of the photospheric field and the pattern of the direction (toward or away from the sun) of the nearby interplanetary field. This substantiates the theoretical model of the transport of solar magnetic fields into interplanetary space by the magnetohydrodynamic expansion of the solar corona.

A1-11 Ness, N.F., and J.M. Wilcox, "Interplanetary Sector Structure, 1962-1966," Solar Phys., 2, 351-359, 1967.

Some properties of the interplanetary magnetic field observed by IMP-3 in the latter half of 1965 are discussed with relation to previous satellite observations of the interplanetary field. The sector property

remains a prominent feature of the observations with the average field direction at the Archimedes spiral angle. The sector pattern has a 27-day recurrence period from 1962 to 1964, and during the year 1964 the pattern appears to be quasi-stable. In 1965 the recurrence period is about 28 days, and the evolution of the pattern is more rapid, with new sectors appearing and expanding.

A1-12 Ness, N.F., and J.M. Wilcox, "Solar Origin of the Interplanetary Magnetic Field," Phys. Rev. Letters, 13, 461-464, 1964.

The initial results of a detailed comparison of interplanetary magnetic field measurements taken by the Interplanetary Monitoring Platform (IMP-I) with solar magnetograph observations of the photospheric magnetic fields as measured at the Mt. Wilson Observatory are presented. Results indicate that during three solar rotations near the minimum of the solar cycle, some of the magnetic field lines passing through the photosphere near the center of the visible disk tended to be dragged out by the solar wind plasma to become part of the nearby interplanetary magnetic field. The best correlation was obtained when the photospheric field was in the same direction throughout an area corresponding to at least two or three days rotation. These conclusions are consistent with a suggested model in which the sense of the interplanetary magnetic field filaments is related to the sense of photospheric magnetic field regions.

A1-13 Ness, N.F., and D.J. Williams, "Correlated Magnetic Tail and Radiation Belt Observations," J. Geophys. Res., 71, 322-325, 1966.

A1-14 Schatten, K.H., N.F. Ness, and J.M. Wilcox, "Influence of a Solar Active Region on the Interplanetary Magnetic Field," Solar Phys., 5, 240-256, 1968.

The interplanetary magnetic field has been mapped between 0.4 and 1.2 AU in the ecliptic plane, extrapolating from satellite measurements at 1 AU. The structure within sectors and the evolution of sectors are discussed. The development of a solar active region appears to produce magnetic loops in the interplanetary medium that result in the formation of a new sector.

A1-15 Speiser, T.W., and N.F. Ness, "Neutral Sheet in the Geomagnetic Tail, Its Motion, Equivalent Currents, and Field Line Connection Through It," J. Geophys. Res., 72, 131-142, 1967.

Discussion of satellite detection of 42 observations of magnetic-field reversals accompanied by a decrease in the field magnitude. Of these, 38 are identified as crossings of a well-developed magnetic neutral sheet or current sheet. The relatively thin neutral sheet lies within a broad region of magnetic field depression and plasma enhancement or "plasma sheet." The neutral sheet frequently appears to be moving relative to the satellite with a maximum velocity of a few kilometers per second, and on many orbits multiple crossings occur.

A1-16 Wilcox, J.M., and N.F. Ness, "Quasi-Stationary Co-Rotating Structure in the Interplanetary Medium," J. Geophys. Res., 70, 5793-5805, 1965.

A quasi-stationary corotating structure in the interplanetary magnetic field has been observed with the IMP 1 satellite during 3 solar rotations. The interplanetary field is directed predominantly away from the sun for 2/7 of a rotation, then toward the sun for 2/7 of a rotation, then away from the sun for 2/7 of a rotation, and finally toward the sun for 1/7 of a rotation. The interplanetary magnetic field magnitude and the solar wind velocity, density, and flux are discussed with regard to this sector structure. As the structure rotates past the earth once every 27 days it influences geomagnetic activity and cosmic-ray density. A recurring stream of protons of a few Mev energy is almost entirely contained within one sector. The solar source of the recurring geomagnetic storm of Dec. 2, 1963, is associated with a ghost unipolar magnetic region in the solar photosphere.

A1-17 Wilcox, J.M., and N.F. Ness, "Solar Source of the Interplanetary Sector Structure," Solar Phys., 1, 437-445, 1967.

The interplanetary sector structure observed by the IMP-1 satellite during three solar rotations in 1963-4 is compared with the photospheric magnetic field structure observed with the solar magnetograph at Mt. Wilson Observatory. The interplanetary sector structure was most prominent on the sun in latitudes between 10°N and 20°N, although the average heliographic latitude of the satellite was 3-1/2°S. A superposed-epoch analysis of the calcium plage structure obtained from the Fraunhofer Institute daily maps of the sun is used to discuss the relation between the structure of the plages and the interplanetary sector structure. A possible explanation for the observations is discussed in terms of a north-south asymmetry in the flow of the solar wind. It is suggested that these observations favor the "equinoctial" hypothesis as compared with the "axial" hypothesis for the explanation of the semiannual maxima in geomagnetic activity.

A1-18 Wilcox, J.M., K.H. Schatten, and N.F. Ness, "Influence of Interplanetary Magnetic Field and Plasma on Geomagnetic Activity During Quiet-Sun Conditions," J. Geophys. Res., 72, 19-26, 1967.

Observations by the IMP 1 satellite of the interplanetary magnetic field and plasma have been compared with the 3-hr geomagnetic activity index K_p. The average K_p is approximately a linear function of the interplanetary field magnitude B in gammas ($\bar{K}_p = (0.33 \pm 0.02)\ B \pm 0.2$). It appears significant that this relation between $\bar{K}_p$ and field magnitude passes through the origin, whereas the linear relation between $\bar{K}_p$ and solar wind velocity does not. The average K_p is approximately a linear function of solar wind velocity, but with perhaps a slightly different slope and zero intercept from the similar relation observed by Snyder, Neugebauer, and Rao with Mariner 2. Little correlation is observed between $\bar{K}_p$ and solar wind density, but this result is consistent with the interplanetary sector pattern discussed by Wilcox and Ness. Cross-correlation as a function of time lag of K_p and interplanetary field (or solar wind velocity) yields a positive peak correlation at zero lag, suggesting that a large part of the response of the magnetosphere to solar wind excitation occurs within the 3-hr K_p period.

A1-19 Williams, D.J., and N.F. Ness, "Simultaneous Trapped Electron and Magnetic Tail Field Observations," J. Geophys. Res., 71, 5117-5128, 1966.

Using data from the polar orbiting satellite 1963 38C, the behavior of the high-latitude energetic ($\geq$ 280 kev) electron trapping boundary, A_c, at 1100 km is presented for the period Mar. 15 through June 3, 1964. A sudden collapse of A_c to lower latitudes during the onset of magnetic storms, as indicated by K_p and D_{st}, is found to be a characteristic feature of the low-altitude trapped electron population. Details of this behavior are presented and discussed. In addition, during this time period, the NASA IMP 1 satellite sampled field characteristics in the geomagnetic tail. Correlated observations of the simultaneously observed behavior during magnetic disturbances of the 1100-km trapped electron population and of the field strength in the tail are presented. In three cases there is agreement and in one case disagreement with the latitude decreases that are predicted with an extended geomagnetic tail configuration. These results are considered to be direct evidence of the important influence exerted by the geomagnetic tail field in governing not only the quiet-time trapped particle distribution, but also the behavior of the trapped particle population during magnetic storms.

- Principal Investigator Group/Conference Proceedings

A1-20 Behannon, K.W., and N.F. Ness, "Satellite Studies of the Earth's Magnetic Tail," Physics of the Magnetosphere, 409-434, 1968. (Proceedings of the Summer Institute, Physics of the Magnetosphere, Boston College, Boston, Mass., June 19-28, 1967. Eds., R.L. Carovillano, J.F. McClay, H.R. Raddski, D. Reidel Publishing Co., Dordrecht, Holland.)

Review of satellite experiments which have extensively mapped the earth's magnetic tail, thus contributing to current knowledge of the structure, temporal behavior, shape, and length of the magnetic tail. The tail is a permanent extension of the magnetosphere with magnetic lines of force pointing directly away from the sun south of the plane of the magnetospheric equator and toward the sun above this plane. The oppositely directed bundles of field lines are separated by a "neutral sheet," which is a weak magnetic-field reaction between 0.1 and 1 R_E thick, and which is generally in motion. Impulsive field magnitude decreases have been observed in the magnetic tail in association with transient electron events. The occurrence of these electron bursts decreases with distance from the neutral sheet. Magnetic storms have been observed in the tail in correlation with worldwide terrestrial disturbances.

A1-21 Fairfield, D.H., "Magnetic Field of the Magnetosphere and Tail," NASA-GSFC, X-616-69-124, Apr. 1969. (Paper to be published in the Proceedings of the Leningrad Conference on Solar Terrestrial Physics, May 1970.)

Earth orbiting spacecraft have made extensive measurements of the solar wind-compressed magnetic field in the sunward magnetosphere and

the extended magnetic field of the geomagnetic tail. Analysis of the measurements indicate that in an average magnetosphere, field lines crossing the earth above 78° + 3° and 69° + 2° geomagnetic latitude in the noon and midnight meridians respectively are extended into the geomagnetic tail. Field lines in the northern and southern hemispheres of the tail are generally oriented parallel or anti-parallel to the earth sun line with two regions being separated by a neutral sheet or current sheet less than 1 R_E thick. The average field magnitude is 16γ at 20 R_E and 7γ at 80 R_E except in a region within about 6 R_E of the neutral sheet where the field is depressed by a factor of 2. The observation of tail-like fields almost 1000 R_E behind the earth by the Pioneer 7 spacecraft sets a lower limit on the radial extent of tail associated effects. Departures from the average magnetosphere field configuration occur at the times of magnetic storms and bay events.

A1-22 Ness, N.F., "Interplanetary Magnetic Field Measurements by the IMP 1 Satellite," Solar Wind, 83-107, 1966. (Proceedings of a Conference held at the Calif. Institute of Technology, Apr. 1-4, 1964. Eds., R.J. Mackin, Jr., M. Neugebauer, Pergamon Press.)

Results of the interplanetary magnetic-field measurements taken by the Interplanetary Monitoring Platform (IMP-1). The interplanetary magnetic fields of solar origin and the solar-terrestrial transients (or magnetic storms) are discussed.

A1-23 Ness, N.F., "Measurements of the Magnetic Fields in Interplanetary Space and the Magnetosphere," Proceedings of the 9th International Conference on Cosmic Rays, 14-25, 1966. (Proceedings held at the Imperial College of Science and Technology, London, England, Sept. 6-17, 1965. Institute of Physics and the Physical Society, London, England.)

Direct measurements of magnetic fields in space have been performed by satellites and space probes since 1958. The results of these experiments reveal the continual confinement of the geomagnetic field by the "solar wind," forming the magnetosphere and the earth's magnetic tail. At 3-6 R_E permanent effects due to "ring currents" have been detected. Enclosing the magnetosphere is a turbulent boundary layer separated from the interplanetary medium by a collisionless MHD shock wave. At the subsolar point the distance to the termination of the regular geomagnetic field is approximately 10 R_E and to the shock wave, 13.4 R_E. The geomagnetic tail is observed out to a distance of 40 R_E trailing away from the sun much in the fashion of cometary tails. The magnetized solar plasma contains a field of approximately 5 gammas which is directed along the classical Archimedean spiral predicted by Parker. The interplanetary field, deduced conclusively to be of solar origin, is structured into four sectors which are readily identifiable during the quiet years of the solar cycle (1963-64). The experiments and their results with respect to our knowledge of fields in space are reviewed.

A1-24 Ness, N.F., "Observations of the Magnetic Field at the Magnetopause and Interaction Region by IMP 1," Solar Wind, 315-335, 1966. (Proceedings of a Conference held at the Calif. Institute of Technology, Apr. 1-4, 1964. Eds., R.J. Mackin, Jr., M. Neugebauer, Pergamon Press.)

Analysis of data from the first 19 orbits of IMP 1. Magnetic-field data taken at the extremity of the geomagnetic field are discussed, and the observed and theoretical boundaries of the magnetopause are compared.

A1-25 Ness, N.F., "Probable Observation of the Wake of the Moon," Solar Wind, 393-400, 1966. (Proceedings of a Conference held at the Calif. Institute of Technology, Pasadena, Calif., Apr. 1-4, 1964, Eds., R.J. Mackin, Jr., M. Neugebauer, Pergamon Press.)

Hypothesis that IMP satellite data gave the first conclusive evidence of the moon's magnetospheric wake. The drastic variation in the characteristics of the magnetic-field data as the satellite passed through certain portions of interplanetary space is seen to evidence a magnetohydrodynamic wake of the moon as it interacts with the solar wind.

A1-26 Ness, N.F., C.S. Scearce, J.B. Seek, and J.M. Wilcox, "Summary of Results from the IMP-1 Magnetic Field Experiment," Space Res. VI, 581-628, 1966. (Proceedings of the 6th International Space Science Symposium, Mar Del Plata, Argentina, May 11-19, 1965.)

Discussion of measurements made with the Interplanetary Monitoring Platform IMP 1 of the magnetic field near the Earth and in cislunar space. The initial apogee of IMP 1 was 197,616 km (31.7 Earth-radii) and the initial perigee was 192 km. Measurements were made in interplanetary space free from geomagnetic effects on the solar wind flow, in the turbulent transition region to the Earth's magnetosphere, and in the magnetosphere itself. It is found that the continual flux of solar plasma confines the geomagnetic field to a region of space surrounding the Earth but extending on the night side to an as yet unknown distance. It appears that this "tail" extends to beyond the orbit of the Moon, and that the Moon therefore must traverse the Earth's magnetic tail once every 29.5 days. The presence of a magnetic neutral sheet in the Earth's magnetic tail implies an enhanced particle flux within it to balance the field pressure.

A1-27 Wilcox, J.M., N.F. Ness, and K.H. Schatten, "Active Regions and the Interplanetary Magnetic Field," Structure Development Solar Active Regions, 390-394, 1968. (IAU Symposium No. 35, Proceedings held in Budapest, Hungary, Sept. 4-8, 1967.)

The relation of solar active regions to the large-scale sector structure of the interplanetary field is discussed. In the winter of 1963-64 (observed by the satellite IMP-1) the plage density was greatest in the leading portion of the sectors and lesser in the trailing portion of the sectors. The boundaries of the sectors (places at which

the direction of the interplanetary magnetic field changed from toward the Sun to away from the Sun, or vice versa) were remarkably free of plages. The very fact that since the first observations in 1962 the average interplanetary field has almost always had the property of being either toward the Sun or away from the Sun (along the Archimedean spiral angle) continuously for several days must be considered in the discussion of large-scale evolution of active regions. Using the observed interplanetary magnetic field at 1 AU and a set of reasonable assumptions the magnetic configuration in the ecliptic from 0.4 to 1.2 AU has been reconstructed. In at least one case a pattern emerges which appears to be related to the evolution of an active region from an early stage in which the magnetic lines closely couple the preceding and following halves of the region to a later stage in which the two halves of the region are more widely separated.

- Principal Investigator Group/Other Publications

A1-28 Bridge, H.S., G.P. Serbu, N.F. Ness, J.A. Simpson, F. McDonald, K.A. Anderson, and J.H. Wolfe, "Initial Results from the First Interplanetary Monitoring Platform (IMP 1)," IG Bulletin No. 84, June 1964. (Reprinted in Transactions of the American Geophys. Union, 45, 501-520, 1964.)

See abstract under A-01.

A1-29 Ness, N.F., "Discussion of Paper by R.W. Fredricks, E.W. Greenstadt, and C.P. Sonett, "Magnetodynamically Induced Ambiguity in the Data from Tilted, Spinning Fluxgate Magnetometers, Possible Application to IMP 1," J. Geophys. Res., 73, 3077-3080, 1968.

Critical review is made of a recent argument by Fredricks et al. (1967), in which it was suggested that satellite data obtained from tilted spinning fluxgate magnetometers are ambiguous. In the argument under analysis, it was posited that because of the latent ambiguity associated with the IMP 1 experiment, an interpretation capable of contributing to a misleading or even false physical picture may arise. It is concluded by the author that the interpretation of the physical significance of the data obtained from the IMP 1 magnetic field experiment has not been misleading.

A1-30 Ness, N.F., "Earth's Magnetic Field, A New Look," Science, 151, 1041-1052, Mar. 1966.

Account of the investigation and mapping of the external geomagnetic field of the earth using earth satellites and space probes. The background of study of the earth's magnetic field is discussed, and the solar wind, the magnetosphere and its boundary, and the distortion of the geomagnetic field are considered. The interplanetary medium, the earth's magnetic tail, and magnetic storms are studied. Data provided by U.S. and USSR satellites and space probes on the geomagnetic field are tabulated, and the trajectories of satellites and space probes which have sampled the distant terrestrial magnetic field and that between the earth and the orbit of the moon are plotted.

A1-31 Ness, N.F., "Interplanetary Medium," Introduction to Space Science, 2nd Edition, 345-371, 1965. (Eds., W.N. Hess, G.D. Mead, Gordon and Breach, Science Publishers, Inc., New York, New York.)

Survey of theoretical and experimental investigations of the propagation of disturbances in the interplanetary medium. The expansion of the solar corona into interplanetary space is discussed from the standpoint of Parker's MHD theory of the solar wind; confirmations of this theory by direct measurements have been made with the aid of artificial satellites and space probes. A simplified, but quantitatively accurate, description of the physical characteristics of the interplanetary medium is given. According to this mode, the interplanetary magnetic lines of force are twisted into Archimedean spirals by the rotation of the sun and the radial flux of the solar wind. The results of plasma measurements and of measurements of the interplanetary magnetic field are cited.

A1-32 Ness, N.F., "Magnetic Structure of Interplanetary Space," NASA-GSFC, X-616-69-334, Aug. 1969.

A brief summary and overview of the present understanding of the interplanetary magnetic field structure is presented. Synoptic studies of the physical properties of the interplanetary medium and in particular the interplanetary magnetic field revealed a sectoring or ordering of the direction and correlation variations of plasma velocity, density, terrestrial magnetic activity, and long lived streams of cosmic rays. Second order results indicate a rich fine scale filamentary structure of the interplanetary medium in which individual flux tubes appear to be directly connected to the sun. From these detailed studies and long term observations, it is now possible to view the interplanetary medium as being structured on three characteristic time scales: microstructure, less than one hour; mesostructure, 1 to 100 hours; and macrostructure, greater than 100 hours.

A1-33 Ness, N.F., Magnetosphere and Its Boundary Layer, NASA, SP-71, 31-40, 1965. (Proceedings of the 2nd Symposium on Protection Against Radiation Hazards in Space, Gatlinburg, Tenn., Oct. 1964.)

The distortion of the earth's magnetic field and the resultant boundary layer region between the magnetosphere and the undisturbed interplanetary medium were measured by the IMP-1 satellite for energetic particles, low energy plasmas, and magnetic fields. A turbulent plasma flow of very high temperatures with fluctuating magnetic fields was found within the transition region, and a distorted geomagnetic field was observed within the magnetosphere that depended upon the strength of the earth's magnetic field and the strength of the solar wind containing it. No termination of the magnetosphere on the leeward side of the solar wind flow was indicated.

A1-34 Ness, N.F., "Observations of the Interaction of the Solar Wind with the Geomagnetic Field During Quiet Conditions," Solar-Terrestrial Physics, 57-89, 1967. (Academic Press Inc., London, England.)

Satellite measurements of the outer geomagnetic field have revealed the distortion and containment of the geomagnetic field and formation of an external magnetic tail as a result of the flux of the solar wind. In addition there appears to be a permanent detached bow shock wave associated with the super-Alfvenic interaction of the solar plasma with the geomagnetic field. Both the shock wave and magnetopause are frequently in motion. Details of the earth's neutral sheet indicate frequent fluctuation of its position in the magnetic tail in the absence of any significant magnetic or solar activity. There remain, however, certain major problems in establishing definitive quantitative models of the physical phenomena which have been observed. It can be anticipated that within 10 years after the discovery of the radiation belts, i.e. 1968, that a great wealth of additional experimental data will be available from the recent sophisticated and high data rate satellites such as EGO's and Pioneers providing definitive as well as simultaneous determinations of separate particle, plasma, and field phenomena.

A1-35 Ness, N.F., "Remarks on Preceding Paper by E.W. Greenstadt," J. Geophys. Res., 70, 5453-5454, 1965.

A1-36 Ness, N.F., "Satellite Measurements of Magnetic Fields in Space," Dynamics of Fluids and Plasmas, 451-471, 1966. (Ed., S.I. Pai, Academic Press, New York, New York.)

The advent of the satellite and space probe era 8 years ago introduced into the realm of extra-terrestrial physics the possibility of directly measuring the properties of interplanetary space and the distant geomagnetic field. Since 1957 an impressive sequence of such in situ experiments has led not only to renewed investigations of well known solar-terrestrial physical problems but also initiated studies investigating completely new phenomenon not previously anticipated. These are represented by the Van Allen radiation belt and the phenomenon of the solar wind and its effect upon the terrestrial magnetic field.

Subsequent to early suggestions by Biermann in 1951 for a continuous and substantial solar corpuscular flux to explain the observed characteristics of Type I comet tails, Parker in the late 1950's developed the theory of the "solar wind" or hydrodynamic expansion of the solar corona interplanetary space. Direct measurements by satellites have confirmed the existence of the solar wind and the continual confinement of the geomagnetic field as well as the development of an extended magnetic tail of the earth. On the sunlit side of the earth, the regular geomagnetic field terminates at approximately 85,000 kilometers while on the nightside of the earth the terrestrial field is observed to trail out in a high distorted fashion at least halfway to the distance to the moon. Standing off from the regular geomagnetic field a boundary has been observed between a turbulent boundary layer and the undisturbed interplanetary medium which is tentatively identified as a collisionless magnetohydrodynamic shock wave. The use of a continuum fluid dynamic analogy applied to the solar wind permits an estimate of the standoff distance for a spherical object which approximates the confined geomagnetic field. Direct comparison with observations is reasonably good and suggests that the phenomenon investigated is indeed a collisionless shock. This paper will discuss the gross characteristics of the distorted geomagnetic field, its boundary layer and the detached bow shock wave as observed recently by satellite experiments.

A1-37 Ness, N.F., and J.M. Wilcox, "Sector Structure of the Quiet Interplanetary Magnetic Field," Science, 148, 1592-1594, 1965.

Observations of the interplanetary magnetic field by the IMP-1 satellite have revealed a regular longitudinal sector structure in this field. The sectors co-rotate with the sun; as an average sector sweeps past the earth the interplanetary field magnitude decreases from greater than 6 gammas to less than 4 gammas and the daily sum of the geomagnetic activity index Kp decreases from greater than 25 to less than 10.

A1-38 Wilcox, J.M., A.D. Ritchie, and N.F. Ness, "Interplanetary Magnetic Field IMP-1, Motion Picture of the Transverse Components," University of California., Ser. 9, Iss. 5, Jan. 1968.

A 16 mm movie, representing a portion of the IMP-1 magnetometer observations of the interplanetary magnetic field is described. The view is parallel to the ecliptic plane, and at an angle of 50° to the earth-sun line. Thus an interplanetary magnetic field in the Archimedes spiral direction appears as a point, and the transverse variations (in the north-south direction and in the azimuthal direction) are seen.

A1-39 Wilcox, J.M., A.D. Ritchie, and N.F. Ness, "Movie of the Interplanetary Magnetic Field," University of California, Ser. 7, Iss. 53, Oct. 1966.

A 16mm movie is described which represents a portion of the magnetometer observations made by the IMP-1 satellite during 1-14 Dec. 1963. The movie represents approximately 12 days of interplanetary field observations, beginning with the second orbit of IMP-1. It is noted that the movie emphasizes in a unique way the dynamic character of the interplanetary field.

- Not Principal Investigator Group/Major Journals

A1-40 Anderson, K.A., "Energetic Electron Fluxes in the Tail of the Geomagnetic Field," J. Geophys. Res., 70, 4741-4763, 1965.

Observation that fluxes of energetic electrons up to 10^7 cm^{-2} sec^{-1} above 45 kev frequently appear in the tail of the geomagnetic tail out to distances of 31.5 earth radii. They characteristically occur as isolated patches, not directly attached to other particle distributions around the earth. It is shown that these particles are usually injected into regions of space at least a few earth radii in size in an impulsive manner. The buildup time for these fluxes at a fixed point in space is typically a few minutes or less. The fluxes then decay away in times of several minutes up to a few hours, during which they may exhibit highly unstable behavior. The frequency of appearance of these fluxes has a radial dependence that rapidly falls off with increasing distance from the earth's center. The island fluxes are sensitive to geomagnetic activity but are present with low frequency even in quiet times. Their relation to other features of the distant radiation zone is discussed.

A1-41 Brody, K.I., and C.T. Russell, "Some Remarks on the Position and Shape of the Neutral Sheet," J. Geophys. Res., 72, 6104-6106, 1967.

Discussion of a relatively simple empirical formula for the location of the neutral sheet in the geocentric solar magnetospheric coordinate system. It is concluded that for properly ordering data taken in the earth's geomagnetic tail, it is necessary to know the direction and velocity of the solar wind outside the tail at the same time as the observations within the tail are being made. Even if the coordinate system used to order the data were rotated with the X axis of the coordinate system pointing in a direction corrected for the nonradial solar wind flow and the associated aberration angle, the neutral sheet does not coincide with the X-Y plane, but rather is a curved surface touching the X-Y plane at the edges of the tail and furthest from the X-Y plane in the center of the tail. An expression is given which should prove useful in studying phenomena in the magnetotail whenever a knowledge of the distance from the neutral sheet is an important parameter.

A1-42 Fredricks, R.W., E.W. Greenstadt, and C.P. Sonett, "Magnetodynamically Induced Ambiguity in the Data From Tilted, Spinning Fluxgate Magnetometers, Possible Application to IMP 1," J. Geophys. Res., 72, 367-382, 1967.

Data from a satellite-borne, tilted, spinning fluxgate magnetometer are subject to inherent ambiguities when the sampled ambient field is dynamically active. These ambiguities are further compounded when the sampling is multirate. In the paper, the intrinsic limitations of a multirate-sampled, tilted fluxgate system are described, the production of false ambient vectors is explained, and the conditions for extracting desired physical quantities, such as field magnitudes and power spectra, are discussed. The results are applied to the Explorer 18 (IMP 1) magnetometer system in the magnetosheath, and it is shown that the ambiguities of the system may in fact limit the interpretability of the Explorer-18 data in some parts of this region or in other regions of magnetic activity. The paper discusses the relevance of dynamic field effects to magnetosheath boundary determinations, to the interpretations of Explorer-18 magnetosheath data as "turbulent" fields, and to the apparent differences between Explorer-18 magnetosheath measurements and those obtained by magnetometers aboard other spacecraft such as Pioneer 1, OGO 1, and Vela 3.

A1-43 Fredricks, R.W., E.W. Greenstadt, and C.P. Sonett, "Reply (To Ness's Discussion of Paper by R.W. Fredericks, E.W. Greenstadt, and C.P. Sonett, 'Magnetodynamically Induced Ambiguity in the Data From Tilted, Spinning Fluxgate Magnetometers, Possible Application to IMP 1')," J. Geophys. Res., 73, 3081-3084, 1968.

A1-44 Greenstadt, E.W., "Interplanetary Magnetic Effects of Solar Flares, Explorer 18 and Pioneer 5," J. Geophys. Res., 70, 5451-5452, 1965. (Letter)

Discussion of an anomalous field magnitude recorded by Explorer 18 on Dec. 14, 1963. The behavior of the ambient field at Explorer 18

during this time is said to be consistent with effects recorded both statistically and in detail during the flight of Pioneer 5 on April 1, 1960, and to serve as a confirmation of the relationships tentatively indicated by the earlier data. It is concluded that the uniqueness, for the given month, of the flare of 0922 UT December 13 makes it a plausible source of the anomalous disturbance recorded by Explorer 18 on December 14.

A1-45 Hirshberg, J., "Interplanetary Magnetic Field During the Rising Part of the Solar Cycle," J. Geophys. Res., 74, 5814-5818, 1969.

Comparison of the interplanetary magnetic field observed during the rising part of the solar cycle with that observed during solar minimum. The 3-hour-average magnetic fields measured by the Ames magnetometer onboard Explorer 33 during the period from November 1966 through February 1967 are compared with earlier results from the same months of 1963 and 1964.

A1-46 Hruska, A., and J. Hruskova, "Long Time-Scale Magnetodynamic Noise in the Geomagnetic Tail," Planetary Space Sci., 17, 1497-1504, Aug. 1969.

Hourly ranges of the magnetic field in the Earth's magnetotail have been determined from 5.46-min field averages measured by the IMP 1 satellite. The amplitude of fluctuations parallel to the local average field B decreases with increasing distance from the neutral sheet. The amplitude of fluctuations perpendicular to B decreases with increasing distance from the Earth. Fluctuations in two directions perpendicular to B, (parallel and perpendicular to the neutral sheet), are coupled, but there is almost no evidence of a correlation between fluctuations parallel to B and fluctuations perpendicular to B. The tail field fluctuations observed in the vicinity of the Earth are well correlated with the geomagnetic activity measured by the K_p-index. It is suggested that two independent types of noise exist in the geomagnetic tail. The first type corresponds to the disturbances propagating across the tail, perpendicular to B, and the second one corresponds to disturbances propagating from the vicinity of the Earth along the tail field-lines.

A1-47 Iijima, T., and T. Nagata, "Constitution of Magnetospheric Storms," Ann. Geophys., 26, No. 2, 417-426, Apr.-June 1970.

The constitutions of magnetospheric storms and the earth's magnetic storms in connection with the penetration of the solar wind energy are examined for eight disturbed days by use of magnetic variations, low energy ion flux (< 50 eV), energetic electron flux (> 50 KeV) on ATS-1 ($r \simeq 6.5$ Re), magnetic variations in the interplanetary space by IMP-1 and IMP-C and simultaneous magnetograms on the earth's surface.

The necessary conditions to generate a magnetic storm by an invasion of the solar wind energy into the magnetosphere seem to be the following two: (a) an enhancement of convection of the magnetospheric low energy plasma, (b) a growth of an asymmetric belt of energetic plasma, where (a) directly enhances the polar SP, while (b) leads to DR-field.

A1-48 Ivanov, K.G., "Was the Magnetic Wake Observed by 'IMP-1' Lunar or Terrestrial," Geomagnetism and Aeronomy, 5, 581-583, 1965.

Discussion of the magnetograms obtained by IMP-1 (1963-46A) in the light of magnetograms obtained simultaneously at ground stations. The analysis leads to the conclusion that the magnetohydrodynamic wake of the earth, directed upward along the solar-plasma flow (at a pre-Alfven flow about the earth's magnetosphere) might have contributed to a great extent to the phenomena observed by IMP-1.

A1-49 Jokipii, J.R., "Correlation of ≥30-keV Electron Pulses and Magnetic Fields in the Magnetosheath and Beyond," J. Geophys. Res., 73, 931-942, 1968.

Simultaneous energetic electron and magnetometer data, obtained in the magnetosheath and beyond the bow shock on the IMP 1 satellite, have been analyzed. Within the 20-sec time resolution available, it is concluded that no unique local correlation exists between the electron pulses and the magnetic field intensity. However, the general ambient field tends to be more disturbed and to be directed more nearly along the sun-earth line during periods when pulses are present than otherwise. Three distinct types of electron events are observed. The first type of event is found in the magnetosheath and may be due to electrons convected with the solar plasma. The second type is clearly associated with multiple crossings of the bow shock. The third type of event apparently occurs beyond the bow shock and is associated with magnetic field fluctuations with periods ≳10 sec. The observations require that the excess particle energy density during pulses be somewhat less than that of the ambient magnetic field. It is thus concluded that the energy spectra of electrons observed in the magnetosheath and beyond are different from those observed in the earth's magnetic tail. Several magnetic neutral sheets observed in interplanetary space were not associated with enhanced counting rates.

A1-50 Kalinin, Y.D., "Nondipole Part of the Geomagnetic Field is Manifest at Magnetosphere Boundary," Geomagnetism and Aeronomy, 7, 271-272, 1967.

The author establishes that the magnetosphere boundary is located above the daytime part of the Earth at distances from the center of the Earth, functions of not only interplanetary plasma parameters, but also of the nondipole part of the geomagnetic field on the basis of data of Explorer-12 and -18.

A1-51 Kovalevskiy, I.V., "Energy Flux of Solar Plasma in a Sectorial Structure of the Interplanetary Magnetic Field," Geomagnetism and Aeronomy, 7, 794-796, 1967.

The three-hour values of the density of kinetic energy flux of the directed motion of the plasma q_1, and the flux density of thermal (q_2) and electromagnetic (q_3) energies for the positive and negative sectors of the interplanetary magnetic field, observed from December 1963 to February 1964 with the aid of AES IMP-1 are computed. The character is discussed of q_1, q_2, q_3 distribution in sectors and their relationship with solar plasma velocity. It is shown that $q_1 \gg q_2 \approx q_3$

and that there is no particular difference between the sectors. Estimates are made of energy fluxes through sectors' cross-sections.

A1-52 Kovalevskiy, I.V., "Relationship Between the Geomagnetic Activity and the Energy Density of Quiet Solar Wind Flux," Geomagnetism and Aeronomy, 7, 797-799, 1967.

According to data of IMP-1 on the sectorial structure of the interplanetary magnetic field, apparently representing a quiet solar wind, estimates are made of energy fluxes of directed motion of thermal and electromagnetic energy incident upon the cross-section of the magnetosphere. It is shown that there are enough energy fluxes of each kind separately even for the creation of the entire complex of geophysical events in a period of moderate magnetic storm. The character is investigated of the link between the three-hourly values of the K_p-index of geomagnetic activity or the amplitudes a_p equivalent to them, with the flux densities of the various forms of energy.

A1-53 Murayama, T., and J.A. Simpson, "Electrons Within the Neutral Sheet of the Magnetospheric Tail," J. Geophys. Res., 73, 89-905, 1968.

The distribution, intensity, and energy spectra of electrons near and within the neutral sheet are studied using the simultaneous measurements of the University of Chicago Au-Si surface-barrier detector (electron energies >160 kev) and the University of California detector (electron energies >45 kev) on the IMP 1 satellite in 1964. Based upon the position of neutral sheet crossings determined by Speiser and Ness from the IMP 1 magnetometer, electron fluxes >160 kev are observed in all of the 20 analyzed neutral sheet crossings. It is shown why these results were not obtained by Anderson and Ness. The electron flux generally has a peak in the neutral sheet that is about twice the amplitude of adjacent regions in the tail. The neutral sheet thickness exceeds the gyroradius of 200-kev electrons by a factor 5. The electron distributions in space and time indicate that they are continuously present within the neutral sheet. A comparison of the energy spectra of electrons in the sheet with electron islands found by Anderson widely distributed in the tail shows that the neutral sheet electrons have energy spectra that are at least as flat as for the islands, and extend in energy above 200 kev. The dependence of neutral sheet electron fluxes upon the radial distance from the magnetic dipole and upon geomagnetic field disturbances is investigated. The present evidence for neutral sheet electrons indicates either (a) that the sheet is well-connected to a region of electron acceleration in the magnetosphere and the sheet behaves like a corridor or channel for electron escape, or alternatively, (b) that the electrons are accelerated in the neutral sheet.

A1-54 Nishida, A., "Coherence of Geomagnetic DP 2 Fluctuations with Interplanetary Magnetic Variation," J. Geophys. Res., 73, 5549-5559, 1968.

From the comparison of the worldwide geomagnetic data with IMP 1 magnetic records obtained in the interplanetary space, it is found that the DP 2 fluctuations, which are thought to be the geomagnetic counter-

part of intensity fluctuations of the magnetospheric convective system, are coherent with variations in the north-south component of the interplanetary magnetic field. This coherence is observed irrespective of whether this component is directed northward or southward. Average time delay between the crossing of an interplanetary magnetic structure across the nose of the bow shock and the associated magnetic variation on the ground is 7 min at the pole and 9 min at the midday equator. Applicability of the proposed models of the magnetospheric electric field to this phenomenon is critically examined, and the penetration of the interplanetary electric field into the magnetosphere is suggested as the origin of the DP 2 phenomenon.

A1-55 Rostoker, G., and C.G. Falthammar, "Relationship Between Changes in the Interplanetary Magnetic Field and Variations in the Magnetic Field at the Earth Surface," J. Geophys. Res., 72, 5853-5863, 1967.

Hourly average values of solar wind velocity and the components of the interplanetary magnetic field obtained by IMP 1 were combined to obtain the interplanetary electric field as measured in a coordinate system with one axis parallel to the earth's magnetic dipole axis. The hourly values of the azimuthal component of the interplanetary electric field were related to the different types of magnetic activity observed at a worldwide chain of stations. It is found that a positive increment in the azimuthal electric field (enhancement of the southward-directed interplanetary magnetic field) is strongly related to the initiation of magnetic bay and storm activity and the establishment of a negative (or less positive) azimuthal electric field during the course of a storm or bay is associated with the start of the recovery phase. Sudden impulses are shown to be equally often associated with negative and positive increments in the azimuthal electric field and are found to be the most common event observed in the study. The combinations of solar-terrestrial parameters that appear to determine the different types of magnetic activity are discussed in light of the results presented in the paper.

A1-56 Wilcox, J.M., "Asymmetry in Geomagnetic Response to the Polarity of the Interplanetary Magnetic Field," J. Geophys. Res., 73, 6835-6836, 1968.

The difference between northern and southern hemispheric geomagnetic activity is investigated as a function of the sector polarity pattern of the interplanetary magnetic field. It is found for the year 1964 that sectors with field directed away from the sun are associated with slightly enhanced northern hemisphere activity, and toward sectors are associated with slightly enhanced southern hemisphere activity.

A1-57 Wilcox, J.M., and R. Howard, "Large-Scale Pattern in the Solar Magnetic Field," Solar Phy., 5, No. 4, 564-574, Dec. 1968.

A clearly evident large-scale pattern in the interplanetary magnetic field during 1964 is used to search for a similar large-scale pattern in the solar magnetic field. It is found that such a

pattern did exist in the photospheric field observations on both sides of the equator over a range of at least 40°N to 35°S. The pattern is basically similar at all these latitudes, and differs from that to be expected from solar differential rotation in three important respects. It is found that the solar magnetic pattern changed at all latitudes investigated within an interval of a few solar rotations.

A1-58 Wilcox, J.M., and R. Howard, "Persistent Solar Magnetic Pattern Extending Over Equatorial Latitudes," Phys. Rev. Letters, 20, No. 22, 1252-1254, May 1968.

Comparison of an interpolated pattern of the interplanetary magnetic field with the photospheric magnetic field during an interval of one year near the minimum of the 11-yr sunspot cycle. This comparison reveals a persistent pattern in the solar field extending over a wide range of heliographic latitude on both sides of the equator.

A1-59 Williams, D.J., "On the Low Altitude Trapped Electron Boundary Collapse During Magnetic Storms," J. Geophys. Res., 72, 1644-1646, 1967.

Results of observations of the collapse of the low-altitude, high-latitude electron-trapping boundary during the magnetic storm which occurred on Apr. 18, 1965. Additional evidence is obtained, showing that the high-latitude trapping boundary collapse observed at low altitudes in the outer zone during magnetic storms is due to field-line extension into the geomagnetic tail to the point where the field lines cannot support a trapped-particle population.

- Not Principal Investigator Group/Other Publications

A1-60 Dungey, J.W., "Reconnection Model of the Magnetosphere," Earth's Particles and Fields, 385-392, 1968. (Proceedings of the NATO Advanced Study Institute, Freising, West Germany, July 31 - August 11, 1967, Ed., B.M. McCormac, Reinhold Book Corp., New York.)

The consequences of reconnection between the field lines of the interplanetary and geomagnetic fields are pursued and attempts are made to relate these to existing or possible observations. In addition to earlier interpretations relating polar substorms to tail reconnection, certain phenomena preceding substorms may be associated with dayside reconnection. The boundaries of the reconnection model are complex and, in particular, the model predicts a diffuse boundary at high latitudes at times of dayside reconnection. The observed variability of the interplanetary field leads to the prediction that the tail has several branches which represent obstacles in the magnetosheath, these obstacles moving more slowly than the surrounding plasma. Some boundaries may be detected by the standard magnetic and plasma observations and some may be associated with spikes of energetic particles even beyond the shock. North-south asymmetry of the tail is also discussed.

A1-61 "Explorer 18 (1963 46A) Magnetic Field Experiment," National Space Science Data Center, NSSDC 67-34, Aug. 1967.

A1-62 Hundhausen, A.J., "Solar Wind Disturbances Associated with Solar Activity," Intercorrelated Satellite Observations Related to Solar Events, 111-129, 1970. (Proceedings of the 3rd ESLAB/ESRIN Symposium, Noordwijk, Netherlands, Sept. 16-19, 1968. Eds., V. Manno, D.E. Page, D. Reidel Publishing Company, Dordrecht, Holland.)

Review and interpretation of spacecraft observations of two different classes of geomagnetic activity, long attributed to particle emission from active solar regions. Major emphasis is placed on the flare-associated phenomena. The role of multiple satellite measurements in studying the propagation and spatial structure of interplanetary disturbances is considered.

A1-63 Kodama, M., "Day-to-Day Variation of Cosmic Ray Diurnal Variation and Interplanetary Magnetic Field," (in Japanese), Reports of the Institute of Physical and Chemical Research, 45, No. 2, 34-42, 1969.

A1-64 Nishida, A., "Interplanetary Origin of DP Electric Fields," University of Tokyo, Institute of Space and Aeron. Sci., Unnumbered, Undated.

Correlational analysis between the activity of polar magnetic disturbances and the condition of the interplanetary magnetic field is reviewed and the origin of the magnetospheric electric fields responsible for the disturbances is discussed. Two distinct kinds of disturbances are produced under the influence of the north-south component B_z of the interplanetary magnetic field. The first of these, DP 2, follows the state of B_z closely with a delay of 15 minutes or so, while the other, DP 1 (polar substorm), typically breaks up 1 to 2 hours after the decrease in B_z. The results are discussed in the light of the reconnection model of the magnetosphere, and it is suggested that DP 2 is the immediate consequence of the penetration of the interplanetary electric field into the magnetosphere, while DP 1 follows the collapse of the field lines which are accumulated to the tail in the course of the convective motion under the DP 2 electric field.

A1-65 Pai, G.L., V. Sarabhai, and M. Wada, "Anisotropy of Galactic Cosmic Rays and Their Interplanetary Magnetic Field," Nature, 206, 703-704, May 1965.

Identification of some of the parameters defining an anisotropy of primary galactic cosmic rays, using the measurements of the interplanetary magnetic field during the period from Nov. 27, 1963, to Feb. 17, 1964, obtained from the IMP-1 satellite. The data provide evidence for the first time that, on a majority of days when T_{max} and T_{min} are between 6 and 9 h, there is a virtual sink of galactic cosmic rays toward the Sun along the spiraling interplanetary magnetic field.

There is in addition a virtual source close to the 1800 direction, but significantly tilted by a small angle (≈ 15 to 20°) toward the Sun. On the other hand, when the anisotropy is mainly sinusoidal, the source is more nearly along the 1800 direction. An explanation for the sink is considered to be possibly related to the scattering by magnetic field irregularities of cosmic rays as they penetrate into the solar system along the spiraling lines of force and mirror at some point close to the Sun.

A1-66 Schatten, K.H., "Large-Scale Configuration of the Coronal and Interplanetary Magnetic Field," University of California, Ser. 9, Iss. 39, Aug. 1968. (Ph.D. Thesis.)

A physical model that is consistent with many of the properties observed in the corona and in interplanetary space has been developed. The model allows the large-scale magnetic field configuration above the photosphere to be computed from photospheric magnetic field observations utilizing a Green's function solution to Maxwell's equations. Sources for the magnetic field are related to the observed photospheric field and to the field computed at a "source" surface about 0.6 solar radii above the photosphere. The model is able to explain the shape of rays and streamers in the inner corona.

The model allows a computation of the magnetic field configuration from the photosphere to the "source" surface. Comparisons with interplanetary magnetic field observations suggest the model is able to trace the open field lines leading from the sun. Coronal green line observations suggest that the closed loop pattern in the inner corona may also be traced.

Comparisons with interplanetary magnetic field observations suggest that new photospheric magnetic features do not make their presence known to the interplanetary sector pattern for about a solar rotation. The photospheric source for the interplanetary field during this period in the rising portion of the present solar cycle appears to be poleward of 25°. The "nozzle" and "mapping" hypotheses are discussed with reference to the model.

The interplanetary magnetic field has been mapped between 0.4 and 1.2 AU in the ecliptic plane, extrapolating from satellite measurements at 1 AU. Structure within interplanetary sectors is related to the effects of the solar wind velocity gradient upon the magnetic field.

Evolution of interplanetary sectors is discussed with particular reference to the development of a particular solar active region. The region appears to produce magnetic loops in the interplanetary medium that result in the formation of a new away-from-the-sun sector. The development of the region is consistent with the "source" surface model calculations that show the development of magnetic loops in the inner corona. The evolution of the region is also suggested by the coronal green line observations. The magnetic fluxes in the bipolar region, the magnetic loop and the resultant sector are in good agreement both in sense and in magnitude. The development of the interplanetary magnetic loops and the new away-from-the-sun sector occurs more than a solar rotation after the initial appearance of the active region.

A1-67 Shevnin, A.D., and Ya.I. Fel'dshteyn, "Dimensions of Cross Section of Magnetotail at Different Intensities of Polar Magnetic Disturbances," Cosmic Res., 6, 730-735, Nov.-Dec. 1968.

Geomagnetic field data measured on the IMP-1 and Explorer-33 satellites, and the position of the southern boundary of the polar auroral oval were used to compute the equatorial semiaxis of the transverse cross section of the elliptically shaped tail of the magnetosphere at a distance of 10 to 80 earth's radii. As the polar disturbances gain in intensity, the contraction of the tail by the solar wind begins to dominate over the expansion of the tail due to the increase in the magnetic flux threading the tail as the southern boundary of the auroral oval shifts toward the equator.

A1-68 Shevnin, A.D., and Ya.I. Fel'dshteyn, "Dimensions of the Magnetosphere Tail's Cross Section at Various Intensities of Polar Disturbances," NASA-GSFC, ST-PF-GM-10792, Jan. 1969. (Trans. from Kosmicheskiye Issledovaniya, 6, 870-876, 1968.)

The elliptically shaped magnetosphere tail's equatorial semiaxis is computed at the distances from 10 to 80 Earth's radii on the basis of magnetic field measurements on AES "IMP-1" and "EXPLORER-33". It is shown that, as polar disturbances increase, the process of tail contraction by solar wind prevails over the expansion due to the increase of magnetic flux in the tail, as the southern boundary of the oval shifts toward the equator.

A1-69 Starkov, G.V., Ya.I. Fel'dshteyn, and A.D. Shevnin, "Magnetic Field in the Tail of the Magnetosphere and Its Dimensions," NASA-GSFC, ST-PF-GM-10692, Mar. 1968. (Trans. from Kosmicheskiye Issledovaniya, 6, 153-154, 1968.)

Discussion of the magnetic-field intensity in the tail of the magnetosphere as a function of the equivalent amplitude of the magnetic activity index on the dark side of the earth. It is shown that the field intensity increases with increasing magnetic disturbances. This is in good agreement with the results of a direct comparison between the field intensity in the tail of the magnetosphere and the value of the K_p index.

A1-70 Troitskaia, V.A., Ya.I. Fel'dshteyn, and R.V. Shepetnov, "PI2 Pulsations, Polar Aurorae Ovals, and the Plasma Density in the Magnetosphere," (in Russian), Akademiia Nauk SSSR, Doklady, 186, 575-577, May 1969.

A1-71 Wilcox, J.M., "Solar and Interplanetary Magnetic Fields," Science, 152, 161-166, Apr. 1966.

The IMP 1 magnetometer experiment observed the interplanetary medium during three solar rotations. Vector measurements with an uncertainty of $\pm$ 1/4 gamma were obtained every 20 sec and averaged at 5.46-min intervals. The influence of the sun on the interplanetary

magnetic field was investigated with respect to a 27-day solar rotation. The region of the sun producing peaks in the interplanetary field was determined to be within 10 to 15 deg of the center of the visible disk. The IMP 1 results also suggested that the field is directed away from the sun for an interval corresponding to about 2/7 of the total circumference, then toward the sun for a 2/7 circumference, then away for a 2/7 circumference interval, and the toward the sun for an interval of about 1/7 circumference. A sector description of the magnetic field pattern of the sun is derived. The analysis of the results has implications for the study of the stellar magnetic fields.

A1-72 Wilcox, J.M., "Solar System Magnetic Fields and Plasmas," Dynamics of Fluids and Plasmas, 433-450, 1966. (Proceedings of a Symposium, University of Maryland, College Park, Md., Oct. 7-9, 1965. Ed., S.I. Pai, Academic Press, Inc., New York.)

Observations of the solar magnetic field in the photosphere with the solar magnetograph, and at a distance from the sun of one astronomical unit with spacecraft magnetometers, are discussed with relation to a physical picture in which the expanding solar wind plasma stretches lines of magnetic force from the photosphere out into the interplanetary medium beyond the earth. The evolution of solar magnetic fields is described beginning with their first appearance in sunspots and bipolar magnetic regions, which then form unipolar magnetic regions and the fields in the polar regions of the sun. A relationship is established between the direction of the photospheric magnetic field at low solar latitudes and the direction of the interplanetary field as observed by spacecraft near the earth. A large-scale longitudinal structure in the interplanetary medium is discussed in which the magnetic field is directed away from the sun for several days and then toward the sun for several days. Finally, the simulation in laboratory experiments of the interaction between the streaming magnetized solar plasma and the dipole-like magnetic field of the earth is described.

B1 Magnetometer

N.F. Ness NASA/Goddard Space Flight Center

Each of two uniaxial fluxgate magnetometers, having dynamic ranges of ±40γ, sampled the magnetic field 30 times within each of six 4.8-sec intervals every 5.46 min. Detector sensitivities were ±0.25γ, and digitization uncertainty was ±0.40γ. A rubidium vapor magnetometer was used to calibrate the fluxgates but did not produce an independently useful data set. The fluxgates functioned normally throughout the useful life of the satellite, and provided usable data through April 5, 1965.

- Principal Investigator Group/Major Journals

B1-01 Anderson, K.A., J.H. Binsack, and D.H. Fairfield, "Hydromagnetic Disturbances of 3- to 15-Minute Period on the Magnetopause and Their Relation to Bow Shock Spikes," J. Geophys. Res., 73, 2371-2386, 1968.

Analysis of data from IMP 2 magnetopause crossings to reveal the character of the motion of the magnetospheric boundary. This boundary is found to be almost always in motion. The spatial amplitudes vary from roughly 0.2 to 2.2 R_E, and the motion is sometimes periodic. The characteristic times of the motion usually range from 3 to 15 min. Sometimes longer-period motions are encountered, probably owing to solar-wind pressure changes. The 3 to 15-min motions are believed to be due to hydromagnetic disturbances on the magnetopause. The existence of these large-amplitudes waves on the magnetopause show that this is not a stable boundary, but the relevant instability cannot be established by the present experiment. However, the magnetopause motions can be shown to be coherent over distances of the order of 10 R_E, since the bow-shock motions measured on the same satellite pass are found to have well correlated amplitudes and characteristic times. Further evidence for the association of energetic electron bow shock spikes with motions of the magnetopause is given. A further experimental result is that the intense bow shock electron spikes lie in the magnetosheath just behind the bow shock. It is suggested that the origin of the electron spikes is in dissipation of hectometer-wave energy.

B1-02 Fairfield, D.H., "Average and Unusual Locations of the Earth's Magnetopause and Bow Shock," NASA-GSFC, X-692-70-452, Dec. 1970. (Accepted for publication in J. Geophys. Res.)

See abstract under A1-03.

B1-03 Fairfield, D.H., "Average Magnetic Field Configuration of the Outer Magnetosphere," J. Geophys. Res., 73, 7329-7338, 1968.

See abstract under A1-04.

B1-04 Fairfield, D.H., "Ordered Magnetic Field of the Magnetosheath," J. Geophys. Res., 72, 5865-5877, 1967.

See abstract under A1-05.

B1-05 Fairfield, D.H., and N.F. Ness, "Magnetic Field Measurements with the IMP 2 Satellite, J. Geophys. Res., 72, 2379-2402, 1967.

Description of IMP 2 satellite measurements of magnetic fields in interplanetary space. Two onboard monoaxial fluxgate magnetometers measured these magnetic fields, the magnetosheath, and the magnetosphere during the time interval between launch and Apr. 7, 1965. Analysis of over 325 hr of interplanetary data distributed throughout the first two months of operation revealed structuring of the interplanetary magnetic field into four recurring sectors of approximately equal size. Average fields within each sector were directed either toward or away from the sun near the theoretical spiral angle. High magnitudes and increased geomagnetic activity tended to occur early in the sectors and lower fields and quiet conditions at the end. Field directions in the magnetosheath were found to be highly dependent on sector direction. Results suggest that fields convected through the bow shock front undergo compression and an angle change at the shock and subsequently tend to become aligned tangent to the magnetopause.

B1-06 Ness, N.F., and J.M. Wilcox, "Interplanetary Sector Structure, 1962-1966," Solar Phys., 2, 351-359, Nov. 1967.

See abstract under A1-11.

- Principal Investigator Group/Conference Journals

B1-07 Behannon, K.W., and N.F. Ness, "Satellite Studies of the Earth's Magnetic Tail," Physics of the Magnetosphere, 409-434, 1968. (Proceedings of the Summer Institute, Physics of the Magnetosphere, Boston College, Boston, Mass., June 19-28, 1967. Eds., R.L. Carovillano, J.F. McClay, H.R. Radoski, D. Reidel Publishing Co., Dordrecht, Holland.)

See abstract under A1-20.

B1-08 Fairfield, D.H., "Magnetic Field of the Magnetosphere and Tail," NASA-GSFC, X-616-69-124, Apr. 1969. (Paper to be published in the Proceedings of the Leningrad Conference on Solar Terrestrial Physics, May 1970.)

See abstract under A1-21.

B1-09 Fairfield, D.H., "Polar Magnetic Disturbances and the Interplanetary Magnetic Field," Space Res. VIII, 107-119, 1968. (Proceedings of Open Meetings of Working Groups of the 10th Plenary Meeting of COSPAR, London, England, July 25-28, 1967.)

IMP 2 magnetic field measurements in the magnetosheath and in interplanetary space have been compared with polar magnetic disturbances. Ground disturbance on a 2.5 minute time scale is represented by the universal time index AE prepared from the digitized magnetograms of six auroral zone observatories. The AE index is compared to the satellite field measurements for intervals totaling more than 600 hours in October and November 1964. Investigation of the magnetosheath or interplanetary directions distributions when ground conditions are quiet or disturbed shows that southward fields are associated with disturbed conditions and northward fields with quiet times. Large disturbances are found to correspond almost exclusively to southward fields and especially to large southward fields. The results indicate the importance of the magnetic field in the coupling mechanism which allows solar wind plasma energy to be converted into energy associated with the ionospheric currents of the auroral electrojet. The results support the reconnection field model where interplanetary field lines connect to geomagnetic field lines producing plasma flow in and around the magnetosphere which drives the high latitude currents.

- Principal Investigator Group/Other Publications

B1-10 Ness, N.F., "Observations of the Interaction of the Solar Wind with the Geomagnetic Field During Quiet Conditions," Solar-

Terrestrial Physics, 57-89, 1967. (Academic Press Inc., London, England.)

See abstract under A1-34.

- Not Principal Investigator Group/Major Journals

B1-11 Kawashima, N., "Analysis of Fluctuations in the Interplanetary Magnetic Field Obtained by IMP-II," J. Geophys. Res., 74, 225-230, 1969.

Data from the IMP 2 magnetic experiment obtained in interplanetary space are analyzed to study the character of the fluctuations in the magnetic field from the MHD point of view. The fluctuation in interplanetary space is quite anisotropic relative to the steady magnetic field, with the fluctuations transverse to the magnetic line of force much larger than the longitudinal component of fluctuations. This anisotropy gradually decays as the amplitude of the fluctuation increases and tends to become rather isotropic. These fluctuations may be related to the thermal anisotropy of solar wind ions, with the conversion of the transverse fluctuations into the longitudinal ones occurring by means of a nonlinear effect when the amplitude of the fluctuation grows above a certain level. Frequency dependence of the mode of fluctuations is also investigated.

B1-12 Meng, C.-I., "Variation of the Magnetopause Position with Substorm Activity," J. Geophys. Res., 75, 3252-3254, June 1970.

Locations of the magnetopause near the noon meridian observed by IMP 2 satellite are compared with the polar substorm activity indicated by the hourly AE index. The use of the AE index is an improvement of earlier studies, which were based on the Kp and ap indices. We find that a distended magnetosphere is associated with geomagnetic quiet conditions (low AE values). When polar substorms are in progress, the magnetosphere is in a compressed condition.

B1-13 Wilcox, J.M., "Asymmetry in Geomagnetic Response to the Polarity of the Interplanetary Magnetic Field," J. Geophys. Res., 73, 6835-6836, 1968.

See abstract under A1-56.

B1-14 Wilcox, J.M., and R. Howard, "Large-Scale Pattern in the Solar Magnetic Field," Solar Phys., 5, No. 4, 564-574, Dec. 1968.

See abstract under A1-57.

B1-15 Wilcox, J.M., and R. Howard, "Persistent Solar Magnetic Pattern Extending Over Equatorial Latitudes," Phys. Rev. Letters, 20, No. 22, 1252-1254, May 1968.

See abstract under A1-58.

- Not Principal Investigator Group/Other Publications

B1-16 Dungey, J.W., "Reconnection Model of the Magnetosphere," Earth's Particles and Fields, 385-392, 1968. (Proceedings of the NATO Advanced Study Institute, Freising, West Germany, July 31- August 11, 1967. Ed., B.M. McCormac, Reinhold Book Corp. New York.)

See abstract under A1-60.

B1-17 Wilcox, J.M., "Solar and Interplanetary Magnetic Fields," Science, 152, 161-166, Apr. 1966.

See abstract under A1-71.

C1 Magnetometer

N.F. Ness NASA/Goddard Space Flight Center

Each of two uniaxial fluxgate magnetometers had a dynamic range of ±40γ and a sensitivity of ±0.25γ. One fluxgate failed at launch, but the other performed normally, sampling the magnetic field 30 times within each of six 4.8-sec intervals every 5.46-min. Uncertainties in data values are ±1.0γ. Useful fluxgate data were transmitted until May 11, 1967. A rubidium vapor magnetometer was included in the experiment package, but it produced no useful data.

- Principal Investigator Group/Major Journals

C1-01 Behannon, K.W., and D.H. Fairfield, "Spatial Variations of the Magnetosheath Magnetic Field," Planetary Space Sci., 17, No. 10, 1803-1816, Oct. 1969.

Measurements by Explorers 28, 33, 34, and 35 have been used to study the spatial characteristics of the magnetic field in the magnetosheath to a distance of 70 R_E behind the earth. Results indicate that the magnetosheath field is several times the strength of the simultaneously measured interplanetary field in the sunward magnetosheath. This magnetosheath to interplanetary magnitude ratio decreases with distance from the subsolar point to values which are frequently less than unity at distances beyond 30 R_E and away from the bow shock. This ratio also displays a dawn-dusk asymmetry which is dependent on the interplanetary field orientation. Interplanetary field lines perpendicular to the earth-sun line are associated with symmetrically distorted magnetosheath field lines in the dawn and dusk hemispheres and are consistent with the draping of field lines around the magnetosheath. When the interplanetary field is aligned near the spiral angle, fields measured in the dusk hemisphere are much more ordered than those measured in the dawn hemisphere behind the earth.

C1-02 Fairfield, D.H., "Average and Unusual Locations of the Earth's Magnetopause and Bow Shock," NASA-GSFC, X-692-70-452, Dec. 1970. (Accepted for publication in J. Geophys. Res.)

See abstract under A1-03.

C1-03 Fairfield, D.H., "Average Magnetic Field Configuration of the Outer Magnetosphere," J. Geophys. Res., 73, 7329-7338, 1968.

See abstract under A1-04.

C1-04 Fairfield, D.H., "Simultaneous Measurements on Three Satellites and the Observation of the Geomagnetic Tail at 1000 Earth Radii," J. Geophys. Res., 73, 6179-6187, 1968.

Analysis of simultaneous magnetic-field measurements in the interplanetary medium in front of the earth and in the magnetosheath near the earth-sun line 60 to 1000 R_E (earth radii) behind the earth. During the last week of September 1966 the heliocentric orbiting spacecraft Pioneer 7 was behind the earth in a position to observe the geomagnetic tail between 900 and 1050 R_E. At the same time Explorer 28 and Explorer 33 were monitoring the interplanetary medium and the magnetosheath near the earth. Comparison of these simultaneous magnetic-field measurements permits the isolation of intervals when Pioneer 7 is observing steady, enhanced-magnitude solar or antisolar-directed fields characteristic of the extended geomagnetic tail. These fields are different from the interplanetary fields convecting past the other two spacecraft. The occurrence of approximately 10 intervals of tail observation of duration from a few minutes to several hours is interpreted as a sweeping of the tail across the spacecraft as the tail responds to variations in the direction of plasma flow. Discontinuous features in the interplanetary magnetic field are also found to convect past the three spacecraft with velocities that compare well with interplanetary solar-wind velocities measured by the Vela satellites at the same time.

C1-05 Hundhausen, A.J., S.J. Bame, and N.F. Ness, "Solar Wind Thermal Anisotropies, Vela 3 and IMP 3," J. Geophys. Res., 72, 5265-5274, 1967.

Solar wind proton velocity distribution functions derived from Vela 3 satellite observations made during July and August 1965 are usually anisotropic in a frame of reference moving with the bulk velocity of the medium. The orientations of these anisotropic distributions are compared with the directions of the interplanetary magnetic field measured on the IMP 3 satellite. On Aug. 3, 4, and 5, 1965, under relatively quiet conditions, the direction of maximum proton temperature was aligned with that of the magnetic field lines. The detailed temporal behavior of the anisotropy and field directions followed the same pattern during periods of slow changes and during the passage of a "magnetic filament" past both satellites. The alignment of the anisotropic distributions and the field lines is shown to hold for the 33-day period for which these data have been compared. Some consequences of the possible plasma instabilities implied by this situation are suggested.

C1-06 Ness, N.F., "Geomagnetic Tail," Reviews of Geophysics, 7, 97-128, 1969.

See abstract under A1-07.

C1-07 Ness, N.F., "Simultaneous Measurements of the Interplanetary Magnetic Field," J. Geophys. Res., 71, 3319-3324, 1966.

Discussion of the preliminary results of a comparison of interplanetary magnetic-field measurements obtained with Pioneer 6 and the IMP-3 satellite. The comparison makes it possible to study the similarity of differences of individual spatial or temporal variations of the interplanetary field from two separate space vehicles.

C1-08 Ness, N.F., and J.M. Wilcox, "Interplanetary Sector Structure, 1962-1966," Solar Phys., 2, 351-359, 1967.

See abstract under A1-11.

C1-09 Schatten, K.H., N.F. Ness, and J.M. Wilcox, "Influence of a Solar Active Region on the Interplanetary Magnetic Field," Solar Phys., 5, 240-256, 1968.

See abstract under A1-14.

C1-10 Schatten, K.H., J.M. Wilcox, and N.F. Ness, "Model of Interplanetary and Coronal Magnetic Fields," Solar Phys., 6, No. 3, 442-455, Mar. 1969.

A model of the large-scale magnetic field structure above the photosphere uses a Green's function solution to Maxwell's equations. Sources for the magnetic field are related to the observed photospheric field and to the field computed at a "source" surface about 0.6 R_E above the photosphere. The large-scale interplanetary magnetic field sector pattern is related to the field pattern at this "source" surface. The model generates magnetic field patterns on the "source" surface that compare well with interplanetary observations. Comparisons are shown with observations of the interplanetary magnetic field obtained by the IMP 3 satellite.

C1-11 Taylor, H.E., "Sudden Commencement Associated Discontinuities in the Interplanetary Magnetic Field Observed by IMP-3," Solar Phys., 6, 320-334, 1969.

The magnetic field measurements made by the magnetic field experiment on the IMP 3 (Explorer 28) spacecraft have been examined at the time of geomagnetic s.s.c. events. 36 such events occurred while IMP-3 was in the interplanetary medium during 1965, 66, and 67 and have been analyzed. Of these events 8 must have been tangential discontinuities, 2 are either tangential discontinuities or rotational discon-

tinuities and 26 are possible shock waves. These 26 possible shocks have similar magnetic signatures an increase of 20% or more in the magnetic field magnitude and a relatively small (always less than 90°) change in direction. The larger s.s.c. events were more likely to be caused by possible shocks while the smaller events were often associated with tangential discontinuities. It was possible to associate solar flares with 14 of the 26 possible shock events. Of these 14 a reliable orientation was deduced for 8 events.

- Principal Investigator Group/Conference Proceedings

C1-12 Behannon, K.W., and N.F. Ness, "Satellite Studies of the Earth's Magnetic Tail," Physics of the Magnetosphere, 409-434, 1968. (Proceedings of the Summer Institute, Physics of the Magnetosphere, Boston College, Boston, Mass., June 19-28, 1967. Eds., R.L. Carovillano, J.F. McClay, H.R. Raddski, D. Reidel Publishing Co., Dordrecht, Holland.)

See abstract under A1-20.

C1-13 Fairfield, D.H., "Magnetic Field of the Magnetosphere and Tail," NASA-GSFC, X-616-69-124, Apr. 1969. (Paper to be Published in the Proceedings of the Leningrad Conference on Solar Terrestrial Physics, May 1970.)

See abstract under A1-21.

C1-14 Wilcox, J.M., N.F. Ness, and K.H. Schatten, "Active Regions and the Interplanetary Magnetic Field," Structure Development Solar Active Regions, 390-394, 1968. (IAU Symposium No. 35, Proceedings held in Budapest, Hungary, Sept. 4-8, 1967.)

See abstract under A1-27.

- Principal Investigator Group/Other Publications

C1-15 Ness, N.F., "Magnetic Structure of Interplanetary Space," NASA-GSFC, X-616-69-334, Aug. 1969.

See abstract under A1-32.

C1-16 Ness, N.F., "Observations of the Interaction of the Solar Wind with the Geomagnetic Field During Quiet Conditions," Solar-Terrestrial Physics, 57-89, 1967. (Academic Press Inc., London, England.)

See abstract under A1-34.

C1-17 Ness, N.F., and H.E. Taylor, "Observations of the Interplanetary Magnetic Field July 4-12, 1966," Annals of the IQSY, 3, 366-374, 1969.

This report discusses simultaneous observations of the interplanetary magnetic field by three widely separated satellites: Explorers 28, 33, and Pioneer 6 during 4-12 July 1966. These data establish the general macrostructure of the field in cislunar space and include the micro-structural feature of the shock wave associated with the geomagnetic sudden commencement (SC) at 2102 on July 8, 1966. Preliminary results and analyses reveal a remarkable correspondence of the measurements by the geocentric satellites Explorer 28 and 33. The very limited data coverage by Pioneer 6 precludes a similar comparison, but is included because the satellite was separated in heliocentric longitude by +44° (with respect to the earth). Thus it provides unique data relative to the region on the Sun (N34, W45) where a class 2B flare occurred on 7 July 0022.

- Not Principal Investigator Group/Major Journals

C1-18 Arnoldy, R.L., "Signature in the Interplanetary Medium for Substorms, J. Geophys. Res., 76, 5189-5201, 1971.

A detailed signature for individual substorms is sought in the interplanetary medium. Hourly values of interplanetary field and plasma parameters are correlated with hourly averages of the AE index. An interplanetary variable involving the southward component of the interplanetary field in the solar magnetospheric coordinate system is shown to be singularly important for the generation of substorms. The parameter best correlated with AE (0.8 correlation coefficient) is the integral or summation of B_z south over time for the hour preceding the AE hourly average. The magnitude of this integral appears to be linearly related to the hourly average of AE. The linearity suggests that the southward interplanetary field represents a continuing dynamic mechanism for the production of substorms rather than just being a trigger for the release of energy that has been stored in the magnetospheric tail. Furthermore, the additional energy that the southward component of the interplanetary field apparently puts into the tail is not accumulated for longer than about 1 hour before it appears as a substorm. A linear fit to AE that uses interplanetary parameters is obtained for two time intervals of data.

C1-19 Green, I.M., E.W. Greenstadt, G.T. Inouye, and C.P. Sonett, "Oblique Shock of the Proton Flare of 7 July 1966," Planetary Space Sci., 18, No. 3, 333-347, Mar. 1970.

The proton flare of July 7, 1966 initiated a shock in the solar wind which arrived at the earth on the 8th, and was observed by three satellite magnetometers on Explorer 33, Imp 3, and Vela 3A, all outside the magnetosphere. The positions of the three spacecraft and the times of shock observation combine to give a kinematically determined local shock normal pointing 65-70 deg below the ecliptic plane at solar ecliptic longitude 165 deg. The sense of obliquity of the shock is consistent with the position of the flare in the heliographic Northwest quadrant. The high degree of obliquity to the ecliptic suggests a tongue shaped shock possibly caused by the horizontal configuration and/or high latitude of the flare.

C1-20 Hruska, A., and J. Hruskova, "Transverse Structure of the Earth's Magnetotail and Fluctuations of the Tail Magnetic Field," J. Geophys. Res., 75, 2449-2457, 1970.

The analysis is based on 5.46-min magnetic field averages measured by the IMP 3 satellite. The effect of the inclination χ of the earth's magnetic axis with respect to the Y; Z-plane of solar magnetospheric coordinates (perpendicular to the earth-sun line) is studied in detail, and a thick sheet of magnetic field depression is shown to exist around the neutral sheet at distances of 30 to 38 R_E in the antisolar direction. The location of the region of magnetic field depression varies with the value of χ; the thickness of the depression region is about 10 R_E in the central parts of the tail, $Y \approx 0$, and is probably higher for $Y > 10\ R_E$. The region of magnetic field depression is identified with the plasma sheet. The sheet of magnetic field depression is characterized by very large, long time-scale fluctuations parallel to the average local magnetic field. A 'flapping motion' of the neutral sheet may be responsible for the large values of some of these fluctuations. The fluctuations perpendicular to local magnetic field are nearly independent of position in the magnetotail. Both types of fluctuations are enhanced during and/or after sudden storm commencements (ssc) and sudden impulses (si) observed at ground stations. The effect is more clearly seen in the perpendicular fluctuations. The information from the interaction between the magnetosphere and a discontinuity in the interplanetary medium is transferred mainly along the lines of force.

C1-21 Iijima, T., and T. Nagata, "Constitution of Magnetospheric Storms," Ann. Geophys., 26, No. 2, 417-426, Apr.-June 1970.

See abstract under A1-47.

C1-22 Meng, C.-I., and S.-I. Akasofu, "Magnetospheric Substorm Observations Near the Neutral Sheet," J. Geophys. Res., 76, 4679-4684, July 1971. (Letter)

C1-23 Nishida, A., "DP 2 and Polar Substorm," Planetary Space Sci., 19, 205-221, 1971.

The morphological distinction between DP 2 fluctuations and polar substorms (DP 1) is explained, and the relation between these two modes of the disturbance is examined. It is found that although DP 1 and 2 tend to occur together, they are not coherent, indicating that they are driven by different electric field systems. This distinction between DP 2 fluctuations and sudden impulses is also discussed.

C1-24 Schatten, K.H., and J.M. Wilcox, "Response of the Geomagnetic Activity Index K_p to the Interplanetary Magnetic Field," J. Geophys. Res., 72, 5185-5191, 1967.

Interplanetary magnetic field data obtained by IMP 3 during eight solar rotations in the latter half of 1965 have been compared

with the 3-hr K_p index. The results are consistent with those obtained by IMP 1 during three solar rotations in the winter of 1963-1964, indicating a stability in the response of geomagnetic activity during these years near solar activity minimum. On the average an interplanetary magnetic field with a southward component is generally more geomagnetically effective than a field with a northward component. This is consistent with the reconnection of interplanetary and geomagnetic field lines as suggested by Dungey (1961). As a function of interplanetary field magnitude B, the average value of the index a_p is more linear than K_p, as might be expected. The relation can be described by $(a_p) = (1.5 \pm 0.1)\ B + 0.7 \pm 0.5$. In the time interval covered by these observations the average value of K_p is consistently higher in sectors with the interplanetary field directed away from the sun than in sectors with the field directed toward the sun.

C1-25 Wilcox, J.M., "Asymmetry in Geomagnetic Response to the Polarity of the Interplanetary Magnetic Field," J. Geophys. Res., 73, 6835-6836, 1968.

See abstract under A1-56.

- Not Principal Investigator Group/Other Publications

C1-26 Dungey, J.W., "Reconnection Model of the Magnetosphere," Earth's Particles and Fields, 385-392, 1968. (Proceedings of the NATO Advanced Study Institute, Freising, West Germany, July 31 - August 11, 1967. Ed., B.M. McCormac, Reinhold Book Corp., New York.)

See abstract under A1-60.

C1-27 Hundhausen, A.J., "Solar Wind Disturbances Associated with Solar Activity," Intercorrelated Satellite Observations Related to Solar Events, 111-129, 1970. (Proceedings of the 3rd ESLAB/ESRIN Symposium, Noordwijk, Netherlands, Sept. 16-19, 1969. Eds., V. Manno, D.E. Page, D. Reidel Publishing Company, Dordrecht, Holland.)

See abstract under A1-62.

C1-28 Nishida, A., "Interplanetary Origin of DP Electric Fields," University of Tokyo, Institute of Space and Aeronautical Science, Unnumbered, Undated.

See abstract under A1-64.

C1-29 Schatten, K.H., "Large-Scale Configuration of the Coronal and Interplanetary Magnetic Field," University of California, Ser. 9, Iss. 39, Aug. 1968. (Ph.D. Thesis)

See abstract under A1-66.

C1-30 Swinson, D.P., "Sidereal Cosmic Ray Diurnal Variations Observed Underground," Acta Physica Academiae Scientiarum Hungaricae, 29, Supplement 1, 501-506, 1970. (Proceedings of the 11th International Conference on Cosmic Rays, Budapest, Hungary, 1969.)

C1-31 Wilcox, J.M., "Solar and Interplanetary Magnetic Fields," Science, 152, 161-166, Apr. 1966.

See abstract under A1-71.

D1 GSFC Magnetometer

N.F. Ness NASA/Goddard Space Flight Center

The instrumentation for this experiment consisted of a boom-mounted triaxial fluxgate magnetometer. Each of the three sensors had a range of ±64γ and a digitization resolution of ±0.25γ. Zero-level drift was checked by periodic reorientation of the sensors. Spacecraft fields at the sensors were not greater than the digitization uncertainty. One vector measurement was obtained each 5.12 sec. The bandpass of the magnetometer was 0 to 5 Hz, with a 20-db per decade falloff for higher frequencies. The detector functioned well between launch and October 10, 1968, but it provided no useful data after that date.

- Principal Investigator Group/Major Journals

D1-01 Behannon, K.W., "Geometry of the Geomagnetic Tail," J. Geophys. Res., 75, 743-753, 1970.

An analysis of magnetic field measurements in the geomagnetic tail from Explorers 33 and 35 during 1967-1968 has shown that there is a broad region of depressed field magnitude approximately 12 R_E thick and centered on the neutral sheet. The solar magnetospheric B_Z component is proportionately larger within that region than outside of it. B_Z is found to decrease with distance from the earth but to be positive on average within the depressed field region out to a distance of 70 R_E, indicating that while for short periods of time the neutral line may be closer to the earth than the orbital distance of the moon, on average it is beyond that distance. A negative B_Z component was found in 2/3 of the measurements outside the depressed field region. This analysis has shown that the magnetotail field diverges on the order of 5° from the tail axis. This result together with the B_Z observations supports a geometry in which for large $|Z_{sm}|$ the tail field is diverging in the Z_{sm} as well as the Y_{sm} direction, but is converging slightly toward the neutral sheet within the depressed field region. The observed divergence produces an increase in the radius of the tail of approximately 3.8 R_E between distances of 20 R_E and 70 R_E from the earth. The combination of expanding tail and reconnection at the neutral sheet can account for an inverse power law field magnitude gradient of the form $B \propto |X|^{-0.3}$. The Explorer 33 and 35 measurements also indicate that the geomagnetic tail has an average aberration of 2.9 ± 0.2°.

D1-02 Behannon, K.W., "Mapping of the Earth's Bow Shock and Magnetic Tail by Explorer 33," J. Geophys. Res., 73, 907-930, 1968.

The Explorer 33 satellite was launched July 1, 1966 and was injected into a highly elliptical earth orbit. The magnetic field experiment onboard the spacecraft consists of a triaxial fluxgate sensor with a maximum dynamic range of ± 64 gammas and a sensitivity of ± 0.25 gammas along each axis. Because of the initial apogee-earth-sun angle of 118° west of the sun, the first 8 orbits of Explorer 33 (July 1 to Nov. 11, 1966) mapped the earth's magnetosheath and magnetic tail from the western flank of the bow shock to the eastern flank. This mapping of the geomagnetic tail out to 80 earth radii established that the tail extends beyond the lunar orbital distance. Explorer 33 has also found that the earth's bow shock is still a detectable boundary between the interplanetary magnetic field and the downstream magnetosheath at a geocentric distance of 75.7 earth radii. The measurements have further suggested that the cross section of the geomagnetic tail is probably not cylindrical and have shown that the magnetic field magnitude in the tail decreases with distance down the tail from the earth.

D1-03 Behannon, K.W., and D.H. Fairfield, "Spatial Variations of the Magnetosheath Magnetic Field," Planetary Space Sci., 17, No. 10, 1803-1816, Oct. 1969.

See abstract under C1-01.

D1-04 Burlaga, L.F., and N.F. Ness, "Tangential Discontinuities in the Solar Wind," Solar Phys., 9, No. 2, 467-477, Oct. 1969.

Six discontinuity surfaces which were observed by magnetometers on 3 spacecraft in the solar wind are considered. It is shown that the actual surface orientations, determined from the measured time delays and solar wind speed, are consistent with the theoretical orientations which were computed from the relation $n = B \times B'$, where n is the normal to the surface of a hydromagnetic tangential discontinuity across which the magnetic field direction changes from B to B'. The plasma and magnetic field data for these discontinuities are consistent with the pressure balance condition, and the magnetic field vectors in the associated current sheets are parallel to the discontinuity surface, as required theoretically. The 6 discontinuity surfaces extended without much distortion over $\approx$ .002 AU. A seventh surface is discussed which satisfied the condition $n = B \times B'$ but which extended without much distortion over 0.02 AU. Most of the surfaces tended to lie along the spiral direction, but one was nearly perpendicular to the spiral direction.

D1-05 Fairfield, D.H., "Average and Unusual Locations of the Earth's Magnetopause and Bow Shock," NASA-GSFC, X-692-70-452, Dec. 1970. (Accepted for publication in J. Geophys. Res.)

See abstract under A1-03.

D1-06 Fairfield, D.H., "Simultaneous Measurements on Three Satellites and the Observation of the Geomagnetic Tail at 1000 Earth Radii," J. Geophys. Res., 73, 6179-6187, 1968.

See abstract under C1-04.

D1-07 Ness, N.F., "Geomagnetic Tail," Reviews of Geophysics, 7, 97-128, 1969.

See abstract under A1-07.

D1-08 Ness, N.F., K.W. Behannon, S.C. Cantarano, and C.S. Scearce, "Observations of the Earth's Magnetic Tail and Neutral Sheet at 510,000 Kilometers by Explorer 33," J. Geophys. Res., 72, 927-933, 1967.

Direct measurements of the earth's magnetic tail at distances beyond the lunar orbit have been performed by a magnetometer carried on the Explorer 33 satellite. The general characteristics of the tail and imbedded neutral sheet are observed to be similar to those reported earlier by IMP 1 at half the lunar distance. Field magnitudes of 10 to 18 γ are found, and the field direction closely parallels the earth-sun line. These results indicate that once each lunar orbit the moon is immersed within the geomagnetic tail for periods up to 4 days. Also the moon may frequently be located within the neutral sheet during these intervals. A preliminary report of data obtained in July-August 1966 is presented.

D1-09 Sonett, C.P., J.D. Mihalov, and N.F. Ness, "Concerning the Electrical Conductivity of the Moon," J. Geophys. Res., 76, 5172-5179, 1971.

The response of the moon to a large discontinuity in the interplanetary magnetic field with $|\Delta B| = 6\gamma$, observed by the lunar satellite Explorer 35, is examined on the basis of presently available theoretical models. A simplified model of the poloidal mode response of the moon to such a discontinuity predicts that its effects will be undetectable at satellite altitude. Ness has earlier presented an interpretation with respect to the electrical conductivity of the lunar interior. The absence of a bow or limb shock wave suggests that the toroidal mode response of the moon is also undetectable at satellite altitudes.

D1-10 Taylor, H.E., K.W. Behannon, and N.F. Ness, "Measurements of the Perturbed-Interplanetary Magnetic Field in the Lunar Wake," J. Geophys. Res., 73, 6723-6735, 1968.

Measurements of the interplanetary magnetic field in the vicinity of the moon have been made from lunar orbit on Explorer 35. No shocks are observed in the vicinity of the moon, either in front of the moon or within 5.4 R_M behind the moon. The interplanetary magnetic field

appears to be convected past the lunar body without much distortion. A regular pattern of magnetic perturbations is observed when passing through the lunar wake. The perturbation amplitude is small and variable, typically less than 30% of the ambient interplanetary magnetic field. Simultaneous measurements made by Explorer 33 while in the interplanetary medium but not in the lunar wake show that even sharp changes in the interplanetary magnetic field are found essentially undistorted in the lunar wake. These simultaneous measurements also help to identify the magnetic perturbation pattern in the wake region.

D1-11 Van Allen, J.A., and N.F. Ness, "Observed Particle Effects of an Interplanetary Shock Wave on July 8, 1966," J. Geophys. Res., 72, 935-942, 1967.

At 2106 UT on July 8, 1966, a distinctive, discontinuous drop in the intensities of solar protons $E_p \sim 0.5$ Mev was observed by Explorer 33 in interplanetary space at 187,000 km in the antisolar direction from the earth. The protons had been emitted by the sun in a flare whose onset time was 0027 UT on July 7. The intensity drop is attributed to the effects of an interplanetary shock wave whose detailed structure was observed by a triaxial flux gate magnetometer on the same satellite.

D1-12 Van Allen, J.A., and N.F. Ness, "Particle Shadowing by the Moon," J. Geophys. Res., 74, 71-93, 1969.

Evaluation of observations made by Explorer 33 and Explorer 35 during the period from Nov. 10 to 22, 1967, when the earth-moon system was bathed in an isotropic, homogeneous beam of solar electrons and protons whose intensities were slowly varying functions of time. During this period, the moon and Explorer 35 passed from interplanetary space through the magnetotail. The angular distributions of the intensity of both electrons and protons were accurately isotropic within the magnetotail as well as in interplanetary space. Study of 33 cases of clear electron shadowing and two cases of less clear shadowing suggests the following principal conclusions: (1) magnetic lines of force from external sources thread through the moon in a rectilinear manner, as though it did not exist, and (2) electron shadowing data provide no direct information on the region of access of interplanetary electrons into the magnetotail, but do provide an upper limit on the trans-B diffusion velocity of electrons due to all causes.

- Principal Investigator Group/Conference Proceedings

D1-13 Behannon, K.W., and N.F. Ness, "Satellite Studies of the Earth's Magnetic Tail," Physics of the Magnetosphere, 409-434, 1968. (Proceedings of the Summer Institute, Physics of the Magnetosphere, Boston College, Boston, Mass., June 19-28, 1967. Eds., R.L. Carovillano, J.F. McClay, H.R. Radoski, D. Reidel Publishing Co., Dordrecht, Holland.)

See abstract under A1-20.

D1-14 Fairfield, D.H., "Magnetic Field of the Magnetosphere and Tail," NASA-GSFC, X-616-69-124, Apr. 1969. (Paper to be published in the Proceedings of the Leningrad Conference on Solar Terrestrial Physics, May 1970.)

See abstract under A1-21.

- Principal Investigator Group/Other Publications

D1-15 Behannon, K.W., H.E. Haney, and H.E. Taylor, "AIMP D and E Magnetic Field Analysis," NASA-GSFC, X-616-68-382, Oct. 1968.

The Goddard Space Flight Center has flown triaxial magnetometers on board AIMP'S D and E, launched in July, 1966 and 1967, respectively. The digital data tapes from these experiments provide the initial inputs to the AIMP D and E Data Processing System. The first stage of this processing system, the Phase I Analysis, converts the raw sensor data to magnetic units, merges it with the trajectory data, rotates to solar ecliptic and other useful coordinate systems and computes statistics. In addition to providing plots of the raw data, subsequent computer programs in the system smooth the data, sort it by time and remove any time overlap. The AIMP E data receive additional processing to correct for errors in magnetic field azimuth in the optical shadow of the moon. The resulting final summary data tapes are then used to generate hourly averages, spectra and automatic plots in various formats. This document describes the programs comprising the processing system, including instructions for the use of the programs, the formats of AIMP data tapes, and examples of output.

D1-16 Ness, N.F., and H.E. Taylor, "Observations of the Interplanetary Magnetic Field July 4-12, 1966," Annals of the IQSY, 3, 366-374, 1969.

See abstract under C1-17.

D1-17 Scearce, C.S., "GSFC Magnetic Field Experiment, Explorers 33 and 35," NASA-GSFC, X-616-69-53, Feb. 1969.

Explorer 33 and 35 are spin stabilized spacecraft launched by NASA from the Eastern Test Range, Cape Kennedy, Florida on July 1, 1966 and July 19, 1967. The primary mission of these spacecraft was to be placed in an orbit about the moon to study the properties of the moon and the earth's magnetic tail at a distance of 60 R_E, with an alternate mission having a highly eccentric earth orbit. Due to the small velocity errors associated with the launch vehicle, the alternate mission had to be selected for Explorer 33, (Madden 1966). Initial apogee was 450,000 Km and perigee in excess of 30,000 Km and an orbital life time in excess of 180 days. Explorer 35 was placed into a lunar orbit on July 22, 1967.

The AIMP Spacecraft telemetry system is based upon the PFM systems used in the earlier IMP programs. The data format consists of 16 frames each containing 16 channels which make up one sequence of data. Each channel has two sub-channels, each being a 160 ms burst of signal at a

frequency between 312.5 Hz to 937.5 Hz for analog data transmission, or a value between 400 Hz (equivalent to a binary 1111) and 775 Hz (equivalent to a binary 0000) in steps of 25 Hz for digital data transmission. A 275 Hz signal is transmitted at channel 0) every odd frame for a unique sync pulse. This system provides a bit rate of 40 bits per second (BPS) for analog data and 25 BPS for digital data. The basic time reference for the telemetry is one sequence (81.92 seconds) in which 1320 digital data bits, approximately 975 analog data bits and 128 synchronization bits are transmitted for an average bit rate of 29.6 BPS.

The GSFC Magnetic Field Experiment makes a vector measurement (three orthogonal components, 8 bits each, for 24 bits per measurement) every frame (5.12 seconds) at channel 4. These data are transmitted during channels 1, 2, 3 and 9, 10, 11 every odd frame. An 8 bit engineering status word is transmitted once every sequence during channel 12, frame 15.

- Not Principal Investigator Group/Major Journals

D1-18 Nishida, A., and K. Maezawa, "Two Basic Modes of Interaction Between the Solar Wind and the Magnetosphere," J. Geophys. Res., 76, 2254-2264, 1971.

By using Explorer 33 and 35 interplanetary plasma and magnetic field data, it is confirmed that there are at least two basic modes in the interaction mechanism between the solar wind and the magnetosphere. The first is the change in the magnetospheric dimension that results from changes in the solar wind dynamic pressure exerted at the magnetopause, and the second is the fluctuation in the magnetospheric DP 2 electric field that is related to fluctuations in the north-south component of the interplanetary magnetic field. Whereas the first can be interpreted essentially by the classical Chapman-Ferraro theory, the second suggests that the interplanetary electric field penetrates deep into the magnetosphere.

D1-19 Webber, W.R., and J.A. Lockwood, "Cosmic-Ray Intensity Variations on January 26-27, 1968," J. Geophys. Res., 74, 5599-5610, 1969.

Discussion of a Forbush decrease of about 4 percent recorded on Jan. 26, 1968, by the Mt. Washington cosmic-ray neutron monitor after an SC magnetic storm. This event is of interest because of the presence of large anisotropies in the cosmic-ray flux, both within and perpendicular to the ecliptic plane during the event, and because satellite data on the interplanetary field and the primary cosmic-ray flux outside any influences of the geomagnetic field are available in addition to the neutron monitor counting rates. In principle, this makes it possible to separate the local geomagnetic perturbations of the cosmic-ray intensity from the modulation in the earth-sun region.

D2 Ames Magnetometer

C.P. Sonett NASA/Ames Research Center

The Ames magnetometer experiment consisted of a boom-mounted triaxial fluxgate magnetometer and an electronics package. The sensors were orthogonally mounted with one sensor oriented along the spin axis of the spacecraft. A motor interchanged a sensor in the spin plane with the sensor along the spin axis every 24 hr, allowing inflight calibration. The instrument package included a circuit for spin demodulating the outputs from the sensors in the spin plane. The noise threshold was <0.4γ. The instrument had three ranges covering ±20, ±60, and ±200γ full scale for each vector component. The digitization accuracy was 1% of the entire range covered for each range. The magnetic field vector was measured instantaneously, and the instrument range was changed after each measurement. A period of 2.05 sec elapsed between adjacent measurements and 6.14 sec between measurements using the same range. The instrument performance was normal until the final spacecraft transmission on May 31, 1971.

- Principal Investigator Group/Major Journals

D2-01 Green, I.M., E.W. Greenstadt, G.T. Inouye, and C.P. Sonett, "Oblique Shock of the Proton Flare of 7 July 1966," Planetary Space Sci., 18, No. 3, 333-347, Mar. 1970.

See abstract under C1-18.

D2-02 Hirshberg, J., "Interplanetary Magnetic Field During the Rising Part of the Solar Cycle," J. Geophys. Res., 74, 5814-5818, 1969.

See abstract under A1-45.

D2-03 Hirshberg, J., A. Alksne, D.S. Colburn, S.J. Bame, and A.J. Hundhausen, "Observation of a Solar Flare Induced Interplanetary Shock and Helium-Enriched Driver Gas," J. Geophys. Res., 75, 1-15, 1970.

On February 13, 1967, a class 3B solar flare occurred at 20°N, 10°W. The resultant disturbance in the solar wind was observed by the Los Alamos plasma probe on Vela 3A and the Ames Research Center magnetometer on Explorer 33. The initial discontinuity in the solar wind was identified as a shock. The normal to the shock made an angle of 60° with the plane of the ecliptic. This extreme angle of tipping indicates that the shock from this flare did not propagate spherically from the sun as described by simple theory. Nine hours after the shock passed, plasma containing 22% helium was observed. Since the solar wind normally contains 4% helium, this observation adds to the increasing body of evidence that flares occur in regions relatively rich in helium. The velocity of the solar wind continued to increase after the helium plasma passed, i.e., at 1 AU the helium-enriched material was still being propelled from behind. This observation is evidence that the plasma continued to be accelerated at the sun for an extended period of time after the flash phase of the flare.

D2-04 Mihalov, J.D., "On Geomagnetic Tail Structure Near the Null Sheet," Planetary Space Sci., 18, No. 12, 1845-1847, Dec. 1970.

The solar magnetospheric coordinate system (X,Y,Z) employed in this note is right-handed and orthogonal, with $+X$ in the solar direction and $+Z$ northward and parallel to a plane that contains Earth's geomagnetic dipole and the X axis. Geomagnetic tail structure normal to the solar-magnetospheric X-Y plane is studied here using hourly average field data from Ames magnetometers on Explorer 33 and Explorer 35 (lunar orbiter).

D2-05 Mihalov, J.D., D.S. Colburn, R.G. Currie, and C.P. Sonett, "Configuration and Reconnection of the Geomagnetic Tail," J. Geophys. Res., 73, 943-959, 1968.

A description of certain aspects of the geomagnetic tail is made using data from the magnetometer on the Explorer 33 satellite. The general shape corresponds with earlier findings of Ness and coworkers. The tail is found regular to distances greater than 82 R_E. The field values for $K_p < 2\pm$ vary from a low of about 4 γ to a high value of 40 γ. Generally the values are in the neighborhood of 10 to 20 γ. A distinct skewing of the field lines away from the solar-antisolar direction is observed, such that an added component of magnetic field in the direction of planetary motion is present on both sides of the region of field reversal. The skewing appears to be greatest near the region of field reversal. Increase in field magnitude with increasing Kp is observed. The radial gradient can be shown to fit a power or exponential law with near equal validity. A correlation analysis of field magnitude with radial distance, ap, and transverse position coordinates, also is discussed. A radial gradient cannot be detected in the outermost half of the data (beyond 58 R_E), although significant correlation with geomagnetic activity remains. No significant cross gradient, apart from a radial gradient, is observed in the tail field. Strong evidence for reconnection of field lines is found, and statistics are presented for a dual mechanism regarding the residual Z field across the region of field reversal. The tail structure seems patchy at the neutral sheet, both near the magnetopause and near satellite apogee.

D2-06 Mihalov, J.D., and C.P. Sonett, "Cislunar Geomagnetic Tail Gradient in 1967," J. Geophys. Res., 73, 6837-6842, 1968. (Letter)

In this letter, the geomagnetic tail gradient during the summers of 1966 and 1967 is examined for secular change. Data from the Ames magnetometers on Explorers 33 and 35 are used. Because the 1967 data are at geocentric distances of less than 66 earth radii, the results presented have different weighting with respect to geocentric distance, compared with the previously published 1966 data that extended to geocentric distances at 81 earth radii.

D2-07 Severny, A., J.M. Wilcox, P.H. Scherrer, and D.S. Colburn, "Comparison of the Mean Photospheric Magnetic Field and the Interplanetary Magnetic Field," Solar Phys., 15, 3-14, 1970.

The mean photospheric magnetic field of the sun seen as a star has been compared with the interplanetary magnetic field observed with spacecraft near the earth. Each change in polarity of the mean solar field is followed about 4 1/2 days later by a change in polarity of the interplanetary field (sector boundary). The scaling of the field magnitude from sun to near earth is within a factor of two of the theoretical value, indicating that large areas of the sun have the same predominant polarity as that of the interplanetary sector pattern. An independent determination of the zero level of the solar magnetograph has yielded a value of 0.1 ± 0.05 G. An effect attributed to a delay of approximately one solar rotation between the appearance of a new photospheric magnetic feature and the resulting change in the interplanetary field is observed.

D2-08 Sonett, C.P., J.D. Mihalov, and N.F. Ness, "Concerning the Electrical Conductivity of the Moon," J. Geophys. Res., 76, 5172-5179, 1971.

See abstract under D1-09.

D2-09 Wilcox, J.M., and D.S. Colburn, "Interplanetary Sector Structure in the Rising Portion of the Sunspot Cycle," J. Geophys. Res., 74, 2388-2392, 1969.

The interplanetary sector structure during the rising portion of the sunspot cycle in 1966 and 1967 has been investigated. The sector pattern is often quasi-stationary for a few rotations, followed by an appreciable change in the next rotation. When a sector boundary passes the earth, geomagnetic activity tends to increase, an effect rather similar to that observed near sunspot minimum. The recurrence period of the interplanetary field during the interval investigated was 27.5 ± 0.1 days.

D2-10 Wilcox, J.M., and D.S. Colburn, "Interplanetary Sector Structure Near the Maximum of the Sunspot Cycle," J. Geophys. Res., 75, 6366-6370, 1970.

- Principal Investigator Group/Conference Proceedings

D2-11 Sonett, C.P., D.S. Colburn, R.G. Currie, and J.D. Mihalov, "Geomagnetic Tail, Topology, Reconnection and Interaction with the Moon," Physics of the Magnetosphere, 461-484, 1968. (Proceedings of the Summer Institute, Physics of the Magnetosphere, Boston College, Boston, Mass., June 19-28, 1967, Ed., R.L. Carovillano, J.F. McClay, H.R. Radoski, D. Reidel Publishing Co., Dordrecht, Holland.)

The geometry of the geomagnetic tail is assessed using data from the Ames magnetometer on the Explorer 33 satellite. The general shape corresponds to the earlier findings of Ness and co-workers. The tail

is found regular to distances greater than 82 R_e. The field values vary for $K_p \leq 2+$ from a low of about 4 gamma to a high value of 40 gamma. Generally the values are near 10 to 20 gamma. A distinct skewing of the field lines away from the solar-antisolar direction is observed, such that an added component of magnetic field in the direction of planetary motion is present on both sides of the null plane. The skewing appears to be greatest near the null plane. Increase in field magnitude with increasing K_p is observed. The radial gradient can be shown to fit a power or exponential law with near equal validity. A correlation analysis of field magnitude with radial distance, ap, and transverse position coordinates is also discussed. Little cross gradient is observed in the tail field. Strong evidnece for reconnection of field lines is found, and statistics are presented for a dual effect regarding the residual Z field across the null plane. Interaction of the tail field with the moon is discussed in terms of the mechanism of Sonett and Colburn.

- Principal Investigator Group/Other Publications

D2-12 Greenstadt, E.W., I.M. Green, and D.S. Colburn, "Earth's Bow Shock, Elapsed-Time Observations by Two Closely Spaced Satellites," Science, 162, 898-901, 1968.

Coordinated observations of the earth's bow shock were made as Vela 3A and Explorer 33 passed within six earth radii of each other. Elapsed time measurements of shock motion give directly determined velocities in the range 1 to 10 km/sec and establish the existence of two regions, one of large amplitude magnetic "shock" oscillations and another of smaller, sunward, upstream oscillations. Each region is as thick as 1 earth radius, or more.

D2-13 Wilcox, J.M., A. Severny, and D.S. Colburn, "Solar Source of Interplanetary Magnetic Fields," Nature, 224, 353-354, Oct. 1969.

Investigation of the relation between the mean magnetic field of the sun and the sector structure of the interplanetary magnetic field. The solar magnetic field is compared with the polarity of the interplanetary magnetic field observed near the earth by the Ames Research Center magnetometers on the Explorer 33 and 35 spacecraft. A very close correspondence between these two magnetic fields can be seen.

- Not Principal Investigator Group/Major Journals

D2-14 Arnoldy, R.L., "Signature in the Interplanetary Medium for Substorms," J. Geophys. Res., 76, 5189-5201, 1971.

See abstract under C1-18.

D2-15 Aubry, M.P., and R.L. McPherron, "Magnetotail Changes in Relation to the Solar Wind Magnetic Field and Magnetospheric Substorms," J. Geophys. Res., 76, 4381-4401, 1971.

Substorm activity is known to be associated with changes in the solar wind parameters and the magnetotail configuration. In this paper we investigate whether the magnetotail changes occur only as a consequence of substorms or also as a direct consequence of changes in the solar wind parameters. Using data from several satellites (OGO 5, ATS 1, Imp 4, Explorer 33 and 35) and 17 ground magnetic observatories, we conclude that the tail responds to both changes in the north-south orientation of the interplanetary field and substorm activity. Specifically, we show the following. (1) A change from a northward to a southward interplanetary field causes a slow increase of the field to be recorded by a satellite within the lobe of the tail, and a thinning of the plasma sheet. (2) A change from a southward to a northward interplanetary field causes the plasma sheet to expand. In contrast, it seems that in the inner magnetosphere the distortion of the magnetic field due to a period of southward interplanetary field is not relieved by an interval of northward field but only through the occurrence of a substorm expansion. (3) A substorm expansion causes a slow decrease of the field within the lobe of the tail and an expansion of the plasma sheet.

D2-16 Dungey, J.W., and D.J. Southwood, "Ultra Low Frequency Waves in the Magnetosphere," Space Science Reviews, 10, 672-688, 1970.

The behaviour of continuous pulsations pc 2-5 observed on the ground has been known for some time. They seldom occur at night, their amplitudes generally increase towards the auroral zones and the sense of rotation of their polarisation often agrees with surface waves on the magnetopause. Recently ULF sonagrams for middle latitudes have shown systematic behaviour and dominant periods. Theoretical study of normal modes for symmetrical models is also well established. If the wave depends on longitude ϕ like $e^{im\phi}$, modes with large m are quasi-transverse and these are likely to be excited and will be emphasised.

The Kelvin-Helmholtz instability has recently been studied in a general formulation. For given fields and plasma properties on both sides of the boundary, a plot of critical wind speed against the direction of the wave fronts shows a cusp, meaning that for most directions of the wind the onset of instability will correspond to the cusp and the nature of the waves can be predicted from this. Almost circularly polarised waves are predicted confirming an earlier heuristic suggestion.

Magnetic data from Explorer 33 shows rather irregular disturbance near the magnetopause, but an integration designed to show the sense of rotation of the polarisation shows clear agreement. The disturbance outside the magnetopause also shows the predicted polarisation, indicating that a substantial part of it must be due to surface waves, whereas previously it was believed to be the turbulence of the magnetosheath.

Bounce resonance has also been invoked to excite ULF waves, particularly those observed at the geostationary orbit, which may also correspond to pg at the ground. They are remarkably regular and quite strictly transverse, suggesting large m. Energetic particles may then see a higher frequency as a result of their drift. A simple

picture of the exchange of energy is obtained using a frame rotating with the wave and it is seen that the wave can be driven by a spatial gradient in the energetic particles. The most important mechanism is due to the tilting of the field lines and the growth rate can be large. The reflection by the ionosphere requires further study.

D2-17 Wilcox, J.M., "Statistical Significance of the Proposed Heliographic Latitude Dependence of the Dominant Polarity of the Interplanetary Magnetic Field," J. Geophys. Res., 75, 2587-2590, 1970.

Discussion of observations of the polarity of the interplanetary magnetic field. A synoptic chart of photospheric magnetic fields observed with the solar magnetograph at Mount Wilson Observatory, for Bartels solar rotations 1800, 1801, and 1802 in the first half of 1965, is shown. A Bartels solar rotation begins 5 days before the corresponding Bartels geomagnetic rotation, thereby allowing for the transit time of solar wind plasma from sun to earth. This is a rectangular equal area projection. Light areas represent out-of-the sun polarity, and dark areas are inward polarity.

- Not Principal Investigator Group/Other Publications

D2-18 Fairfield, D.H., "Magnetic Field of the Magnetosphere and Tail," *NASA-GSFC, X-616-69-124, Apr. 1969. (Paper to be published in* the Proceedings of the Leningrad Conference on Solar Terrestrial Physics, May 1970.)

See abstract under D1-01.

D2-19 Hundhausen, A.J., "Solar Wind Disturbances Associated with Solar Activity," Intercorrelated Satellite Observations Related to Solar Events, 111-129, 1970. (Proceedings of the 3rd ESLAB/ESRIN Symposium, Noordwijk, Netherlands, Sept. 16-19, 1969. Eds., V. Manno, D.E. Page, D. Reidel Publishing Company, Dordrecht, Holland.)

See abstract under A1-62.

D2-20 Lindgren, S.T., "Solar and Galactic Cosmic Rays and the Interplanetary Magnetic Field 28 January - 25 February 1967," Acta Physica Academiae Scientiarum Hungaricae, 28, Supplement 2, 401-407, 1970. (Proceedings of the 11th International Conference on Cosmic Rays, Budapest, Hungary, 1969.)

Solar and galactic particle fluxes after the 28 January 1967 particle flare are discussed in relation to interplanetary field observations. A soft pre-event began at 0214 on 28 January. It shows modulation features carried by the solar wind from Explorer 22, 67 R_E upstream, to IMP-3, 15 R_E downstream from the earth. The interplanetary magnetic field shows a sudden, major change of direction in coincidence with the onset of the main event, which begins at 0835. New injections of ener-

getic protons take place late on 2 and 13 February. The enhanced diurnal variation seen by neutron monitors 31 January-7 February coincides well with a twofold increase in the magnitude of the interplanetary magnetic field. Several hours before a magnetic storm at the end of this period, the interplanetary magnetic field appears to be strongly squeezed; it enters the ecliptic plane from below at a Θ-angle of 60° and with a magnitude of 10 gammas.

D2-21 Shevnin, A.D., and Ya. I. Fel'dshteyn, "Dimensions of Cross Section of Magnetotail at Different Intensities of Polar Magnetic Disturbances," Cosmic Res., 6, 730-735, Nov.-Dec. 1968.

See abstract under A1-67.

E1 GSFC Magnetometer

N.F. Ness NASA/Goddard Space Flight Center

The experiment consisted of a boom-mounted triaxial fluxgate magnetometer. Each sensor had dual ranges of ±24γ and ±64γ, with digitization resolutions of ±0.94γ and ±0.25γ, respectively. Zero level drift was checked, until May 20, 1969, by periodic reorientation of the sensors. Spacecraft interference was <0.125γ. One vector measurement was obtained each 5.12 sec. The bandpass of the magnetometer was 0 to 5 Hz, with a 20-db per decade falloff for higher frequencies. The experiment has functioned normally from launch to the present (March 12, 1971).

• Principal Investigator Group/Major Journals

E1-01 Behannon, K.W., "Geometry of the Geomagnetic Tail," J. Geophys. Res., 75, 743-753, 1970.

See abstract under D1-01.

E1-02 Behannon, K.W., "Intrinsic Magnetic Properties of the Lunar Body," J. Geophys. Res., 73, 7257-7268, 1968.

Reversal of the ambient tail field by 180° when the moon and Explorer 35 in lunar orbit traverse the neutral sheet permits a separation of permanent and induced field contributions to the total field observed near the moon. When compared with calculated permanent and induced field effects, the results of this analysis lead to new upper limits of 10^{20} gauss cm^3 on the lunar magnetic moment and 4 γ on the lunar surface field. Limiting the moment induced in the moon by the magnetotail field permits an upper limit of 1.8 to be set on the bulk relative magnetic permeability of the moon.

E1-03 Behannon, K.W., and D.H. Fairfield, "Spatial Variations of the Magnetosheath Magnetic Field," Planetary Space Sci., 17, No. 10, 1803-1816, Oct. 1969.

See abstract under C1-01.

E1-04 Burlaga, L.F., and N.F. Ness, "Tangential Discontinuities in the Solar Wind," Solar Phys., 9, No. 2, 467-477, Oct. 1969.

See abstract under D1-04.

E1-05 Fairfield, D.H., "Average and Unusual Locations of the Earth's Magnetopause and Bow Shock," NASA-GSFC, X-692-70-452, Dec. 1970. (Accepted for publication in J. Geophys. Res.)

See abstract under A1-03.

E1-06 Ness, N.F., K.W. Behannon, C.S. Scearce, and S.C. Canterano, "Early Results from the Magnetic Field Experiment on Lunar Explorer 35," J. Geophys. Res., 72, 5769-5778, 1967.

Explorer 35 was injected into a selenocentric orbit on July 22, 1967. Analysis of measurements near periselene (800 km from the lunar surface) while the moon is within the geomagnetic tail suggest that the moon is not magnetized and that its moment is less than 4×10^{20} cgs units ($<10^{-5}$ of the earth). Rapid diffusion of interplanetary magnetic field lines through the lunar body limits the effective average electrical conductivity to a maximum value of 10^{-5} mho/m. Thus capture of interplanetary magnetic field lines by the moon and formation of a lunar magnetosphere as theorized by Gold are not substantiated. A lunar bow shock wave has not yet been observed when the moon is located in the interplanetary medium or the magnetosheath of the earth.

E1-07 Ness, N.F., K.W. Behannon, H.E. Taylor, and Y.C. Whang, "Perturbations of the Interplanetary Magnetic Field by the Lunar Wake," J. Geophys. Res., 73, 3421-3440, 1968.

Results of a study which indicate the absence of a detectable lunar bow shock wave. Using a theoretical model of plasma flow due to Whang, a first-order solution of the perturbed interplanetary magnetic field is compared with observations. It is concluded that the perturbations can be partially explained on the basis of the magnetization, gradient, and curvature currents induced in the disturbed solar plasma flow. The umbral increase and the innermost penumbral decrease are consistent with the first-order theory, and it is suggested that a high-order approximation is required to explain the newly detected penumbral increases and additional penumbral fluctuations.

E1-08 Ness, N.F., and K.H. Schatten, "Detection of Interplanetary Magnetic Field Fluctuations Stimulated by the Lunar Wake," J. Geophys. Res., 74, 6425-6438, 1968.

Analysis of detailed magnetic-field measurements in the vicinity of the moon has revealed the presence of rapid fluctuations up to the instrument bandpass of 5 Hz with amplitudes of several gammas. These disturbances are transmitted both up- and downstream from the penumbra into regions of space directly connected to the penumbra by the magnetic field. Similar fluctuations are not observed in the center of the lunar wake, the solar wind plasma umbra, where no plasma is present. Power spectral analyses made in a field-aligned coordinate system reveal that these fluctuations have approximately the same amplitude both parallel and transverse to the average field direction. Statistical studies are presented of the frequency of occurrence of the disturbances as a function of the distance to the point of observation from the lunar wake and of the fluctuation amplitude. These observations suggest that the fluctuations have their source where the solar wind proton and electron distribution functions are disturbed by the removal of particles by absorption by the moon.

E1-09 Ogilvie, K.W., and N.F. Ness, "Dependence of the Lunar Wake on Solar Wind Plasma Characteristics," J. Geophys. Res., 74, 4123-4128, 1969.

Simultaneous measurements in cislunar space of the characteristics of the solar wind plasma as observed by Explorer 34, and the perturbed magnetic field in the lunar wake as detected by Explorer 35, were performed. The plasma parameter for the ions was found to be more important in determining the magnitude of the umbral positive and penumbral negative anomalies than the direction of the interplanetary magnetic field. A quantitative comparison was made of these observations with the lunar wake theory of Whang.

E1-10 Ogilvie, K.W., and N.F. Ness, "Reply (To 'Dependence of the Lunar Wake on Solar Wind Plasma Characteristics')," J. Geophys. Res., 75, 234, 1970.

E1-11 Schatten, K.H., "Search for Magnetic Monopoles in the Moon," Phys. Rev., 1, No. 8, 2245-2251, Apr. 1970.

The effects of a possible magnetic charge of the moon upon the magnetic field in the lunar vicinity have been analyzed. Magnetic field observations obtained by the GSFC magnetometer aboard Explorer 35 have been studied to search for these effects. Using these observations it is possible to obtain a measure of the net difference between the number of northern and southern monopoles within the moon which are of opposite sign. The search has resulted in negative findings and places an approximate upper limit on the average difference in the number of monopoles within the moon at 1.6×10^{-7} cm^{-3} or 10^{-32} per nucleon.

E1-12 Sonett, C.P., J.D. Mihalov, and N.F. Ness, "Concerning the Electrical Conductivity of the Moon," J. Geophys. Res., 76, 5172-5179, 1971.

See abstract under D1-09.

E1-13 Taylor, H.E., K.W. Behannon, and N.F. Ness, "Measurements of the Perturbed-Interplanetary Magnetic Field in the Lunar Wake," J. Geophys. Res., 73, 6723-6735, 1968.

See abstract under D1-10.

E1-14 Van Allen, J.A., J.F. Fennell, and N.F. Ness, "Asymmetric Access of Energetic Solar Protons to the Earth's North and South Polar Caps," J. Geophys. Res., 76, 4262-4275, 1971.

During the energetic solar particle event that began on January 24, 1969, the ratio N/S of the intensity of protons $E_p > 0.3$ MeV over the earth's north (N) polar cap ($\Lambda > 80°$) to that over its south (S) polar cap ($-\Lambda > 80°$) varied from a value greater than 20 to about 1, as observed with satellite Injun 5 in a low altitude polar orbit. The interplanetary intensity of protons was measured simultaneously with similar detectors on Explorer 33 and Explorer 35 in two nearly-orthogonal planes and in eight different directions on the unit sphere (some overlap). High values of the N/S ratio early in the event corresponded to an extraordinarily strong anisotropy of intensity in interplanetary space with the anisotropy vector pointing dominantly southward. The N/S ratio dropped toward 1 as the interplanetary beam relaxed toward isotropy. Similar, though less well determined, findings applied to protons $E_p > 3.4$ MeV and alpha particles $E\alpha > 1.18$ MeV. The directions of interplanetary field lines that connect with the respective polar caps are uniquely identified by intensity considerations. The interplanetary magnetic vector was measured on Explorer 35 also. Early in the event, the earth was in a solar positive ($\vec{B}$ outward from the sun) magnetic sector ($\phi SE \approx 140°$), with a dominantly southward direction ($\Theta_{SE} \approx -40°$ to $-70°$). The anisotropy vector was approximately parallel to the magnetic vector and in the same sense. The composite evidence favors the direct access of energetic particles to the earth's polar caps via magnetic field lines interconnected between the terrestrial field and the interplanetary medium; it strongly contradicts models that contemplate diffusion across the magnetospheric tail as an important feature of particle access.

E1-15 Van Allen, J.A., and N.F. Ness, "Particle Shadowing by the Moon," J. Geophys. Res., 74, 71-93, 1969.

See abstract under D1-12.

E1-16 Whang, Y.C., "Field and Plasma in the Lunar Wake," Phys. Rev., 186, No. 1, 143-150, Oct. 1969.

A theory is presented to explain the observed variations of the magnetic field and plasma in the vicinity of the moon. Under the

guiding-center approximation, solutions for the plasma flow near the moon are obtained from the kinetic equation. The creation of a plasma cavity in the core region of the lunar optical shadow disturbs the interplanetary magnetic field. Maxwell's equations are used to study perturbations of the magnetic field in the lunar wake. The acceleration drift current, which was omitted from the earlier work, is included in the present theory in the calculation of the total electric current in the lunar wake. Numerical solutions of Maxwell's equations are obtained. When the interplanetary magnetic field lines penetrate into the lunar body, due to sudden change of magnetic permeability the magnetic field is disturbed at the lunar limbs. Propagations of this disturbance with magnetoacoustic speed form a Mach cone downstream, which is sometimes observed as the exterior increase of field magnitude in the lunar penumbra. Perturbations of the magnetic field are restricted to the region inside the Mach cone; the region outside remains undisturbed. The numerical results agree extremely well with experimental data from the Explorer 35 spacecraft.

E1-17 Whang, Y.C., "Interaction of the Magnetized Solar Wind with the Moon," Phys. Fluids, 11, No. 5, 969-975, May 1968.

The experimental results obtained from the Explorer 35 spacecraft indicate that a detached bow shock wave does not exist in the vicinity of the moon. Thus, the flow conditions near the moon do not resemble those near the magnetosphere of the earth. The solar-wind flow around the moon is treated theoretically as a free-molecule flow of guiding-center plasma. Analytical results are obtained to describe the ion flow in the vicinity of the moon. The disturbed region forms a long wake in the downstream of the moon. The thickness of the wake, measured perpendicular to the plane of the solar-wind velocity and the interplanetary magnetic field, is constant at one lunar diameter. On the other hand, the width of the wake, measured parallel to that plane, increases with distance from the moon.

E1-18 Whang, Y.C., "Theoretical Study of the Magnetic Field in the Lunar Wake," Phys. of Fluids, 11, 1713-1719, Aug. 1968.

When the solar wind interacts with the moon, the plasma shadow region on the dark side of the moon forms a long lunar wake. In the plasma umbra a detectable plasma flow is absent, and in the penumbra the plasma flux increases from the void condition in the umbra to the interplanetary condition outside. A theoretical model for perturbations of the magnetic field in the plasma shadow is studied by directly solving Maxwell's equations for steady-state solutions. The perturbation of the field is assumed to be due to the magnetization current, the gradient drift current, and the curvature drift current. Numerical solutions are obtained to describe the variations of the magnetic field, and the results are in good agreement with experimental observations from the Explorer 35 satellite.

E1-19 Whang, Y.C., and N.F. Ness, "Observations and Interpretation of the Lunar Mach Cone," J. Geophys. Res., 75, 6002-6010, 1970.

The existence of a lunar Mach cone in the flow of the magnetized, warm collisionless solar plasma has been determined from magnetometer data on Lunar Explorer 35. The axis of the Mach cone indicates that

the direction of the solar wind comes from ~4.5° west of the sun as viewed from the moon. Due to the variability of the magnetic field direction, the spacecraft has actually observed the three-dimensional wake region of the interaction of the solar wind with the moon. The lack of axial symmetry of the observed lunar Mach cone provides the first experimental evidence for the anisotropic propagation of magneto-acoustic waves in the solar wind. The average Mach angle is found to be ~8° in the directions perpendicular to the magnetic field vector, and ~5.5° in the direction parallel to the field leading to a velocity anisotropy of $V_\perp/V_\parallel = 1.4$. This compares favorably with the nominal expected value in the solar wind of ~1.5, assuming $\beta = 1$ and $T_\parallel/T_\perp = 1.2$.

- Principal Investigator Group/Conference Proceedings

E1-20 Ness, N.F., "Electrical Conductivity and Internal Temperature of the Moon," Space Res., 10, 969-974, 1970. (Proceedings of 12th Plenary COSPAR Meeting, Prague, Czechoslovakia, 1969.)

Detailed measurements of the interplanetary magnetic field in the immediate vicinity of the moon have been performed since July 1967 by Lunar Explorer 35. The magnetic field is found to be only slightly distorted with no evidence for a bow shock wave. During the interval February to July 1968, periselene passed through the solar wind umbral region. A study of the propagation of discontinuities in the interplanetary magnetic field through the lunar body has been completed. The induction of electrical currents in the lunar interior indicates an effective time constant for eddy current decay of less than 20 seconds. This means an electrical conductivity of less than 10^{-4} mhos/meter in the lunar interior. The electrical conductivity of silicate rocks depends mainly upon temperature. Thus limitations on possible thermal models of the moon, consistent with the electrical conductivity measurements, can be obtained. These results are compared with various models of the thermal history to obtain a class of allowed lunar interiors. The conclusion is that the moon must be a relatively young body (1×10^9 years old) if it possesses a homogeneous heat source composition similar to chondritic meteorites. If differentiation of radiogenic heat sources near to the surface has taken place, the moon can be old (4×10^9 years).

E1-21 Ness, N.F., "Interaction of the Solar Wind with the Moon," NASA-GSFC, X-692-70-141, Apr. 1970. (Paper to be published in the Proceedings of the 'Inter-Union Commission on Solar-Terrestrial Physics' International STP Symposium, Leningrad, USSR, May 11-19, 1970.)

The current state of experimental and theoretical studies of the interaction of the solar wind with the moon is reviewed. The Explorer 35 has provided since July 1967 definitive experimental results regarding the perturbations of the interplanetary magnetic field and plasma in the lunar wake. The moon appears to behave as a nonmagnetic, non-electrically conducting fully absorbing spherical obstacle in the solar wind flow. The principle features of the plasma field perturbations are the following: A downwind plasma umbral void containing an enhanced interplanetary magnetic field only slightly perturbed in direction. A downward penumbral region aft of a rarefaction wave or Mach cone, ellip-

tical in cross sectional geometry, contains a reduced plasma flux and magnetic field. A very limited penumbral region, upwind of the lunar Mach cone, sometimes contains an enhanced magnetic field and plasma flux. A broad region both upstream and downstream from the lunar wake is connected to it by the interplanetary magnetic field in which rapid fluctuations of the magnetic field occur with an amplitude that decreases with distance from the wake.

E1-22 Ness, N.F., "Recent Results from Lunar Explorer 35," NASA-GSFC, X-616-68-335, Sept. 1968. (Paper presented at the Conference on the Physics of the Moon and Planets, Kiev, USSR, Oct. 1968.)

Measurements since July 1967 from lunar orbit by Explorer 35 have provided significant data on the moon and its environment. When the moon is imbedded in the geomagnetic tail, no intrinsic lunar magnetic field is detected, limiting its magnetic moment to 10^{20} cgs units, less than 10^{-6} of the earth's. This corresponds to an intrinsic lunar field of less than 40 μ Gauss on the lunar surface. The magnetic susceptibility of the moon is less than 1.8 μ_0 if the interior is below the Curie point. In interplanetary space no evidence is found for a bow shock wave due to the flow of the supersonic solar wind plasma past the moon. A solar plasma shadow or cavity evolves on the nightside of the moon as the moon absorbs the plasma with small perturbations of the magnitude and direction of the interplanetary magnetic field. The imbedded interplanetary magnetic field appears to diffuse as rapidly through the interior of the moon as the solar wind convectively transports it past the moon.

E1-23 Ness, N.F., Y.C. Whang, H.E. Taylor, and K.W. Behannon, "Solar Plasma Flow Past the Moon," Proceedings of the 6th International Symposium on Rarefield Gas Dynamics, 2, 1575-1586, 1969.

- Principal Investigator Group/Other Publications

E1-24 Behannon, K.W., H.E. Haney, and H.E. Taylor, "AIMP D and E Magnetic Field Analysis," NASA-GSFC, X-616-68-382, Oct. 1968.

See abstract under D1-15.

- Not Principal Investigator Group/Major Journals

E1-25 Krall, N.A., and D.A. Tidman, "Magnetic Field Fluctuations Near the Moon," J. Geophys. Res., 74, 6439-6443, 1969.

It is proposed that magnetic field fluctuations in the solar wind near the moon are due to ballistic effects, i.e., they derive from electrons recently arrived from regions of plasma turbulence and are not connected with either wave or stability properties in the regions where the fluctuations are observed.

E1-26 Michel, F.C., "Discussion of the Paper by K.W. Ogilvie and N.F. Ness, 'Dependence of the Lunar Wake on Solar Wind Plasma Characteristics'," J. Geophys. Res., 75, 233, 1970.

E1-27 Michel, F.C., "Lunar Wake at Large Distances," J. Geophys. Res., 73, 7277-7283, 1968.

The expected properties of the lunar wake at large distances are examined in light on the Explorer 35 data on the solar wind interaction with the moon. It is concluded that any geomagnetic activity expected by means of the interaction of this wake with the magnetosphere would be below the limit of detectability by present methods.

It is also concluded on the basis of energy conservation that the 14-15 December 1963 disturbance observed on Explorer 18 and interpreted by Ness to the wake of the moon was actually a disturbance already in the solar wind itself, and not generated by the moon, although the very mild disturbance of 11 February 1964 might be attributed to the lunar wake, as was suggested by Ness. The December disturbance involved at least two orders of magnitude more disturbance energy than we could attribute to a lunar source. The February disturbance is semiquantitatively consistent with turbulence being present in the lunar wake.

E1-28 Nishida, A., and K. Maezawa, "Two Basic Modes of Interaction Between the Solar Wind and the Magnetosphere," J. Geophys. Res., 76, 2254-2264, 1971.

See abstract under D1-18.

E1-29 Patel, V.L., "Sudden Impulses in the Geomagnetotail," J. Geophys. Res., 73, 3407-3419, 1968.

Magnetic field observations made by IMP 1 satellite are used to study sudden impulses (SIs) in the magnetospheric tail. A total of seven SIs that are correlated with the satellite data in the tail were observed terrestrially. Large and well-defined SIs in the surface magnetograms show definite correlation with the tail field. However, not all sudden changes observed in the tail field have associated SIs. The characteristics of these observed SIs are discussed, and velocities of the propagation in the tail from 870 to 1300 km per sec are obtained. There is an indication that some of the sudden impulses were originated in the tail and propagated to the surface of the earth. Also, in some events the sudden impulses originated on the sunward side of the magnetosphere and propagated into the tail. Possible mechanisms for the generation of the SIs are discussed. Two events of micropulsations associated with the sudden impulses are also found. In one case, the propagation of these micropulsations from the tail to the earth's surface appears to have been confined to 10° longitudinal range.

E1-30 Siscoe, G.L., E.F. Lyon, J.H. Binsack, and H.S. Bridge, "Experimental Evidence for a Detached Lunar Compression Wave," J. Geophys. Res., 74, 59-69, 1969.

The behavior of the solar-wind flux and direction measured on Explorer 35 in the near lunar wake is presented. The flux near the leading edge of the wake tends to be greater than the free-stream value and decreases below detectability near the wake axis. There is probably a small ($\lesssim 3°$) deflection of the wind away from the moon near the leading edge and a deflection toward the wake axis in the region of reduced flux. These features correlate well with variations in the magnetic field. An interpretation of the observed structure is offered that utilizes the theory of two-dimensional steady simple waves in magnetohydrodynamics. A novel feature of the interpretation is the inference of a deflection of the solar wind from the region of the lunar limb to account for the structure near the leading edge of the wake.

E2 Ames Magnetometer

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The Ames magnetometer experiment consisted of a boom-mounted triaxial fluxgate magnetometer and an electronics package. The sensors were orthogonally mounted, with one sensor oriented along the spin axis of the spacecraft. A motor interchanged a sensor in the spin plane with the sensor along the spin axis every 24 hr, allowing inflight calibration. The instrument package included a circuit for spin demodulating the outputs from the sensors in the spin plane. The noise threshold was $<0.4\gamma$. The instrument had three ranges covering ± 20, ± 60, and $\pm 200\gamma$ for each vector component. The digitization accuracy was 1% of the entire range covered for each range. The magnetic field vector was measured instantaneously, and the instrument range was changed after each measurement. A period of 2.05 sec elapsed between adjacent measurements and 6.14 sec between measurements using the same range. The instrument performance has been normal as of December 1970.

- Principal Investigator Group/Major Journals

E2-01 Colburn, D.S., J.D. Mihalov, and C.P. Sonett, "Magnetic Observations of the Lunar Cavity," J. Geophys. Res., 76, 2940-2957, 1971.

Data from the Ames magnetometer experiment on the lunar orbiter Explorer 35 are examined for a period exceeding 4 months and covering more than 200 orbits. The main features of the diamagnetic cavity disclosed earlier are confirmed. The magnetic signature of the cavity is a variable phenomenon, sometimes vanishing entirely and on rare occasions displaying a decreased field in the interior in contrast to the more common increase. A positive correlation of cavity field increases with K_p and proton thermal speed is consistent with a model based on simple diamagnetism. Exterior small perturbations of the interplanetary field often occur outside the diamagnetic signature. Exterior peak occurrences do not correlate well with cavity signals or

any obvious property of the interplanetary field, including magnitude, orientation, and noisiness; however, some control by orientation is not excluded. The peaks tend to occur at a lower proton thermal speed. The general lack of correlation and theoretical considerations indicate a solar-wind-limb interaction as the cause of the external peaks.

E2-02 Mihalov, J.D., "On Geomagnetic Tail Structure Near the Null Sheet," Planetary Space Sci., 18, No. 12, 1845-1847, Dec. 1970.

See abstract under D2-04.

E2-03 Mihalov, J.D., D.S. Colburn, and C.P. Sonett, "Observations of Magnetopause Geometry and Waves at the Lunar Distance," Planetary Space Sci., 18, 239-258, Feb. 1970.

Magnetic observations at the lunar distance of the magnetopause, or boundary between the geomagnetic tail and the magnetosheath, are surveyed. The boundary surfaces are shown to have normal vectors from which an average tail aberration induced by the earth's heliocentric motion of 9 (plus or minus 5) deg and a flaring half-angle of about 9 deg is found. The boundary is assumed to be a tangential discontinuity. The average ecliptic diameter of the tail at lunar distance is 50 earth radii. Using 21 normal vectors, a statistical variation transverse to the tail axis three times that along the axis is shown. This may correspond to magnetic perturbations induced by the Kelvin-Helmholtz instability; the variations of the unit normals are consistent with circumferential oscillations having wavelengths smaller by 1/3 to 1/10 than those of waves moving in the downstream direction. The circumferential oscillations appear to give evidence of fluting of the tail surface. Several distinct types of boundary signature are identified. Boundary speeds which usually exceed typical spacecraft velocities of about 1 km/sec are deduced from simple models of boundary motion. Implied boundary thicknesses are usually about 1000 km, but perhaps are as low as about 30 km in some instances. Use of Kp as an indicator of solar wind conditions does not reveal correlation with the number of multiple crossings or the changes in magnetic field magnitude across the boundary.

E2-04 Mihalov, J.D., and C.P. Sonett, "Cislunar Geomagnetic Tail Gradient in 1967," J. Geophys. Res., 73, 6837-6842, 1968. (Letter)

See abstract under D2-06.

E2-05 Severny, A., J.M. Wilcox, P.H. Scherrer, and D.S. Colburn, "Comparison of the Mean Photospheric Magnetic Field and the Interplanetary Magnetic Field," Solar Phys. 15, 3-14, 1970.

See abstract under D2-07.

E2-06 Sonett, C.P., D.S. Colburn, and R.G. Currie, "Intrinsic Magnetic Field of the Moon," J. Geophys. Res., 72, 5503-5507, 1967.

Description of preliminary magnetometer observations of the magnetic field in the near neighborhood of the moon taken during the first and second lunar orbits of Explorer 35. Only evidence that the moon contains no intrinsic magnetic fields with magnitude greater than 2 γ in this region and at the altitude of perilune is considered. It is noted that the transparency of the moon to steady-state tail fields does not rule out an electromagnetic interaction. Such an interaction will exist if the bulk electrical conductivity of the moon is sufficiently high. The highest impedance path to the closure of body currents to the neighborhood plasma will determine the strength of the interaction. An upper bound estimate of the strength of the interaction suggests that the perturbation field cannot rise to a level greater than 0.014 γ, since the interaction is strictly subsonic.

E2-07 Sonett, C.P., J.D. Mihalov, and N.F. Ness, "Concerning the Electrical Conductivity of the Moon," J. Geophys. Res., 76, 5172-5179, 1971.

See abstract under D1-09.

E2-08 Wilcox, J.M., and D.S. Colburn, "Interplanetary Sector Structure in the Rising Portion of the Sunspot Cycle," J. Geophys. Res., 74, 2388-2392, 1969.

See abstract under D2-09.

E2-09 Wilcox, J.M., and D.S. Colburn, "Interplanetary Sector Structure Near the Maximum of the Sunspot Cycle," J. Geophys. Res., 75, 6366-6370, 1970.

- Principal Investigator Group/Other Publications

E2-10 Colburn, D.S., R.G. Currie, J.D. Mihalov, and C.P. Sonett, "Diamagnetic Solar-Wind Cavity Discovered Behind Moon," Science, 185, 1040-1042, 1967.

Examination of preliminary Ames-magnetometer data from Explorer 35 (the lunar orbiter). The data show no evidence of a lunar bow shock, but an increase of the magnetic field by about 1.5 γ (over the interplanetary value) is evident on the moon's dark side, as well as dips in field strength at the limbs. Interpretation of these spatial variations in the field as derived from plasma diamagnetism is consistent with a plasma void on the dark side, and steady-state (B = 0) magnetic transparency of the moon.

E2-11 Wilcox, J.M., A. Severny, and D.S. Colburn, "Solar Source of Interplanetary Magnetic Fields," Nature, 224, 353-354, Oct. 1969.

See abstract under D2-13.

- Not Principal Investigator Group/Major Journals

E2-12 Arnoldy, R.L., "Signature in the Interplanetary Medium for Substorms, J. Geophys. Res., 76, 5189-5201, 1971.

See abstract under C1-18.

E2-13 Aubry, M.P., and R.L. McPherron, "Magnetotail Changes in Relation to the Solar Wind Magnetic Field and Magnetospheric Substorms," J. Geophys. Res., 76, 4381-4401, 1971.

See abstract under D2-15.

E2-14 Michel, F.C., "Lunar Wake at Large Distances," J. Geophys. Res., 73, 7277-7283, 1968.

See abstract under E1-27.

E2-15 Wilcox, J.M., "Statistical Significance of the Proposed Heliographic Latitude Dependence of the Dominant Polarity of the Interplanetary Magnetic Field," J. Geophys. Res., 75, 2587-2590, 1970.

See abstract under D2-17.

- Not Principal Investigator Group/Other Publications

E2-16 Parks, G.K., and R. Pellat, "Correlation of DP-2 Interplanetary Space Magnetic and Trapped Particle Fluctuations," U. of Toulouse, Toulouse, France, Unnumbered, Undated.

During two several hour intervals on August 26-27 and 29, 1967 when Nishida and Mazeawa (1971) reported observing DP-2 interplanetary magnetic field fluctuations, the ATS-1 geostationary satellite orbit covered the local times between noon and midnight. Since trapped ATS-1 electron fluxes in this local time sector are minimally affected by substorm activities (Lezniak and Winckler, 1970; Parks, 1970), a search was made to evaluate whether trapped radiation would be redistributed by these interplanetary fluctuations. This article will report and discuss observations of correlated interplanetary magnetic field and trapped particle fluctuations and deduce properties of the magnetospheric electric field from observations of particle redistribution effects. One conclusion reached in this preliminary study is that the interplanetary magnetic fluctuations of the DP-2 type represent a strong driving source for particle diffusion.

E2-17 Whang, Y.C., "Theoretical Study of the Magnetic Field in the Lunar Wake," Phys. of Fluids, 11, 1713-1719, Aug. 1968.

See abstract under E1-18.

F1 Magnetometer

N.F. Ness NASA/Goddard Space Flight Center

This experiment consisted of a triaxial fluxgate magnetometer. Each sensor had dual ranges of ±32γ and ±128γ, and digitization errors of ±0.16γ and ±0.64γ, respectively. Automatic range selection was included. The sensor parallel to the spin axis was on a 6-ft boom and was flipped every 3.9 days to check the zero level. The other two sensors were on a separate boom. Vector measurements were returned each 2.56 sec. An on board autocorrelation computer was included. Autocorrelation data based on 240 samplings were returned on alternate components each 20.45 sec. The experiment worked well until May 3, 1969 (spacecraft reentry date).

- Principal Investigator Group/Major Journals

F1-01 Behannon, K.W., and D.H. Fairfield, "Spatial Variations of the Magnetosheath Magnetic Field," Planetary Space Sci., 17, No. 10, 1803-1816, Oct. 1969.

See abstract under C1-01.

F1-02 Burlaga, L.F., K.W. Ogilvie, D.H. Fairfield, M.D. Montgomery, and S.J. Bame, "Energy Transfer at Colliding Streams in the Solar Wind," NASA-GSFC, X-692-70-270, July 1970. (Accepted for publication in Astrophys. J., 164, 1971.)

Processes occurring when a fast stream of solar plasma overtakes a slower one are investigated using Explorer 34 and Vela 4B measurements of the relevant proton, α-particle, electron and magnetic field parameters for 3 events. The protons are heated by an amount such that the maximum thermal speed approximately equals the relative speed of the 2 streams. The proton thermal anisotropy does not increase, indicating that either the heating is not due to hydromagnetic wave damping alone, or both MHD heating and an isotropization mechanism are operative. The α-particles are heated in proportion to the protons, but the electron temperature does not measurably increase. The magnetic field intensity reaches a maximum after the density, and the field fluctuations with frequencies $(1.5 \times 6) \times 10^{-3}$ Hz are unusually high in the hot spots but not adjacent to them. The hypothesis that such fluctuations are propagating from colliding streams is not supported. The proton density and temperature profiles are consistent with the results of a non-steady, non-linear adiabatic fluid model. A hydromagnetic 3-fluid model with heat conduction is needed to explain the other observations.

F1-03 Burlaga, L.F., and N.F. Ness, "Tangential Discontinuities in the Solar Wind," Solar Phys. 9, No. 2, 467-477, Oct. 1969.

See abstract under D1-04.

F1-04 Burlaga, L.F., K.W. Ogilvie, and D.H. Fairfield, "Microscale Fluctuations in the Interplanetary Magnetic Field," Astrophys. J., 155, L171-L175, Mar. 1969.

Results of simultaneous measurements of the interplanetary plasma and magnetic field, obtained during 1967 by the Explorer 34 satellite. The results show that microscale magnetic-field fluctuations are governed by the local balance between the proton thermal energy density and the magnetic-field energy density.

F1-05 Fairfield, D.H., "Average and Unusual Locations of the Earth's Magnetopause and Bow Shock," NASA-GSFC, X-692-70-452, Dec. 1970. (Accepted for publication in J. Geophys. Res.)

See abstract under A1-03.

F1-06 Fairfield, D.H., "Bow Shock Associated Waves Observed in the Far Upstream Interplanetary Medium," J. Geophys. Res., 74, 3541-3553, 1969.

Fifty orbits of Explorer 34 data have been used to study 0.01-0.05 Hz transverse waves in the interplanetary medium region between the bow shock and the spacecraft apogee of 34 R_E. It is concluded that the waves are associated with the earth's bow shock since they only occur when projection of the interplanetary field observed at the spacecraft intersects the shock. The waves are observed 18.5% of the time when a total of 134 days of interplanetary data is considered, but more than 90% of the time when the field has the proper orientation with respect to the bow shock. On the basis of this result it is suggested that these waves with 20-100 second periods are a permanent feature of the solar wind-earth interaction. The transverse component of the waves is typically several gammas in amplitude in 4-8 gamma fields. The disturbance vector in the XY plane generally exhibits the same sense of rotation in a coordinate system where the field is oriented along the positive Z axis. Attenuation of wave amplitudes with distance from the bow shock is estimated to be only a factor of 2 when the spacecraft is 15 R_E from the bow shock. The absence of waves at particular field orientations, even though the field line intersects the shock, is interpreted as a propagation effect. This observation is the basis for calculations that yield an average velocity in the plasma frame of 2.7 $\pm$ 0.4 times the solar wind velocity. Whistler propagation and local generation by two-stream instability are discussed as alternate theoretical explanations for the presence of the waves. It is suggested that the data favor the latter mechanism.

F1-07 Fairfield, D.H., and N.F. Ness, "Configuration of the Geomagnetic Tail During Substorms," J. Geophys. Res., 75, 7032-7047, 1970.

IMP 4 vector magnetic field measurements and the geomagnetic AE index are utilized in studying the configuration of the geomagnetic tail within 34 R_E and its variations during substorms. The existence of a depressed field magnitude region corresponding to the average position of the plasma sheet is confirmed and the average solar magnetospheric component of the field is found to be northward and independent of distance from the expected position of the neutral sheet for $Z_{SM} \lesssim 8R_E$. The Z_{SM} component measured some distance from the equatorial plane is a measure of flux crossing the neutral sheet and can be studied as a function of time during substorms. Prior to and during the early phases of a substorm the tail field magnitude increases and the northward field component decreases as the plasma sheet becomes thin. Later in the substorm the field magnitude decreases and the northward field component increases as the tail field relaxes to a more dipolar state. The greater number of field lines crossing the neutral sheet after the substorm is consistent with an expanded plasma sheet and supports reconnection theories. Enhanced Z_{SM} components after substorms and during the rare occurrences of very quiet intervals suggest that many more field lines close near the earth and fewer go into the geomagnetic tail at these times.

F1-08 Fairfield, D.H., and N.F. Ness, "Magnetic Field Fluctuations in the Earth's Magnetosheath," J. Geophys. Res., 75, 6050-6060, 1970.

IMP 4 measurements have been used to study magnetic field fluctuations in the sunward hemisphere of the magnetosheath. Power spectra have been computed in the frequency range below 0.2 Hz in a field-aligned coordinate system which allows the separation of transverse and longitudinal perturbations. Power levels of different passes through the magnetosheath typically vary by an order of magnitude or more and spectral peaks are frequently seen throughout the frequency range studies. Spatial variations of wave amplitudes are characterized by enhancements of the transverse mode near both the shock and the magnetopause but these variations tend to be smaller than the day to day variations. The dawn quadrant of the magnetosheath tends to exhibit a somewhat higher level of fluctuations. Transverse waves are often linearly polarized and they tend to have their disturbance vector aligned with the shock and magnetopause surfaces. Compressional fluctuations tend to be larger than transverse fluctuations at low frequencies but transverse amplitudes dominate at higher frequencies. On three unique orbits when the bow shock was located more then 9 R_E outside its average location the magnetosheath power levels were depressed by more than an order of magnitude below their normal lowest levels. Transverse fluctuations were dominant at these times. A weak positive correlation was found between magnetosheath fluctuations and geomagnetic activity.

- Principal Investigator Group/Other Publications

F1-09 Mish, W., "IMP F and G Phase 1 Magnetic Field Analysis," NASA-GSFC, X-612-67-602, Mar. 1968.

This paper describes the Phase I Analysis Program developed to analyse the magnetic field data from the GSFC magnetic field experi-

ment flown on IMP F and to be flown on IMP G. The Phase I Analysis converts the raw X, Y, Z sensor data as received on the Magnetic Field Experiment Tape into vector measurements of the ambient magnetic field observed by the experiment. These data are computed for four frames of reference - Apparent, Payload, Solar Ecliptic and Solar Magnetospheric. In addition 20.45 second (sequence) statistics are computed for the last three coordinate systems and SC 4020 plots of these statistics as a function of time can be obtained. Finally a summary tape is produced containing detailed data and sequence statistics as well as the output from the autocorrelation computer, trajectory data and identification information. This summary tape provides the input to the Phase II analysis.

F1-10 Mish, W.H., "IMP F and G Phase 2 Magnetic Field Analysis," NASA-GSFC, X-612-68-125, July 1968.

As implied in the title, the Phase II Magnetic Field Analysis is the second major step in the processing of the magnetic field data from IMP-F and G. The Phase I Analysis has been described in detail in a companion publication. In summary the Phase I Analysis has converted the raw X, Y, Z, sensor data are received on the Magnetic Field Experiment Tape into vector measurements of the ambient magnetic field observed by the experiment. These data are computed for four frames of reference - Apparent, Payload, Solar Ecliptic and Solar Magnetospheric. In addition sequence statistics are computed for the last three coordinate systems. These computed data are saved on the Binary Summary Tape written by the Phase I Analysis. These Summary Tapes are used as input to the utility sort program and the sorted version of the tape is used as input to the Phase II Analysis where additional data editing and analysis are performed.

The major functions of this process are as follows:

1) Elimination of redundant sequences.
2) Creation of hourly average cards for SE, SM or Solar Magnetic (GM) coordinates.
3) Detail plots of Payload, SE or SM coordinates.
4) Spectral analysis of the data from the autocorrelation computer.
5) Production of a Nonredundant Binary Summary Tape.

The Nonredundant Binary Summary Tape and/or hourly average cards are used as input to subsequent analysis programs, e.g., Spectral Analysis, Simultaneous Plots.

F1-11 Ness, N.F., "Magnetic Structure of Interplanetary Space," NASA-GSFC, X-616-69-334, Aug. 1969.

See abstract under A1-32.

- Not Principal Investigator Group/Major Journals

F1-12 Aubry, M.P., and R.L. McPherron, Magnetotail Changes in Relation to the Solar Wind Magnetic Field and Magnetospheric Substorms, J. Geophys. Res., 76, 4381-4401, July 1971.

See abstract under D2-15.

F1-13 Burlaga, L.F., "Large Velocity Discontinuities in the Solar Wind," Solar Phys. 7, 72-86, 1969.

Analysis of the results of interplanetary plasma observations made by Explorer 34, in which 11 discontinuous solar-wind speed changes (not associated with shocks) of more than 60 km/sec in less than 3 min were detected. These events called uD's may show a velocity change of either sign, but the plasma density and temperature do not change appreciably across them. The existence of these uD's is shown to be consistent with the theory of the Helmholtz instability.

F1-14 Burlaga, L.F., "Reverse Hydromagnetic Shock in the Solar Wind," Cosmic Electrodynamics, 1, 233-238, 1970.

This paper identifies a reverse hydromagnetic shock in the solar wind. The shock surface is oriented along the spiral direction, and it separates a high speed stream from a compressed, anomalously hot plasma ahead of the stream.

F1-15 Burlaga, L.F., and K.W. Ogilvie, "Causes of Sudden Commencements and Sudden Impulses," J. Geophys. Res., 74, 2815-2825, 1969.

The causes of 19 worldwide changes in the earth's magnetic field, occurring between June and December 1967, were determined by examining magnetic field and plasma data for the solar wind near the earth. Seven of the events were classified as storm sudden commencements (ssc) and four as sudden impulses (si) by most stations reporting them. All of the ssc's were caused by hydromagnetic shocks. Two of the si's were negative impulses (si^-) and were caused by tangential discontinuities across which the density decreased. The other two si's were distinct pulses in the magnetograms, and were caused by dense spots in the solar wind with dimensions $\approx$0.005 AU. There was no consensus among the reporting magnetic observatories as to whether the remaining eight events should be called si's or ssc's. Five of these events were caused by shocks and the other three by tangential discontinuities in the solar wind, but there seems to be no sure way to predict the type of structure from the shape of the magnetogram pulse. The rise time of the impulse in the H component of the magnetogram is apparently determined by something other than the type, the speed, or the thickness of an interplanetary discontinuity that caused the event.

F1-16 Burlaga, L.F., and K.W. Ogilvie, "Magnetic and Thermal Pressures in the Solar Wind," Solar Phys., 15, No. 1, 67-71, Nov. 1970.

Explorer 34 solar wind data for the period June to December, 1967 show that (a) the magnetic pressure, $P_B \equiv B^2/8\pi$, and thermal pressure, $P_k \equiv npkT_p + n_\alpha kT_\alpha + n_e kT_e$, are variable and positively correlated on a scale of $\gtrsim$ 2 days, but (b) changes in P_B and P_k are anticorrelated on a scale ~ 1 hr (~0.01 AU). Thus, dynamical hydromagnetic processes ($dv/dt \neq 0$) must occur on the mesoscale, but the solar wind tends to be in equilibrium ($P_B + P_k \sim$ constant) on a smaller scale, the microscale. The 3-hr averages show that the most probable value of $\beta \equiv P_k/P_B$ is $\beta' = 1.0 \pm 0.1$, which implies that the most probable state of the solar wind at 1 AU is not one of equipartition between the thermal energy and magnetic energy. The average total pressure for a given bulk speed ($\bar{P}(V)$ =

$P_k + P_\beta$) is essentially independent of V, implying that P is not determined by the heating or acceleration mechanisms of the solar wind; the average pressure is $\bar{P} = (2.9 \pm 1.5) \times 10^{-10}$ dyne/cm^2.

F1-17 Ogilvie, K.W., and J.F. Arens, "Acceleration of Protons by Interplanetary Shocks," J. Geophys. Res., 76, 13-20, 1971.

Observations of charged particles at the time of passage of interplanetary shocks past the satellite Explorer 34 are discussed. The short duration increases in flux seen at 1 Mev are interpreted as particle acceleration, and are found to be consistent in duration and magnitude with the idea of energy gain by successive reflection between the earth's bow shock and the incoming propagating shock. The corresponding correlation length of the interplanetary field is deduced to be $\sim 5 \times 10^{-3}$ A.U. From the small sample observed it appears that shocks occurring when the interplanetary magnetic field at the observers position does not intersect the bow shock do not show particle flux increases, and that particles from the solar wind are not accelerated to 1 Mev by any of the observed shocks.

F1-18 Ogilvie, K.W., and L.F. Burlaga, "Hydromagnetic Shocks in the Solar Wind," Solar Phys., 8, No. 2, 422-434, Aug. 1969.

The Rankine-Hugoniot relations are applied to shock-like discontinuities measured by both magnetic field and plasma instruments on the satellite Explorer 34 between May 30, 1967 and January 11, 1968.

Shock normals were either determined from the magnetic field observations, or from the times of occurrence of the discontinuity at Explorers 33, 34 and 35. The Rankine-Hugoniot relations are obeyed to the accuracy of the observations, and the values of shock velocities, density ratios, and Mach numbers indicate that at 1 AU the typical interplanetary shock is not strong, although all the events studied caused geomagnetic impulses.

G1 Magnetometer

N.F. Ness NASA/Goddard Space Flight Center

A boom-mounted triaxial fluxgate magnetometer measured magnetic fields in the interplanetary medium, in the magnetosheath, and in the geomagnetic tail. The magnetometer had dynamic ranges of ±40 γ and ±200 γ with respective sensitivities of ±0.2 γ and ±1.0 γ. Automatic onboard range selection was included. Measurement of the energy spectra of magnetic field fluctuations will be accomplished through a computation of the autocorrelation function in an onboard digital processor. The detector has functioned well to date (March 1971).

- Principal Investigator Group/Other Publications

G1-01 Mish, W., "IMP F and G Phase 1 Magnetic Field Analysis," NASA-GSFC, X-612-67-602, Mar. 1968.

See abstract under F1-09.

G1-02 Mish, W.H., "IMP F and G Phase 2 Magnetic Field Analysis," NASA-GSFC, X-612-68-125, July 1968.

See abstract under F1-10.

Plasma Experiments

A2 MIT Faraday Cup

H.S. Bridge — Massachusetts Institute of Technology

A five-element split collector Faraday cup was used to measure solar wind particles in the following sequence: positive ions from 45 to 105 ev, positive ions from 95 to 235 ev, positive ions from 220 to 640 ev, positive ions from 560 to 1800 ev, electrons from 65 to 210 ev, and positive ions from 1700 to 5400 ev. (The split plane of the collector was in the spin equatorial plane of the spacecraft.) Measurements consisted of 22 instantaneous current samples, each separated by 0.16 sec (spanning more than one satellite rotation). These measurements represented the sum of the current to the split collector, the maximum difference current encountered during spacecraft rotation, and which half collector was maximum. The entire sequence required 2.8 min and was repeated every 5.5 min. The entrance cone for this Faraday cup had a half-angle of about 80°. Interference was encountered from refracted particles (with the most pronounced effect at about 70° incidence to cup normal), from secondary electrons, and from ultraviolet radiation. Useful data were obtained from launch until January 13, 1965. However, there was poor data coverage during the last 7 months because of intermittent satellite transmission.

- Principal Investigator Group/Conference Proceedings

A2-01 Bridge, H.S., A. Egidi, A.J. Lazarus, E.F. Lyon, and L. Jacobson, "Preliminary Results of Plasma Measurements on IMP-A," Space Res. V, 969-978, 1965. (Proceedings of the 5th International Space Science Symposium, Florence, Italy, May 12-16, 1964.)

Preliminary IMP-A plasma measurements made with a Faraday-cup-type instrument are presented. The main results are as follows: (1) A directed flux of positive plasma ions is always observed in regions beyond the influence of the earth. (2) On each satellite pass two transitions in the plasma properties are usually observed; one transition can be identified with the magnetopause and one with a shock front created by the supersonic plasma stream. At the subsolar point, 12:00 hr: typical geocentric distances to these regions are $10R_e$ and $14R_e$ respectively; on the dawn side of the magnetosphere, 06:00 hr. the corresponding distances are $14R_e$ and $23R_e$. (3) In the transition region between the shock and the magnetopause a hot isotropic flux of positive plasma ions is observed.

A2-02 Lyon, E.F., "Explorer 18 Plasma Measurements," Solar Wind, 295-314, 1966. (Proceedings of a Conference held at the California Institute of Technology, Pasadena, Calif., Apr. 1-4, 1964. Eds., R.J. Mackin, M. Neugebauer, Pergamon Press.)

Analysis of some of the data obtained from the plasma measurements of Explorer 18. A map is constructed of the transition zone between the magnetosphere and the solar wind. Plasma-detector response data from various regions are discussed.

A2-03 Olbert, S., "Summary of Experimental Results from M.I.T. Detector on IMP-1," Physics of the Magnetosphere, 641-659, 1968. (Proceedings of the Summer Institute, Physics of the Magnetosphere, Boston College, Boston, Mass., June 19-28, 1967. Eds., R.L. Carovillano, J.F. McCloy, H.R. Radoski, D. Reidel Publishing Co., Dordrecht, Holland.)

Discussion of information obtained by the IMP-1 satellite concerning the magnetopause, the magnetosheath, the bow shock and the adjoining interplanetary domain. The quantity of data obtained made it possible to form large-scale averages of the measured macroscopic plasma variables, such as the density, the stream velocity, temperature, etc., and thereby test various theoretical models of "collisionless" plasma shocks, the fluid properties of the plasma, etc. Summarizing the most significant conclusion of the investigations, it is stated that a macroscopic fluid model may be considered as adequate for the purpose of a description of the gross features of the solar wind.

- Principal Investigator Group/Other Publications

A2-04 Bridge, H.S., G.P. Serbu, N.F. Ness, J.A. Simpson, F. McDonald, K.A. Anderson, and J.H. Wolfe, "Initial Results from the First Interplanetary Monitoring Platform (IMP 1)," IG Bulletin No. 84, June 1964. (Reprinted in Transactions of the American Geophys. Union, 45, 501-520, 1964.)

See abstract under A-01.

- Not Principal Investigator Group/Major Journals

A2-05 Egidi, A., G. Pizzella, and C. Signorini, "Measurement of the Solar Wind Direction with the IMP 1 Satellite," J. Geophys. Res., 74, 2807-2814, 1969.

Measurement of the direction of the solar wind by analysis of the data obtained from the IMP 1 satellite. During the period from November 27, 1963, to February 24, 1964, the solar wind was, on the average, in the ecliptic plane (50% of cases between -2° and +2°) and came from west of the sun on 72% of the cases; the average value of the ecliptic longitude was -1.5°. If a systematic error of 1° is allowed, the above figures become 56% and 86% in the two extreme cases. This result indicates that, in the above period of time, the solar wind has tendency to anticorotate with the sun.

A2-06 Wilcox, J.M., K.H. Schatten, and N.F. Ness, "Influence of Interplanetary Magnetic Field and Plasma on Geomagnetic Activity During Quiet-Sun Conditions," J. Geophys. Res., 72, 19-26, 1967.

See abstract under A1-18.

A3 GSFC Faraday Cup

G.P. Serbu NASA/Goddard Space Flight Center

The retarding potential analyzer was a three-element planar Faraday cup. It was mounted normal to the spacecraft spin axis and had an effective look angle of 5 ster. Coarse and fine resolution modes were programmed for both ions and electrons. These modes consisted of 15 steps each for retarding voltages of 0 to 28 and 0 to 100 v. The entire ion and electron sequence was repeated once every 10.92 min, and each 15-step spectrum analysis required 5.4 sec. The experiment operated from launch for about 20 hr when failure of a mechanical programmer switch terminated operations. The data were adversely affected by secondary electrons.

- Principal Investigator Group/Conference Proceedings

A3-01 Serbu, G.P., "Results from the IMP-1 Retarding Potential Analyzer," Space Res. V, 546-574, 1965. (Proceedings of the 5th International Space Science Symposium, Florence, Italy, May 12-16, 1964.)

Presented are some preliminary experimental results obtained with a planar geometry retarding potential analyzer that was flown on the IMP-1 Satellite. The plasma energy spectrum for both ions and electrons was measured in the range from 0 to 100 electron volts. Charged particle density measurements have been obtained continuously from 1000 km to 30 earth radii. The results show a sharp decrease of about an order of magnitude in charged particle density at about 4.5 R_E, similar to the decrease deduced from whistler observations. The electrons exhibited thermal energies for geocentric distances less than 4.5 R_E. The average electron energy then increased gradually to values above 100 electron volts at about 8 R_E. The observed satellite potential was less than 1 v positive.

- Principal Investigator Group/Other Publications

A3-02 Bridge, H.S., G.P. Serbu, N.F. Ness, J.A. Simpson, F. McDonald, K.A. Anderson, and J.H. Wolfe, "Initial Results from the First Interplanetary Monitoring Platform (IMP 1), IG Bulletin No. 84, June 1964. (Reprinted in Transactions of the American Geophys. Union, 45, 501-520, 1964.)

See abstract under A-01.

- Not Principal Investigator Group/Other Publications

A3-03 "Explorer 18 (1963 46A) Retarding Potential Experiment," National Space Science Data Center, NSSDC 67-36, Aug. 1967.

A4 Electrostatic Analyzer

J.H. Wolfe NASA/Ames Research Center

A quadrispherical electrostatic analyzer with a current collector and an electrometer amplifier was used to detect and analyze the positive ion component of the incident plasma and to study its gross flow characteristics. Protons were analyzed in 14 energy channels between 0.025 and 16 kev. The instrument was mounted on the satellite equatorial plane and had a view angle of 15° in this plane and of 90° in the plane containing the spin axis. The satellite's equatorial plane was divided into three contiguous sectors (111.8°, 111.8°, and 136.4°) by use of an optical aspect sensor. The peak flux in one sector was recorded at one analyzer plate potential per revolution of the satellite. (No information as to the position within the sector in which the peak flux occurred was retained.) After 14 revolutions, all energy channels had been scanned, and the process was repeated for the next sector. A complete scan in energy and sector was repeated every 5.46 min. No data were obtained for the brief periods when the satellite was in the magnetosphere. The instrument operated well until April 1964 when it started operating intermittently. Its operation continued to degrade thereafter.

- Principal Investigator Group/Major Journals

A4-01 Wolfe, J.H., R.W. Silva, and M.A. Myers, "Observations of the Solar Wind During the Flight of IMP 1," J. Geophys. Res., 71, 1391-1340, 1966.

Discussion of some of the principal results of an experiment designed to investigate the properties of the solar wind and its interaction with the geomagnetic field. The main objective of the experiment was to measure the energy per unit charge and gross flow characteristics of the positive ion component of the incident plasma as a function of radial distance from the earth. This experiment was carried out on the Imp 1 (Explorer 18) spacecraft using a curved plate electrostatic analyzer. Plasma observations indicate that three distinct regions of space were traversed by the satellite. The first was the geomagnetic cavity where no plasma was observed within the dynamic range of the instrument. The second was the region of turbulent plasma flow associated with the interaction between the solar wind and the geomagnetic field. The third was interplanetary space where the free-streaming solar wind was observed. The results presented cover the first 2-1/2 months of satellite life. The plasma data obtained in interplanetary space revealed that the solar wind density rarely exceeded 3 ions/cm^3. The transition region observations are discussed in the light of present theory.

- Principal Investigator Group/Other Publications

A4-02 Beck, C.W., T.B. Fryer, and C.N. Burrous, "Solar Wind Measurement Techniques, Part 2, Solar Plasma Energy Spectrometers," NASA-ARC, Unnumbered, Undated.

This report describes the curved plate electrostatic solar plasma instruments designed by NASA, Ames Research Center for the Orbiting Geophysical Observatory and Interplanetary Monitoring Platform satellites. These instruments measure the flux, angle of incidence, and energy spectrum of the positive ions with the solar plasma. They are capable of detecting a flux of 10^5 protons/cm^2 sec (10^{-14} amperes with a capture area of 0.5 cm^2) over an energy range from 450 ev to 18 kev with an angular resolution of better than $\pm 4°$.

A4-03 Bridge, H.S., G.P. Serbu, N.F. Ness, J.A. Simpson, F. McDonald, K.A. Anderson, and J.H. Wolfe, "Initial Results from the First Interplanetary Monitoring Platform (IMP 1)," IG Bulletin No. 84, June 1964. (Reprinted in Transactions of the American Geophys. Union, 45, 501-520, 1964.

See abstract under A-01.

- Not Principal Investigator Group/Other Publications

A4-04 "Explorer 18 (1963 46A) Ames Plasma Probe Experiment," National Space Science Data Center, NSSDC 67-35, Aug. 1967.

B2 MIT Faraday Cup

H.S. Bridge — Massachusetts Institute of Technology

This five-element Faraday cup measured electrons between 130 and 265 ev and ions in the following five energy windows: 40 to 90, 95 to 230, 260 to 650, 700 to 2000, and 1700 to 5400 ev. For each 5.46-min interval, 22 usable instantaneous current samples were recorded for each energy window, separated by 0.16 sec each. Two collector plates were used to yield information about the angular variation out of the satellite spin plane. The sum and difference of the currents on the two plates and the direction with maximum current were telemetered. The effect of secondary electrons has not been eliminated. This effect could be very significant within the earth's plasmapause. The instrument produced data throughout the operational life of the spacecraft, and provided essentially continuous data through April 5, 1965.

- Principal Investigator Group/Major Journals

B2-01 Anderson, K.A., J.H. Binsack, and D.H. Fairfield, "Hydromagnetic Disturbances of 3- to 15-Minute Period on the Magnetopause and Their Relation to Bow Shock Spikes, J. Geophys. Res., 73, 2371-2386, 1968.

See abstract under B1-01.

B2-02 Binsack, J.H., "Plasmapause Observations with the MIT Experiment on IMP 2," J. Geophys. Res., 72, 5231-5237, 1967. (Correction published in J. Geophys. Res., 73, 3608, 1968.)

Discussion of the plasma experiment flown on the IMP 2 satellite which detected the boundary of the region of dense thermal ions in the inner magnetosphere. The location of this boundary corresponds to the knee region investigated by whistler techniques. In the dawn hemisphere the boundary assumes a nearly circular shape during times of low magnetic activity (3-hr $K_p \leq 1$). An empirical relationship between the average L shell of the boundary and the 3-hr K_p index has been found to be $L = 6 - 0.6\ K_p$.

B2-03 Binsack, J.H., and V.M. Vasyliunas, "Simultaneous IMP-2 and OGO-1 Observations of Bow Shock Compression," J. Geophys. Res., 73, 429-433, 1968. (Letter)

Quantitative investigation of the question of whether large-scale motions of the bow shock that occur during the magnetic storms result primarily from the overall compression of the entire magnetosphere-magnetosheath system by the enhanced solar-wind dynamic pressure. The investigation was made, using simultaneous observations from the MIT plasma probes on IMP 2 and OGO 1. It was verified that this shock motion occurs nearly simultaneously on the dawn and dusk sides of the magnetosheath. It was possible to use one satellite to monitor the solar-wind pressure, while the other was observing the shock.

- Principal Investigator Group/Conference Proceedings

B2-04 Binsack, J.H., "Shock and Magnetopause Boundary Observations with IMP-2," Phys. of Magnetosphere, 605-621, 1968. (Proceedings of Conference on Phy. of Magnetopause, Boston College, June 19-28, 1967.)

The magnetopause and bow shock boundaries data obtained from the flight of the IMP-2 satellite are discussed. The boundary crossings during the first twelve orbits of the IMP-2 are catalogued into one of six types, determined by the character of the signals observed before and after the crossing. Plasma experiment data show that the boundaries of the magnetosheath are extremely pliable and responsive to solar and geomagnetic activity. Even during relatively quiet periods, the boundaries appear to remain in motion although on a smaller scale. Rapid varying fluxes in energy and direction are observed to be characteristic of the shock boundary layer. The operations of the plasma detector are reviewed.

B3 GSFC Faraday Cup

G.P. Serbu NASA/Goddard Space Flight Center

The retarding potential analyzer was a four-element Faraday cup. It was mounted normal to the spacecraft spin axis and had an effective look angle of 5 ster. The experiment operated for 5.2 sec in each of four modes once every 648 sec. In two modes, 15-step spectra for ions

were determined for retarding potentials in the ranges -5 v to +15 v and -5 v to +45 v. In the other two modes similar information for electrons was obtained by changing the signs of the potentials. The instrument experienced secondary electron contamination but returned essentially continuous data until April 5, 1965.

- Principal Investigator Group/Major Journals

B3-01 Serbu, G.P., and E.J.R. Maier, "Low Energy Electrons Measured on IMP 2," J. Geophys. Res., 71, 3755-3766, 1966.

The integral spectrum for low-energy electrons has been measured with detailed definition of temperature and number density throughout the IMP 2 orbit. Electrons are found to have a Maxwellian distribution at energies below 2.0 ev with a component of higher energy. The electron temperature typically increases from above the ionosphere as the square of the radial distance, whereas the number density decreases approximately as the inverse cube of the distance out to 5 R_E. From 5 to 15.9 R_E (apogee) the temperature remains between 1.0 and 2.0 ev, and the number density remains between 25 and 50 electrons/cm^{-3}. It is verified that the observed positive ion density of 25-50 cm^{-3} is in agreement with the number of electrons observed per unit volume in the solar wind region. The location of the magnetopause is not evident in the low-energy electrons; however, a small temperature increase is noted at the shock boundary. An intensity increase is noted in the energetic electron component in the magnetosheath. Data for a six-month period covering a 180° sector of the earth's environment is reported on. These observations constitute the first integral measurements in the solar wind region of charged particle spectra in the energy range 0-45 ev. Our observations of the number density are in disagreement with presently accepted solar wind theory but are not inconsistent with previous measurements of the streaming ions.

- Principal Investigator Group/Conference Proceedings

B3-02 Serbu, G.P., and E.J.R. Maier, "Thermal Plasma Measurements within the Magnetosphere," Space Res. VII, 1, 527-534, 1967. (Proceedings of the 7th International Space Science Symposium, Vienna, Austria, May 10-18, 1966.)

Observation that both the ion and electron components of the plasma present within the magnetosphere exhibit, at most times, a Maxwell-Boltzmann energy distribution. The temperature of the electron gas increases by a factor of about 10 from above the ionosphere to an altitude of 2.5 x 10^4 km (5 R_E geocentric). Over this same region, the density decreases to a minimum of about 50 cm^{-3}. Less pronounced variations of temperature and density with radial distance are noted beyond 5 R_E. The simultaneous observation of ion and electron density profiles provides verification of charge neutrality over vertical dimensions on the order of kilometers.

- Not Principal Investigator Group/Major Journals

B3-03 Managadze, G.G., I.M. Podgornyy, and V.D. Rusanov, "Plasma Flow

Past a Two-Dimensional Magnetic Dipole," NASA-GSFC, ST-PP-EXP-10742, Sept. 1968. (Geomagnetizm i Aeronomiya, 8, 545-548, 1968.)

The interaction is investigated of supersonic plasma flow with a dipole magnetic field. The results of measurements are in agreement with the assumption of collisionless shock wave formation.

B3-04 Mayr, H.G., and H. Volland, "On the Magnetospheric Temperature Distribution," J. Geophys. Res., 73, 4851-4858, 1968.

- Not Principal Investigator Group/Other Publications

B3-05 Bezrukikh, V.V., T.K. Breus, and K.I. Gringauz, "Estimates of Upper Limit of Ion Temperatures at 7000-30,000 km from Elektron 2 Measurements," Cosmic Res., 5, 678-679, Sept.-Oct. 1967.

Estimation of the upper bound of the ion temperature T_i from the change in the collector current of a charged-particle trap with a zero-potential at the external grid. For distances of 2.1, 3.5, 4.2, and 5.3 earth radii, the T_i values were 0.65, 0.85, 1.1, 1.1, and 1.1, respectively.

B4 Electrostatic Analyzer

J.H. Wolfe NASA/Ames Research Center

A quadrispherical electrostatic analyzer with a current collector and an electrometer amplifier was intended to detect and analyze the positive ion component of the incident plasma and to study its gross flow characteristics. The planned monitoring of the interplanetary medium was not accomplished because the apogee that the satellite achieved was lower than expected. Protons were analyzed in 12 energy channels between 0.7 and 8 kev. The instrument was mounted on the satellite's equatorial plane and had a view angle of 15° in this plane and of 90° in the plane containing the spin axis. The satellite's equatorial plane was divided into three contiguous sectors (61°, 95°, and 204°) by use of an optical aspect sensor. The peak flux in one sector was recorded at one analyzer plate potential per revolution of the satellite. (No information as to the position within the sector in which the peak flux occurred was retained.) After 12 revolutions, all the energy channels had been scanned, and the process was repeated for the next sector. A complete scan in energy and sector was repeated every 5.46 min. Because the instrument was not capable of observing magnetospheric plasma, no data were obtained for the time when the satellite was in the magnetosphere. The instrument operated well during the time when data could be recorded.

- Principal Investigator Group/Conference Proceedings

B4-01 Wolfe, J.H.; R.W. Silva; and M.A. Myers, "Preliminary Results from the Ames Research Center Plasma Probe Observations of the Solar Wind - Geomagnetic Field Interaction Region on IMP 2 and OGO 1," Space Res.; VI; 680-700, 1966. (Proceedings of the 6th International Space Science Symposium, Mar Del Plata, Argentina, May 11-19, 1965.)

Review of satellite measurements on the characteristics of the plasma in the region of transition between the solar wind and the geomagnetic field. Data obtained with the Interplanetary Monitoring Platform, IMP 2, and with the Orbiting Geophysical Observatory, OGO 1, are discussed. The data indicate that there is, in general, a decrease of less than a factor of two in the connective velocity of the plasma as it passes from interplanetary space into the transition region. This is accompanied by a temperature increase of alsmost an order of magnitude. Evidence is presented for significant plasma acceleration in the transition region. Other features are discussed which apparently question the validity of interpreting the interaction of solar plasma with the geomagnetic field in terms of an aerodynamic analogy. A possible mechanism for the injection of high-energy particles into the magnetosphere is also presented.

- Principal Investigator Group/Other Publications

B4-02 Beck, C.W.; T.B. Fryer, and C.N. Burrous, "Solar Wind Measurement Techniques, Part 2, Solar Plasma Energy Spectrometers," NASA-ARC, Unnumbered; Undated.

See abstract under A4-02.

- Not Principal Investigator Group/Other Publications

B4-03 "Explorer 21 (1964 60A) Solar Wind Protons Experiment," National Space Science Data Center, NSSDC 69-03, Jan. 1969.

C4 Electrostatic Analyzer

J.H. Wolfe NASA/Ames Research Center

A quadrispherical electrostatic analyzer with a current collector and an electrometer amplifier was intended to detect and analyze the positive ion component of the incident plasma and to study its gross flow characteristics as a function of radial distance from the earth. The instrument failed at launch and thus produced no useful data.

- Principal Investigator Group/Other Publications

C4-01 Beck, C.W., T.B. Fryer, and C.N. Burrous, "Solar Wind Measurement Techniques, Part 2, Solar Plasma Energy Spectrometers," NASA-ARC, Unnumbered, Undated.

See abstract under A4-02.

D3 MIT Faraday Cup

H.S. Bridge — Massachusetts Institute of Technology

A split-collector Faraday cup mounted on the spacecraft equator was used to study the directional intensity of solar wind ions and electrons. The following 25-sec sequence was executed three times for ions and once for electrons each 328 sec. Twenty-seven directional current samples from the two collectors were taken in the energy per charge window from 80 to 2850 v. The currents in the two collectors were then sampled in eight energy per charge windows between 50 and 5400 v at the azimuth at which peak current appeared in the previous 27 measurements. Due to telemetry limitations, only the following data were returned to earth every 328 sec: for ions, the sums of currents measured on the two collector plates twice and the difference once; for electrons, the sums once. The experiment worked well from launch until final spacecraft data transmission on May 31, 1971.

- Principal Investigator Group/Major Journals

D3-01 Nishida, A., and K. Maezawa, "Two Basic Modes of Interaction Between Solar Wind and the Magnetosphere," J. Geophys. Res., 76, 2254-2264, 1971.

See abstract under D1-18.

- Principal Investigator Group/Conference Proceedings

D3-02 Lyon, E., A. Egidi, G. Pizella, H. Bridge, J. Binsack, R. Baker, and R. Butler, "Plasma Measurements on Explorer 33, 1. Interplanetary Region," Space Res. VIII, 99-106, 1968. (Proceedings of the 8th International COSPAR Conference, London, July 25-28, 1967.)

Evaluation of plasma measurements made by Explorer 33, starting from July 1, 1966. Assuming reasonably stationary plasma properties, a measurement of the sum of the currents can be combined with one of the differences to provide the complete plasma flow parameters. It is pointed out, however, that the problem is extremely complex, owing to the difficulty of accurately representing the response function of the detector by an analytical expression. For this stage of the analysis; a method was chosen whereby a series of model calculations was performed for various sets of plasma parameters by means of particle-trajectory tracing within the detector. The result of these

operations is a library of expected-current sets for various plasma-parameter sets. The Explorer 33 data indicate that the magnetosphere is roughly cylindrical out to 75 earth radii with a radius of typically 20 earth radii.

- Not Principal Investigator Group/Major Journals

D3-03 Arnoldy, R.L., "Signature in the Interplanetary Medium for Substorms," J. Geophys. Res., 76, 5189-5201, 1971.

See abstract under C1-18.

D3-04 Aubry, M.P., and R.L. McPherron, "Magnetotail Changes in Relation to the Solar Wind Magnetic Field and Magnetospheric Substorms," J. Geophys. Res., 76, 4381-4401, 1971.

See abstract under D2-15.

D3-05 Hirshberg, J., and D.S. Colburn, "Interplanetary Field and Geomagnetic Variations - A Unified View," Planetary Space Sci., 17, 1183-1206, 1969.

The relationship between interplanetary magnetic fields seen by the Ames magnetometer on board Explorer 33 and surface magnetic variations has been studied. The emphasis of the study is toward achieving a unified view of all the experimental results, both of this study and previous studies. Various statistical studies of the relationship between K_p and parameters of the solar wind were carried out. The effect of the direction of the Z component of the interplanetary field is confirmed. In all other statistical studies the data were divided into two groups, one in which the 3-hr average field pointed northward, and the other in which it pointed southward. In this way, we show, for example, that the tendency toward an association of high K_p with intense interplanetary fields is independent of the North-South effect. Other statistical investigations were also carried out. The Sun was considerably disturbed during the period covered by this study, giving an excellent opportunity to observe the magnetic configuration of flare-induced interplanetary storms and their relation to geomagnetic storms. The interplanetary storm was found to be typified by persistent, strong fields (up to 30 γ) that rise far out of the ecliptic plane. As discussed below, this is to be expected on the basis of simple models. Further, it was found that high-velocity plasma and intense, highly disturbed interplanetary fields are also typical of interplanetary storms. The close association of these parameters in the interplanetary medium is one cause of confusion in interpretations of geomagnetic studies. During the flare-produced storm of February 15, 1967, there was a remarkably close temporal association between events in space and on the surface. This event is discussed in detail.

- Principal Investigator Group/Other Publications

D3-06 Hundhausen, A.J., "Solar Wind Disturbances Associated with Solar

Activity," Intercorrelated Satellite Observations Related to Solar Events, 111-129, 1970. (Proceedings of the 3rd ESLAB/ESRIN Symposium, Noordwijk, Netherlands, Sept. 16-19, 1969. Eds., V. Manno, D.E. Page, D. Reidel Publishing Company, Dordrecht, Holland.)

See abstract under A1-62.

E3 MIT Faraday Cup

H.S. Bridge Massachusetts Institute of Technology

A multi-grid, split-collector Faraday cup mounted on the equator of the spacecraft was used to study the directional intensity of solar wind positive ions and electrons with particular emphasis on the interaction of the solar wind with the moon. Twenty-seven integral current samples (requiring about 4.3 sec) were taken in an energy per charge window from 80 to 2850 v. Then the current was sampled in eight differential energy per charge windows between 50 and 5400 v at the azimuth where the peak current appeared in the previous series of the integral measurements. These measurements (integral and differential) took about 25 sec. Both the sum and difference of collector currents were obtained for positive ions. Only the sum was obtained for electrons. A complete set of measurements (two collector plate sums and one difference for protons and one collector plate sum for electrons) required 328 sec. The experiment worked well from launch until its failure in July 1968.

- Principal Investigator Group/Major Journals

E3-01 Lyon, E.F., H.S. Bridge, and J.H. Binsack, "Explorer 35 Plasma Measurements in the Vicinity of the Moon," J. Geophys. Res., 72, 6113-6117, 1967.

Statement of certain initial conclusions about the influence of the moon on the flow of charged solar-wind particles. These conclusions are based on early plasma measurements obtained by a Faraday-cup-type detector flown on Explorer 35. The plasma experiment was designed to measure both positively and negatively charged particles over a range of energy-to-charge ratios from 50 to 5400 v. It is found that it is unlikely that the lunar presence perturbs the solar-wind flow sufficiently to be observed at more than a few tens of lunar radii downstream.

E3-02 Nishida, A., and K. Maezawa, "Two Basic Modes of Interaction Between the Solar Wind and the Magnetosphere," J. Geophys. Res., 76, 2254-2264, 1971.

See abstract under D1-18.

E3-03 Siscoe, G.L., E.F. Lyon, J.H. Binsack, and H.S. Bridge, "Experimental Evidence for a Detached Lunar Compression Wave," J. Geophys. Res., 74, 59-69, 1969.

See abstract under E1-30.

E3-04 Siscoe, G.L., F.L. Scarf, I.M. Green, J.H. Binsack, and H.S. Bridge, "Very-Low-Frequency Electric Fields in the Interplanetary Medium, Pioneer 8," J. Geophys. Res., 76, 828-844, 1971.

We present Pioneer 8 observations of magnetosheath and interplanetary VLF electric fields, consisting of hourly ranges of the potential amplitude in a broadband channel (0.1 to 100 kHz) and in a 15% bandpass channel centered on 400 Hz. Significant signals are correlated with position with respect to earth, and with solar wind plasma parameters obtained from the lunar orbiting Explorer 35 spacecraft. We detect two principal features: noise bursts or spikes with duration less than approximately 10 sec, and persistent signals with durations typically 1 day or more. The noise bursts coincide with plasma and magnetic field discontinuities where these data are available for comparison. The persistent signals correlate loosely with solar wind density, and this correlation holds whether the density increases are due to interplanetary shocks, the 'snow plow' effect, or other processes. Although the experiment is too limited to provide unambiguous determination of the wave modes, at present it appears most likely that ion acoustic waves have been detected.

E3-05 Siscoe, G.L., F.L. Scarf, D.S. Intriligator, J.H. Wolfe, J.H. Binsack, H.S. Bridge, and V.M. Vasyliunas, "Evidence for a Geomagnetic Wake at 500 Earth Radii," J. Geophys. Res., 75, 5319-5330, 1970.

A comparison of the Explorer 35 solar wind plasma data with the data obtained by Pioneer 8 during a pass through the tail region at a geocentric distance of 500 R_E suggests the presence of a geomagnetic wake. The wake was characterized by a reduced density or increased temperature or both and by an almost unmodified flow speed as compared with upstream values. The change in density or temperature was of the order of 2 to 4. The wake is discussed in relation to the drag on the magnetosphere. A simple hydrodynamic calculation of wave drag effects gives approximate agreement with observed magnitudes, but the wake region appears to be somewhat larger than expected. Possible effects to account for this include heat diffusion out of the wake and a two-fluid effect in which ions are heated more than electrons at the bow shock. The data do not provide evidence for a viscous boundary layer in the usual sense, but a magnetic surface drag is not excluded. Finally, the possibility of local heating at the boundary is shown to be incapable of accounting for all wake features.

- Principal Investigator Group/Other Publications

E3-06 Lyon, E.F., G.L. Siscoe, and H.S. Bridge, "Explorer 35 Observations of the Solar Wind-Moon Interaction," MIT, CSR TR-68-7, 1968.

This report summarizes the status of the Lunar Explorer 35 plasma measurements as of July 1968. The instrumentation and the telemetry format are described, and the measurements that were obtained are analyzed in relation to the solar wind-moon interaction. Figures are included to illustrate the instrumentation and scientific results.

- Not Principal Investigator Group/Major Journals

E3-07 Aubry, M.P., and R.L. McPherron, "Magnetotail Changes in Relation to the Solar Wind Magnetic Field and Magnetospheric Substorms," J. Geophys. Res., 76, 4381-4401, 1971.

See abstract under D2-15.

- Not Principal Investigator Group/Other Publications

E3-08 Ness, N.F., "Interaction of the Solar Wind with the Moon," NASA-GSFC, X-692-70-141, Apr. 1970. (Paper to be published in the Proceedings of the 'Inter-Union Commission on Solar-Terrestrial Physics," International STP Symposium, Leningrad, USSR, May 11-19, 1970.)

See abstract under E1-21.

E3-09 Whang, Y.C., "Field and Plasma in the Lunar Wake," Phys. Rev., 186, No. 1. 143-150, Oct. 1969.

See abstract under E1-16.

E3-10 Whang, Y.C., "Theoretical Study of the Magnetic Field in the Lunar Wake," Phys. of Fluids, 11, 1713-1719, Aug. 1968.

See abstract under E1-18.

E4 GSFC Faraday Cup

G.P. Serbu NASA/Goddard Space Flight Center

A planar multi-grid sensor programmed as a retarding potential analyzer was used to observe the intensity of the electron and ion components of the low-energy plasma near the moon. Integral spectra were obtained for both ions and electrons in the energy range from 0 to 500 ev. A complete spectrum was obtained every 80 sec. Except for the period July 25, 1967, to January 12, 1968, the experiment has worked well (as of March 1971).

- Principal Investigator Group/Major Journals

E4-01 Serbu, G.P., "Explorer 35 Measurements of Low Energy Plasma in Lunar Orbit," J. Geophys. Res., 74, 372-376, 1969. (Letter)

A planar multigrid sensor, programmed as a retarding potential analyzer, was used to measure low energy plasma, E < 500 eV, during lunar orbits of Explorer 35. The collector current was measured by a logarithmic electrometer which is sensitive to both current polarities in the range from 1×10^{-6} to 3×10^{-12} amperes. Electron current-voltage characteristics are depicted to illustrate the variations in current magnitude, and changes in satellite potential, as the satellite moves from sunlight into the lunar shadow. A series of sequential time observations are presented to show the systematic variation in the measured electron currents as a function of orbital position through the lunar shadow. Data are tabulated on lunar plasma void observations, deduced from the observed gradient in the electron plasma density ratio and changes in the satellite-to-plasma potential. Preliminary analyses indicate: (1) No clear evidence exists for a lunar ionosphere at altitudes in excess of 825 km above the surface. (2) A characteristics variation in satellite-to-plasma potential is observed as a direct consequence of solar illumination.

- Principal Investigator Group/Other Publications

E4-02 Serbu, G.P., and E.J.R. Maier, "Proposal for AIMP-E Low Energy Integral Spectrum Measurement," NASA-GSFC, X-615-66-396, Aug. 1966.

Measurements of the low energy spectrum of ions and electrons were made by Explorers 18, 22, 28, and 33 in the magnetosphere, shock region, and interplanetary medium. Since lunar-related objectives were not met in Explorer 33, the authors proposed an experiment for AIMP-E to conduct studies in the vicinity of the moon. A Faraday cup of planar geometry would measure ions and electrons in six energy intervals from below a few ev to 500 ev. Figures showing results from Explorer 33 are included to illustrate where improvements could be made in AIMP-E.

F3 GSFC Electrostatic Analyzer

K.W. Ogilvie NASA/Goddard Space Flight Center

An electrostatic analyzer and an E x B velocity selector normal to the spacecraft spin axis were used to separately determine proton and alpha particle spectra in the solar wind. For each species, measurements in the energy per charge range 310 to 5100 ev were made at 14 points logarithmically equispaced in energy. During individual spacecraft rotations, counts were obtained in each of sixteen 22.5-deg sectors for a given species and energy. The sum of these counts, the sum of the squares of these counts, and the sector number of maximum counting were telemetered to earth. After successive 61.44-sec spectral determinations for protons and alpha particles, 15 consecutive readings for protons at 1408 ev were obtained. A period of 3.07 min separated two spectra of the same species. The instrument operated

normally until January 30, 1968. At that time it was turned off since it was spending all its time in the magnetosphere. Later, attempts to reactivate the sensor failed.

- Principal Investigator Group/Major Journals

F3-01 Burlaga, L.F., "Large Velocity Discontinuities in the Solar Wind," Solar Phys., 7, 72-86, 1969.

See abstract under F1-13.

F3-02 Burlaga, L.F., "Reverse Hydromagnetic Shock in the Solar Wind," Cosmic Electrodynamics, 1, 233-238, 1970.

See abstract under F1-14.

F3-03 Burlaga, L.F., and K.W. Ogilvie, "Causes of Sudden Commencements and Sudden Impulses," J. Geophys. Res., 74, 2815-2825, 1969.

See abstract under F1-15.

F3-04 Burlaga, L.F., and K.W. Ogilvie, "Heating of the Solar Wind," Astrophys. J., 159, 659-670, Feb. 1970.

Using three-hour average values of the bulk speed V and proton temperature T of the solar wind, derived from observations conducted on the satellite Explorer 34, it is shown that $T^{1/2} = (.036 \pm .003) V - (5.54 \pm 1.50)$ where V is in km/sec and T in kilo-degrees Kelvin. Results from other experiments at different parts in the solar cycle are also consistent with this relation. The V-T relation puts an important constraint on solar wind theories. There is still no satisfactory theory which gives the high-temperatures and high speeds which are observed. Some results are presented which support the view that the solar wind can be described by a 2-fluid model with extended heating by hydromagnetic waves near the sun.

F3-05 Burlaga, L.F., and K.W. Ogilvie, "Magnetic and Thermal Pressures in the Solar Wind," Solar Phys. 15, No. 1, 67-71, Nov. 1970.

See abstract under F1-16.

F3-06 Burlaga, L.F., and K.W. Ogilvie, "Observations of the Magnetosheath-Solar Wind Boundary," J. Geophys. Res., 73, 6167-6178, 1968.

Use of data from the Explorer 34 satellite to show that discontinuous transitions between the magnetosheath and the interplanetary medium occur simultaneously in the proton spectrum, the flow

direction, and the magnetic field intensity during both geomagnetically quiet and disturbed times. A few boundary crossings were observed for which the plasma spectra appear to indicate a diffuse transition; a detailed study of an extreme example of such a crossing, based on simultaneous measurements of the spectra, the flow direction, and the magnetic field intensity, shows that the apparent diffuseness requires no new hypotheses for its explanation, but can be the result of motions of a bow shock. Observations of the velocity field in the neighborhood of the outer boundary of the magnetosheath are presented and are compared with results of the fluid theory, which predicts a standing shock. It is shown that, along the boundary on the flank of the magnetosheath, the ratios of the magnetosheath flow speed to the interplanetary flow speed are in close quantitative agreement with a prediction of the fluid theory, which is essentially independent of the Mach number and the adiabatic exponent. A highly directional flow in the region $30° \lesssim \phi \lesssim 100°$ was observed, where ϕ is the sun-earth-satellite angle. The direction of this flow is consistent with the bow shock theory.

F3-07 Burlaga, L.F., K.W. Ogilvie, and D.H. Fairfield, "Microscale Fluctuations in the Interplanetary Magnetic Field," Astrophys. J., 155, L171-L175, Mar. 1969.

See abstract under F1-04.

F3-08 Burlaga, L.F., K.W. Ogilvie, D.H. Fairfield, M.D. Montgomery, and S.J. Bame, "Energy Transfer at Colliding Streams in the Solar Wind," NASA-GSFC, X-692-70-270, July 1970. (Accepted for publication in Astrophys. J., 164, 1971.)

See abstract under F1-02.

F3-09 Lazarus, A.J., K.W. Ogilvie, and L.F. Burlaga, "Interplanetary Shock Observations by Mariner 5 and Explorer 34," Solar Phys., 13, No. 1, 232-239, July 1970.

During 1967 we had an opportunity to study the characteristics of the flow of the interplanetary plasma behind two shock fronts in the solar wind observed at well-separated points. One of the points was 1 A.U., where the satellite Explorer 34 was in a highly eccentric orbit around the earth. The other was provided by the space probe Mariner 5, which was moving towards the sun. Each spacecraft carried a plasma measuring instrument. We shall discuss observations made by these instruments during the period June 25-26, and on August 11, 1967. During June, the spacecraft were relatively close to each other, but for the August event they were separated by about 0.1 A.U. and were on the Sun-Earth line. The transit times for the solar plasma between the two spacecraft were approximately one hour and approximately seven hours respectively. Examination of the data shows a high degree of correlation between the measurements made at both separations indicating that features in the solar wind retain their identity over distances of the order of 0.1 AU.

F3-10 Ogilvie, K.W., and J.F. Arens, "Acceleration of Protons by Interplanetary Shocks," J. Geophys. Res., 76, 13-20, 1971.

See abstract under F1-17.

F3-11 Ogilvie, K.W., and L.F. Burlaga, "Hydromagnetic Shocks in the Solar Wind," Solar Phys., 8, No. 2, 422-434, Aug. 1969.

See abstract under F1-18.

F3-12 Ogilvie, K.W., L.F. Burlaga, and T.D. Wilkerson, "Plasma Observations on Explorer 34," J. Geophys. Res., 73, 6809-6824, 1968.

Description of the results of the observations of the Goddard Space Flight Center/University of Maryland plasma experiment on Explorer 34 during three magnetic storms, May 30, June 5, and June 25, 1967. Particular attention is given to the interaction of discontinuities with the earth and to changes in the abundance of helium in the plasma. Detailed comparisons with magnetic field observations on the same satellite are used to interpret the observations and to identify shocks and tangential discontinuities. The observations are consistent with the relationship derived by Siscoe (1966) between the magnitude of such sudden changes in the earth's magnetic field and the solar wind parameters. The local shock speeds are derived from data obtained at the time of the sudden commencements. An example of an si^+ si^- pair is discussed, and in this case the negative impulse is shown to be due to a tangential discontinuity rather than a shock, whereas the positive impulse is associated with a shock. Helium observations are described which show that during the main phase of some geomagnetic storms the abundance ratio n_a/n_p shows a marked increase. In the May 30 storm it attained a value of 0.15 ± 0.02, 5-1/2 hr after the SC, an increase of seven times over the value observed earlier.

F3-13 Ogilvie, K.W., and N.F. Ness, "Dependence of the Lunar Wake on Solar Wind Plasma Characteristics," J. Geophys. Res., 74, 4123-4128, 1969.

See abstract under E1-09.

F3-14 Ogilvie, K.W., and N.F. Ness, "Reply (To 'Dependence of the Lunar Wake on Solar Wind Plasma Characteristics')," J. Geophys. Res., 75, 234, 1970.

F3-15 Ogilvie, K.W., and T.D. Wilkerson, "Helium Abundance in the Solar Wind," Solar Phys., 8, 435-449, 1969.

Observations of hydrogen and helium ions in the solar wind have been carried out by the Goddard Space Flight Center - University of Maryland plasma instrument on Explorer 34. These ions are completely

separated by means of electrostatic and magnetic fields. The average value of the ratio of number densities is 0.051 ± .02, derived from over 3000 h of measurement. Variations about this value from about 0.01 up to greater than 0.15 occur, and there are more high values than can be explained by random variation. A tentative association with some geomagnetic storms is suggested. The above value of abundance, assuming that plasma emitted in the ecliptic plane is a fair sample of the output of the sun, combined with other recent work by other methods indicate that the solar abundance may be about half the previously quoted estimates of approximately 0.1.

- Principal Investigator Group/Conference Proceedings

F3-16 Ogilvie, K.W., and L.F. Burlaga, "Hydromagnetic Observations in the Solar Wind," Particles and Fields in the Magnetosphere, 82-94, 1970. (Proceedings of the Symposium of the Summer Advanced Study Institute, Santa Barbara, Calif., Aug. 4-15, 1969. Ed., B.M. McCormac, D. Reidel Publishing Co., Dordrecht, Holland.)

The Rankine Hugoniot relations are applied to shock-like discontinuities measured by both magnetic field and plasma instruments on the satellite Explorer 34 between May 30, 1967 and January 11, 1968. Shock normals were either determined from the magnetic field observations or from the times of occurrence of the discontinuity at Explorer 33, 34, and 35. The Rankine Hugoniot relations are obeyed to the accuracy of the observations, and the values of shock velocities, density ratios, and Mach numbers indicate that at 1 AU the typical interplanetary shock is not strong, although all the events studies caused geomagnetic impulses.

- Principal Investigator Group/Other Publications

F3-17 Ogilvie, K.W., L.F. Burlaga, and T.D. Wilkerson, "Observations of the Interplanetary Plasma," NASA-GSFC, X-616-68-441, Nov. 1968. (Paper prepared as a talk, not to be published.)

Measurements made on the satellite Explorer 34 are discussed from the point of view of the hydromagnetic description of the interplanetary medium. Results involving the observation of the earth's bow shock and propagating shocks and discontinuities are used to demonstrate that this description is a useful one. The characteristics of large velocity discontinuities indicate the presence of the Helmholtz instability in the interplanetary medium. The observations of helium are described and show that the average value of na/np is 0.05 ± 0.015, where na and np are the helium and proton densities respectively. The response of the geomagnetic field to conditions in the solar wind is discussed in terms of Siscoe's theory of response to impulsive changes, and in terms of the relation between ΣKp and the plasma bulk speed.

F3-18 Ogilvie, K.W., R.I. Kittredge, and T.D. Wilkerson, "Crossed Field Velocity Selector," Rev. Sci. Instr., 39, 459-465, 1968.

Calculation of the paths of particles passing through crossed fields, with special application to the case where the particle does not complete a cycloidal oscillation. The use of such crossed fields in velocity selectors for space flight and in the laboratory is discussed. Curves are given which help in the choice of parameters for such applications.

F3-19 Ogilvie, K.W., N. McIlwraith, and T.D. Wilkerson, "Mass-Energy Spectrometer for Space Plasmas," Rev. Sci. Instr., 39, 441-451, 1968.

A satellite-borne instrument for the study of the interplanetary medium is described in detail. This plasma experiment illustrates a whole class of such measurements that can now be done on small unmanned scientific satellites. Plasma ions are resolved in both energy and mass per unit charge in order to determine hydrogen-helium abundance ratio, ion temperatures in the "solar wind" and transition region, and the angular distributions and fluctuations of ion flux. Protons and alpha particles with energy per unit charge between 300 and 5000 ev are resolved to better than 5 particles in 10^3, and their energy spectrum is determined. Instead of current measurements, we employ single ion counting with an efficiency of 75% at rates up to 3×10^7 sec^{-1}. A histogram of counts against angular rotation is formed with a quantization of 23° and its area, variance and the azimuthal position of the peak derived by a small computer for transmission to the earth over a data link with a capacity of approximately 6 bits/sec. Provision is made for a preliminary study of variations in the ion flux with periods greater than a few seconds.

F3-20 Ogilvie, K.W., N. McIlwraith, H.J. Zwally, and T.D. Wilkerson, "Probe for the Interplanetary Plasma," (Proceedings of the 6th International Conference of Ionization Phenomena in Gases, Paris, 91-96, 1963.)

The energy distributions of protons and other species of ions in interplanetary space as well as at satellite altitudes will be studied using a new detection technique. Observations will be made as a function of time, direction, and position over an energy range of at least 10 eV to 10 KeV, with a maximum sensitivity of 10^{-18}A, and the capability to detect single ions. Previous studies of the "solar wind" suggest many important measurements of its state, its interactions with planets, and its wave phenomena. The present instrument, which is 10 x 30 x 20 (cm^3) in size, contains an electrostatic energy analyzer, a secondary-electron-scintillation detector, high voltage supplies, and signal conditioning circuits. Laboratory work demonstrates constant response for protons having energies from 30 eV to 3 KeV and a minimum detectable current corresponding to about ten particles per second. Progress is reported on the development of a velocity selector for separating ionic species, hopefully leading to the solution of an important problem in solar wind studies: the determination of the relative abundance of protons and alpha particles.

- Not Principal Investigator/Major Journals

F3-21 Fairfield, D.H., "Average and Unusual Locations of the Earth's Magnetopause and Bow Shock," NASA-GSFC, X-692-70-452, Dec. 1970. (Accepted for publication in J. Geophys. Res.)

See abstract under A1-03.

F3-22 Michel, F.C., "Discussion of the Paper by K.W. Ogilvie and N.F. Ness, 'Dependence of the Lunar Wake on Solar Wind Plasma Characteristics,'" J. Geophys. Res., 75, 233, 1970.

- Not Principal Investigator Group/Other Publications

F3-23 Hundhausen, A.J., "Solar Wind Disturbances Associated with Solar Activity," Intercorrelated Satellite Observations Related to Solar Events, 111-129, 1970. (Proceedings of the 3rd ESLAB/ESRIN Symposium, Noordwijk, Netherlands, Sept. 16-19, 1969. Eds., V. Manno, D.E. Page, D. Reidel Publishing Company, Dordrecht, Holland.)

See abstract under A1-62.

F3-24 Ogilvie, K.W., L.F. Burlaga, and H. Richardson, "Analysis of Plasma Measurements on IMP-F," NASA-GSFC, X-612-67-543, Dec. 1967. (Paper not to be published.)

Goddard Space Flight Center scientists designed an instrument to obtain spectral and directional information for protons and α particles in the area of space covered by the polar orbiting satellite Explorer 34 (IMP F). This report describes the methods that are used to convert the basic quantities measured by the IMP-F plasma probe to a set of physical quantities that provide the most fundamental description possible of the plasma in the interplanetary medium in the magnetosheath. Programs for analysis of quick-look data are described and sample printout and flow charts are given.

F3-25 Schaefer, D.H., and J.W. Snively, Jr., "On-Board Plasma Data Processor," Rev. Sci. Instr., 39, 452-458, 1968.

A computing device that calculates quantities related to the mean, variance, and mode of the distribution of plasma as a function of the azimuthal angle of the spin-stabilized satellite is aboard Explorer 34. The device uses a combination of integrated circuits and discrete components including tunnel diodes. Performing computations aboard the spacecraft and telemetering the results of the calculations permit important features of the data to be sent using about one-twentieth of the number of information bits that would be required to transmit histograms of the collected data.

F3-26 Snively, J.W., Jr., "Statistical Data Compression Technique," NASA, TN D-3616, Oct. 1966.

Data contained in a histogram can be compressed by calculating and transmitting two quantities: The area of the histogram and the sum of the squares of each bar of the histogram. The paper presents a survey of what knowledge one has about the original histogram when given only these two quantities. A set of theorems is derived which indicates the magnitude limits of the individual bars of the histogram as a function of these two quantities. The technique results in a data compression factor of greater than 10 for certain scientific experiments where the only information required is the amplitude distribution of the individual histogram bars.

Energetic Particle Experiments

A5 Ion Chamber and GM Counters

K.A. Anderson University of California at Berkeley

The instrumentation for this experiment, designed to measure fluxes of geomagnetically trapped particles, consisted of a 3-in.-diameter Neher type ionization chamber and two Anton 223 Geiger-Mueller tubes. The ion chamber responded to electrons and protons with E > 1 and 17 Mev, respectively. Both GM tubes were mounted parallel to the spacecraft spin axis. GM tube A detected electrons with E > 45 kev scattered off a gold foil. The acceptance cone for these electrons had a 61° full angle, and its axis of symmetry made an angle of 59.5° with the spacecraft spin axis. GM tube A responded omnidirectionally to electrons and protons with E > 6 and 52 Mev, respectively. GM tube B had no direct access to the space environment and omnidirectionally responded to background electrons and protons with E > 6 and 52 Mev, respectively. Pulses from the ion chamber were accumulated for 326.08 sec and read out once every 327.68 sec. Counts from GM tube A were accumulated for 39.36 sec and read out six times every 327.68 sec. Counts from GM tube B were accumulated for 39.36 sec and read out five times every 327.68 sec. This experiment performed normally from launch through May 10, 1965.

- Principal Investigator Group/Major Journals

A5-01 Anderson, K.A., "Energetic Electron Fluxes in the Tail of the Geomagnetic Field," J. Geophys. Res., 70, 4741-4763, 1965.

See abstract under A1-40.

A5-02 Anderson, K.A., "Radial Dependence of Energetic Electron Fluxes in the Tail of the Earth's Magnetic Field," Phys. Rev. Letters, 14, 888-890, 1965.

IMP 1 detected energetic electron fluxes of terrestrial origin in 126 energetic electron islands from 10 R_e out to 31.5 R_e (geocentric).

It was determined previously that substantial fluxes of energetic electrons frequently occur in regions near the midnight meridian at much larger radial distance than they do on the sunlit side of the earth. New results indicated that electron fluxes in the magnetic tail which were observed at the satellite show two characteristic time constants, one on the order of one minute and the other many minutes to a few hours. For nearly all electron islands occurring in the tail, the short time constant occurs at early times followed at later times by the longer time constant. Possible explanations for the occurrence of these fluxes are given.

A5-03 Anderson, K.A., H.K. Harris, and R.J. Paoli, "Energetic Electron Fluxes in and Beyond the Earth's Outer Magnetosphere," J. Geophys. Res., 70, 1039-1050, 1965.

Extension of energetic charged particle measurements to distances of 31.5 Earth radii made possible by the highly eccentric orbit of the IMP A satellite. It is stated that fluxes of energetic electrons on the order of 10^4 cm^{-2} sec^{-1} have frequently been measured in the transition region and in interplanetary space. The occurrence of electrons in regions where there can be no geomagnetic trapping has been found to be more frequent on the sides of the geomagnetic cavity than over the subsolar region. Arguments that the origin of the electrons found outside regions of geomagnetic trapping is magnetospheric are given. In the tail of the geomagnetic cavity there are islands of energetic electron fluxes up to 10^6 cm^{-2} sec^{-1} and several Earth radii in the spatial extent. It is noted that these electron islands seem to be confined to a rather small region of latitudes.

A5-04 Anderson, K.A., and R.P. Lin, "Observations on the Propagation of Solar-Flare Electrons in Interplanetary Space," Phys. Rev. Letters, 16, 1121-1124, June 1966.

It is shown that the propagation of ~40 keV solar electrons in the neighborhood of the earth is highly anisotropic in two respects: first, electrons are observed only from flares near W60° solar longitude; and second, the electron fluxes exhibit anisotropic pitch angle distributions. The observations were made from the first and third interplanetary monitoring platform satellites during 1964, 1965 and 1966. Three important flare associations are drawn from the tabulated data: (1) all but one of the solar electron events are clearly associated with flares, (2) importance of the flares is small in most instances, and (3) flares ejecting the electron fluxes occur in several different plage regions.

A5-05 Anderson, K.A., and C.-I. Meng, "Layer of Energetic Electrons (>40 keV) Near the Magnetopause," J. Geophys. Res., 75, 1827-1836, 1970.

We find that the magnetopause is permanently covered by a layer of energetic electrons extending from the dayside of the magnetosphere to at least about 60 R_E downstream along the tail. The layer has a thickness of about 1 to 2 R_E. The flux of energetic electrons in this layer shows a clear dependence on the geomagnetic activity indicated by the 3-hour K_p index. These findings are based on the observations of energetic electron fluxes of IMP 1, IMP 3, and lunar-orbiting Explorer 35 satellites.

A5-06 Anderson, K.A., and N.F. Ness, "Correlation of Magnetic Fields and Energetic Electrons on the IMP 1 Satellite," J. Geophys. Res., 71, 3705-3727, 1966.

See abstract under A1-01.

A5-07 Lin, R.P., and K.A. Anderson, "Electrons >40 keV and Protons >500 keV of Solar Origin," Solar Phys., 1, 446-464, 1967.

Results of observations of electrons with kinetic energies ≲40 kev associated with solar flares. All the known solar-flare electron events observed since late 1963 are described in tabular form. Two distinct classes of these events are distinguished: (1) prompt electrons, which arrive within an hour of the flare, and (2) delayed electrons, which arrive about a day following the flare. Promptly arriving electrons are found to be of two types: the simple events associated with flares which occur in the absence of a large-area Type I radio-noise storm, and the complex events resulting from flares beneath these large radio-noise regions. The propagation of energetic solar-flare electrons to the earth is described in terms of cones of propagation. Solar-flare electron fluxes do not show filamentary structure even at times when the protons from the same flare do. This suggests that electrons are injected into the interplanetary field from regions distinct from the proton-injection region. The association of proton fluxes with energies >500 kev with the delayed electron events is discussed.

A5-08 Lin, R.P., and K.A. Anderson, "Periodic Modulations of the Energetic Electron Fluxes in the Distant Radiation Zone," J. Geophys. Res., 71, 1827-1835, 1966.

Periodic modulations of the energetic (>45 kev) electron fluxes are observed throughout the distant radiation zone by Geiger counters aboard Imp 1 and 2. These modulations have periods from a few minutes to half an hour, and coherent trains of these modulations are observed lasting as long as several hours. The peak-to-valley ratios are often an order of magnitude or more, and the strongest and most persistent periodicity is about six minutes. The largest and most regular modulations occur in the skirt region near the 0300 local time meridian (LSEP = 120°). Modulations of somewhat reduced amplitude are observed in the geomagnetic tail; in the transition region, and near the bow shock. We believe that these modulations of the electron fluxes are evidence for strong hydromagnetic wave activity throughout the distant radiation zone. These modulations increase in amplitude and extent with Kp. No such modulations are observed inside L = 8 except when the daily Kp sum is greater than 23. The fact that the periods of these modulations tend to be about six minutes suggests that a resonant effect is occurring in the magnetosphere or in the transition region.

- Principal Investigator Group/Conference Proceedings

A5-09 Anderson, K.A., "Energetic Electron Spikes in and Beyond the Transition Region," Proceedings of the 9th International Conference on Cosmic Rays, 1, 520-527, 1965. (Proceedings held at

Imperial College of Science and Technology, London, England, Sept. 6-17, 1965.)

IMP satellite measurements show that the energetic radiation around the earth may be divided into the Van Allen trapping zone in which charged particles drift completely around the earth and the distant radiation zone, in which there is no complete azimuthal drift around the earth due to distortions of the geomagnetic field. The distant radiation zone exhibits several distinct features. Among these are the transition spikes. It is shown here that their appearance is very sensitive to geomagnetic disturbance indexes. It is also shown that on many occasions the frequency and size of these energetic electron spikes increase systematically from the magnetopause to the bow shock. Beyond the shock, spikes still appear but with lower frequency and smaller size.

A5-10 Anderson, K.A., "Wave-Energetic Particle Associations in the Magnetosphere," Earth's Particles and Fields, 429-439, 1968. (Proceedings of the NATO Advanced Study Institute, Freising, West Germany, July 31 - August 11, 1967. Ed., B.M. McCormac, Reinhold Book Corp., New York.)

Analysis of the rapid changes in the intensities of the wave-energetic particle associations in the magnetosphere, based on available satellite and rocket observations collected in recent years. It is pointed out that groups of microbursts often have the same periods as fast magnetic pulsations, that the occurrence of fast-variation microburst group precipitation is nearly always accompanied by micropulsations having nearly equal periods, and that an important class of wave-energetic particle associations is related to vlf electromagnetic radiation in the magnetosphere.

- Principal Investigator Group/Other Publications

A5-11 Anderson, K.A., "Energetic Particles in the Earth's Magnetic Field," Annual Review Nuclear Science, 16, 291-344, 1966.

Study of radiation zones in the earth's magnetic field. The theory of motion of charged particles in magnetic fields is considered, and methods used in investigating the electron energies and proton fluxes are discussed. The spatial extent of Van Allen radiation is examined, and its features are classified.

A5-12 Anderson, K.A., R.J. Paoli, and G.H. Pitt, "Technical Description of the University of California IMP-1 Energetic Particle Equipment. 2 - Description of the Data Format on Magnetic Tapes Supplied to the NASA Data Center," University of California Technical Report NAS5-2989, Ser. 7, Iss. 32, Sept. 1966.

Detailed description of the University of California Space Science Laboratory experiment on IMP 1. Three detectors, two Geiger-Mueller tubes, and one ionization chamber were used to measure energetic particles. Omnidirectional measurements were obtained or protons of

E > 17 Mev and E > 52 Mev. Directional observations of electrons E > 45 kev were also made by one GM tube. The telemetry format is described, and diagrams of the instrumentation is given. The structure and format of the two University of California data tapes are included in an appendix.

A5-13 Bridge, H.S., G.P. Serbu, N.F. Ness, J.A. Simpson, F. McDonald, K.A. Anderson, and J.H. Wolfe, "Initial Results from the First Interplanetary Monitoring Platform (IMP 1); IG Bulletin No. 84, June 1964. (Reprinted in Transactions of the American Geophys. Union, 45, 501-520, 1964.)

See abstract under A-01.

A5-14 "Final Report for Energetic Particle Studies on the First Interplanetary Monitoring Satellites (July 1, 1962 to June 30, 1967)" University of California, Space Science Lab. Ser. 8, Iss. 107, 1967.

This report concerns the use that has been made of the scientific data from the University of California energetic particle experiments on the IMP-1, 2 and 3 spacecraft. An important part of the University of California activity under the NAS 5-2989 contract has been graduate student participation. Two graduate students from the Physics Department made invaluable contributions both to the flight hardware phase and to the data analysis. Mr Hugh K. Harris received a Master of Arts degree and Dr. Robert P. Lin received a Doctor of Philosophy degree using data from the IMP-1, 2 and 3 spacecraft.

One of the important uses of the IMP-1, 2, 3 data has been to obtain simultaneous measurements of particle fluxes at different points in space. This has been carried out in a number of cases using Explorer 33, OGO-1, and OGO-3 data. In this way the IMP-1, 2, 3 data has contributed to the work of graduate students on other projects. Mr. Stephen Kahler, who has analyzed OGO-1 and 3 data has also made frequent and effective use of the IMP-1, 2, 3 results. Mr. E.C. Roelof did Ph.D. work with our group and the IMP-1, 2, 3 data proved exceedingly useful to him. Thus, the NAS 5-2989 has contributed greatly to the graduate education program in the Physics Department and Space Sciences Laboratory at Berkeley.

Another important aspect of the data analysis has been collaboration with other IMP experimenters. The first such collaboration was with Dr. Norman Ness of the NASA Goddard Space Flight Center. Another paper was written combining the results from the University of California energetic particle experiment, the GSFC magnetometer experiment (Dr. D.H. Fairfield) and the MIT plasma cup (Dr. J.H. Binsack).

Edited data tapes containing all information from the UC experiment on IMP-1 have already been received by the NASA Space Sciences Data Center. We plan to deposit the IMP-2 tapes in late 1967 and the IMP-3 tapes in 1968.

Although the NAS 5-2989 contract expired on 30 June 1967, much more data analysis remains to be done. NASA Headquarters has agreed to support further efforts and we now expect to work on IMP-1, 2, and 3 data until at least early in 1969.

The remainder of the report consists of the follows topics:

I. Technical description of the University of California experiment on IMP-1, 2, and 3. This includes calibration curves for the ionization chambers.
II. A description of the data tape format.
III. A summary of the computer programs developed to process the data from the UC experiment.
IV. A bibliography of articles published or submitted for publication that are based on data from the IMP-1, 2, and 3 spacecraft.
V. The abstract from Dr. R.P. Lin's Ph.D. thesis which was based on IMP-1, 2, and 3 data.

- Not Principal Investigator Group/Major Journals

A5-15 Fan, C.Y., G. Gloeckler, and J.A. Simpson, "Acceleration of Electrons Near the Earth's Bow Shock and Beyond," J. Geophys. Res., 71, 1837-1856, 1966.

Observations of groups of electrons of energies >30 kev in the earth's magnetosheath, at the earth's bow shock, and in a region extending out to several earth radii beyond the shock. These measurements were made with a gold-silicon surface barrier detector on board the IMP 1 satellite, in the period of Nov. 27, 1963, to Feb. 13, 1964. At times of enhanced solar wind velocity, having a 27-day recurrence, electron spikes were observed out to ~200,000 km, which is near satellite apogee. To investigate the origin of the electrons in spikes found in the magnetosheath, at the bow shock, and beyond the shock to distances of several earth radii, the temporal variation and energy spectrums of the electrons in the outer radiation belt, but near the magnetospheric boundary, also were analyzed. It was found that the hardening in the energy spectrum of the trapped electrons in the radiation belt follows closely the compression of the boundary of the magnetosphere controlled by the strength of the solar wind. However, this change in spectrum was not observed for the electrons in the spikes. For this reason it is argued that the spikes are not groups of electrons escaping from the outer radiation belt, but rather are locally accelerated electrons. The Fermi acceleration mechanism proposed by Jokipii and Davis is discussed.

A5-16 Murayama, T., and J.A. Simpson, "Electrons Within the Neutral Sheet of the Magnetospheric Tail," J. Geophys. Res., 73, 89-905, 1968.

See abstract under A1-53.

- Not Principal Investigator Group/Other Publications

A5-17 "Explorer 18 (1963 46A) Energetic Particles Experiment," National Space Science Data Center, NSSDC 67-38, Aug. 1967.

A6 Scintillator and GM Telescopes

F.B. McDonald NASA/Goddard Space Flight Center

This experiment consisted of two detector systems. The first was a dE/dx vs E telescope with thin and thick CSI scintillators (one each) and an anticoincidence plastic scintillation counter. The telescope axis was normal to the spacecraft spin axis. Counts of particles penetrating the thin CsI scintillator and stopping in the thick CsI scintillator were accumulated during one 39.36-sec interval every 5.46 min. The relative contribution to the count rate of various species (electrons between 3 and 12 Mev, ions with charge = 1, 2, atomic mass = 1, 2, 3, 4, and energy between 18.7 and 81.6 Mev/nucleon) and energy spectral information were determined by 512-channel pulse height analysis performed simultaneously on the output of both CsI scintillators six times every 5.46 min. The second detector system consisted of two Geiger-Mueller tube telescopes oriented parallel and perpendicular to the spacecraft spin axis. Each telescope consisted of two colinear GM tubes. The parallel and perpendicular telescopes measured the sum of counts due to protons with E > 70 Mev and electrons with E > 6.5 Mev and the sum of counts due to protons with E > 65 Mev and electrons with E > 6 Mev, respectively. Counts registered in any one of the four GM tubes were also accumulated. These omnidirectional counts were due to protons with E > 50 Mev plus electrons with E > 4 Mev. The parallel, perpendicular, and omnidirectional count rates were obtained for one 40-sec accumulation interval during successive normal 81.9-sec telemetry sequences. Thus, any one count rate was measured for 40 sec once each 5.46 min. Both detector systems worked well from launch until May 8, 1964.

- Principal Investigator Group/Major Journals

A6-01 Balasubrahmanyan, V., E. Boldt, and R.A.R. Palmeira, "Solar Modulation of Galactic Cosmic Rays," J. Geophys. Res., 72, 27-36, 1967.

The modulation of galactic protons and He nuclei during the last solar cycle is analyzed according to Parker's theory. The mechanism of modulation remains essentially the same during several years of low solar activity (1961-1965). The modulation near solar maximum (1959) implies that the scale sizes of the magnetic inhomogeneities in the solar wind are reduced below the values at solar minimum. An adequate description at solar maximum would require further refinements of the theory. The proton-to-He-nucleus ratio outside the solar system is shown to be consistent with the value ≈6, in a kinetic-energy/nucleon representation, for the interval 100-1000 Mev/nucleon.

A6-02 Balasubrahmanyan, V., G.H. Ludwig, F.B. McDonald, and R.A.R. Palmeira, "Results from the IMP 1 GM Counter Telescope Experiment," J. Geophys. Res., 70, 2005-2019, 1965.

Results from the Geiger counter telescope on board the IMP 1 satellite. The detector system consisted of four pancake-type GM counters forming two mutually perpendicular telescopes and an omnidirectional detector. Comparison of the intensity measured by the two perpendicular telescopes reveals an anisotropy in the recovery

phase of the 11-year variation. Time variations of the omnidirectional intensity were correlated with the planetary index K_p, and inferences about interplanetary field irregularities and solar wind cavity structures are presented. These results are shown to be in general agreement with Parker's description of the cosmic-ray modulation by the solar wind.

A6-03 Bryant, D.A., T.L. Cline, V.D. Desai, and F.B. McDonald, "Continual Acceleration of Solar Protons in the Mev Range," Phys. Rev. Letters, 14, No. 13, 481-484, Mar. 1965.

Evidence is presented for the long term persistence of a new solar emitted component consisting or protons in the 3 to 20 MeV region. These low energy protons are contained in streams of approximately 30 to 120 degrees width of the Earth's orbit and are present over many solar rotations. These recurrence events are characterized by both a very low intensity level and a very steep energy spectrum: In contrast to the solar proton event, no velocity dispersion is observed among the various energy groups. When a stream is encountered, it is observed that both 3 and 10 MeV particles are present simultaneously, indicating that a quasi-equilibrium state has been established. Results from Explorer measurements of these particles are discussed. The continued presence of these particles is taken as evidence that they are being continually accelerated by the sun. Whether this acceleration occurs near the solar surface or in interplanetary space at the turbulent interface between the faster moving plasma of the stream and the slower moving plasma at the quieter surrounding region cannot be determined as yet. The latter interpretation is preferred as data tends to support this view.

A6-04 Cline, T.L., G.H. Ludwig, and F.B. McDonald, "Detection of Interplanetary 3- to 12-Mev Electrons," Phys. Rev. Letters, 13, No. 28, 786-789, Dec. 1964.

Direct observations have been made with a scintillator telescope of interplanetary electrons in the 3- to 12-Mev range with the IMP-1 satellite (Explorer XVIII). Electron data, reported only when the satellite was beyond 125000 kilometers, were free from effects due to trapped radiation. When a table was constructed from data taken at apogee to show intensity versus measured energy loss and total energy, a distinct versus measured energy loss and total energy, a distinct counting rate component of minimum ionizing energy loss and low apparent energy was seen. Analysis indicated three different particle groups, two of which were thought to be secondary radiations consisting of either gamma rays or spurious cosmic rays. When these secondary effects were eliminated, the resulting corrected spectra suggested that the electrons seen daily may have the same origin as the extra ones seen on days of increased electron flux. The existence of an interplanetary flux of electrons lower in energy presents the possibility of cosmic origin of electrons, despite many arguments supporting galactic origin.

A6-05 Cline, T.L., and F.B. McDonald, "Relativistic Electrons from Solar Flares," Solar Phys., 5, 507-530, 1968.

Discussion of observations of interplanetary relativistic electrons from several solar-flare events monitored through 1964 to mid-1967. These are the first direct spectral measurements and time histories, made outside the magnetosphere, of solar-flare electrons having relativistic velocities. The 3- to 12-MeV electrons detected have kinetic energies about two orders of magnitude higher than those solar electrons previously studied in space, and measurements of both the time histories and energy spectra for a number of events in the present solar cycle were carried out. These measurements are compared with solar X-ray data and with measurements of related interplanetary solar protons. Energy spectra and total numbers of the interplanetary electrons, compared with those of the flare-site electrons calculated from X-ray and microwave measurements, indicate that probably a small fraction of flare electrons escapes into interplanetary space.

A6-06 McDonald, F.B., and G.H. Ludwig, "Measurement of Low Energy Primary Cosmic Ray Protons on IMP-1 Satellite," Phys. Rev. Letters, 13, No. 26, 783-785, Dec. 1964.

The first precise determination of the intensity and energy spectra of primary cosmic ray protons in the 15-75 MeV interval has been made with a three element energy vs energy-loss telescope aboard the IMP-1 (Explorer XVIII) satellite. This spacecraft had an apogee of 193,000 km, and only data obtained well beyond the effects of the earth's magnetosphere are considered. The measurements reported here cover the time interval December 8, 1963, to May 6, 1964, and are considered to be representative of the period just prior to solar minimum. The proton intensity in the range 15-75 MeV was observed to be 19 proton/m^2-sec-ster or approximately 1% of the total primary cosmic ray intensity, and to exhibit a steeply falling energy spectrum toward lower energies, decreasing by a factor of 5 over this interval. One point for helium was obtained in the range 65-75 MeV/nuc.

- Principal Investigator Group/Conference Proceedings

A6-07 Balasubrahmanyan, V., D.E. Hagge, G.H. Ludwig, and F.B. McDonald, "Galactic Cosmic Rays at Solar Minimum, 1965," Proceedings of the 9th International Conference on Cosmic Rays, 1, 427-436, 1966. (Proceedings held at the Imperial College of Science and Technology, London, England, Sept. 6-17, 1965.)

A synthesis of preliminary experimental results from cosmic ray experiments flown on OGO-1, IMP-1, 2, and 3, and high-latitude Skyhook balloon flights provides charge and energy spectra extending from about 20 Mev per nucleon to 1 Gev/nucleon for hydrogen to neon. A multiple Geiger counter cosmic ray monitor on these four satellites provided information on the total flux greater than 50 Mev/nucleon. The period from March to June 1965 appears to have minimum solar modulation effects and is operationally defined to be the solar cosmic ray minimum. Energy spectra for particles from H to Ne from 25 Mev/nucleon to 1 Gev/nucleon are presented. Results on the long-term temporal variation of He nuclei and protons are discussed. The L/M ratio at 100 Mev/nucleon and above 600 Mev/nucleon are found to be

0.29 ± 0.05 and 0.30 ± 0.03. The C/He ratio at 100 Mev/nucleon is found to be 0.021 ± 0.005 whereas above 600 Mev/nucleon the same ratio is found to be 0.036 ± 0.004. The change in this ratio appears to suggest the deceleration of the nuclei of higher Z in the interstellar gas due to ionization.

A6-08 Balasubrahmanyan, V., E.C. Roelof, R.P. Bukata, and R.A.R. Palmeira, "Co-Rotating Modulations of Cosmic Ray Intensity Detected by Spacecrafts Separated in Solar Azimuth," Acta Physica Academiae Scientiarum Hungaricae, 29, Supplement 2, 31-36, 1970. (Proceedings of the 11th International Conference on Cosmic Rays, Budapest, Hungary, 1969.) (Also, NASA-GSFC, X-611-69-413, Sept. 1969.)

The daily cosmic ray intensity from the IMP-C (Explorer XVIII) geiger-counter monitor (Ep $\gtrsim$ 50 MeV) and Pioneer VI scintillation telescope (Ep $\gtrsim$ 7.5 MeV) have been statistically analyzed by the use of correlation functions. When the two spacecrafts are close to each other, the cross-correlation function agreed closely with the auto-correlation function of either detector, showing that both detectors were responding comparably and reliably to cosmic ray fluxes. When Pioneer VI and IMP-C were separated by ~50° (October-December 1966), the variations in the detector rates appear to be mainly due to galactic cosmic rays. Solar flare contributions $\gtrsim$ 7.5 Mev have been eliminated from the Pioneer VI data by regression analysis using low energy rates (7.5 MeV $\lesssim$ Ep $\lesssim$ 44 MeV). Comparison of IMP-C and neutron monitor rates shows no detectable variations in solar proton outflow of Ep $\gtrsim$ 50 MeV. The cross-correlation function between the detectors during this quiet period reaches a significant peak (0.67 ± 0.05) with a lag of ~3 days between data from IMP-C and Pioneer VI. Also, the cross-correlation function (displaced by -3 days) is qualitatively similar in form to the auto-correlation function from IMP-C. It is proposed that there are numerous long-lived regions of modulated cosmic ray flux following the general spiral configuration of the interplanetary magnetic field as the field structure co-rotates with the sun. This interpretation is consistent with the observations of recurrent Forbush decreases in early 1966 reported by McCracken, Rao, and Bukata (1966).

A6-09 Balasubrahmanyan, V., and D. Venkatesan, "Spectral Variations in Short Term (Forbush) Decreases and in Long Term Changes in Cosmic Ray Intensity," Acta Physica Academiae Scientiarum Hungaricae, 29, Supplement 2, 327-336, 1970. (Proceedings of the 11th International Conference on Cosmic Rays, Budapest, Hungary, 1969.)

Data are available from satellites IMP A, B, and C and OGO A on a continuous basis over the period November 1963-May 1967. The cosmic ray intensity registered by GM counters on these satellites, of energy ≥50 MeV is compared with the intensities recorded by neutron monitors, at the equatorial station, Huancayo, at the high latitude station, Deep River, and at the polar station, Alert. Spectral variations during the Forbush decreases and during long term changes in cosmic ray intensity are investigated, and the results discussed in terms of current ideas.

A6-10 Cline, T.L., G.H. Ludwig, and F.B. McDonald, "IMP Observations of Primary 3-Mev Electrons," Solar Wind, 73-80, 1966. (Proceedings of a Conference held at the California Institute of Technology, Pasadena, Calif., Apr. 1-4, 1964. Eds., R.L. Mackin, Jr., M. Neugebauer, Pergamon Press.)

Discussion of some phenomena observed with the satellite Explorer 12 and IMP. Periodic fluctuations were observed in the solar-proton flux, together with a recurrence pattern in particle events. Electrons of interplanetary origin, with energies of about 3 Mev, reportedly have been detected in interplanetary space.

A6-11 Simnett, G.M., T.L. Cline, and F.B. McDonald, "Time Variations of the 4 to 12-Mev Interplanetary Electron Intensity Between 1963 and 1968," Acta Physica Academiae Scientiarum Hungaricae, 29, Supplement 1, 151-158, 1970. (Proceedings of the 11th International Conference on Cosmic Rays, Budapest, Hungary, 1969.) (Also, NASA-GSFC, X-611-69-413, Sept. 1969.)

The interplanetary electron intensity between 4 and 12 MeV has been monitored with the IMP-1, -3, and -4 spacecraft from November 1963 to April 1964, June 1965 to April 1967 and May 1967 to April 1969, respectively. There are a variety of types of time variations in the intensity; these include flare-associated and recurrent solar electron events, and other short-term effects, such as small quiet-time increases and Forbush decreases, superimposed on the longer-term modulation. The quiet-time intensity increases are strongly correlated with solar rotation, but are generally not coincident with increases of the low-energy proton intensity; in fact, there is frequently an anticorrelation between the two. This pattern indicates the possibility of a solar origin for the quiet-time increases. However, since the background electron intensity does undergo large Forbush decreases, not coincident with solar-flare electron events, the existence of a real solar modulation of the galactic intensity is also indicated. The overall change in the quiet-time background intensity between December 1965 at solar minimum and August 1968 is less than a factor of two, but is not interpreted as vanishingly small.

- Principal Investigator Group/Other Publications

A6-12 Bridge, H.S., G.P. Serbu, N.F. Ness, J.A. Simpson, F.B. McDonald, K.A. Anderson, and J.H. Wolfe, "Initial Results from the First Interplanetary Monitoring Platform (IMP 1)," IG Bulletin No. 84, June 1964. (Reprinted in Transactions of the American Geophys. Union, 45, 501-520, 1964.

See abstract under A-01.

A6-13 "Earth Satellite Experiment for Measuring the Charge and Energy Spectra of the Primary Cosmic Rays," NASA-GSFC, X-611-63-253, Nov. 1963.

An experiment has been built to measure the energy spectra of the various nuclear constituents from protons through oxygen in the range ~15 to 90 Mev per nucleon. In addition it will provide a measurement of the electron spectrum in the energy range 2.3 to 20 Mev. It employs a 0.45 gm/cm^2 CsI scintillation detector to measure the rate of energy loss dE/dx, a 9 gm/cm^2 CsI scintillator to measure the total energy E, and a guard plastic scintillator to ensure that the particles come to rest in the total energy scintillator and to assist in defining the directional characteristics of the detector. Two parameter analysis is employed to permit a complete mapping of N versus E and dE/dx. Signal conditioning equipment presents the data in proper form to the spacecraft central data handling system. A quasi-floating point digital counting system counts a number of pulse rates to serve as a check on the operation of the primary instrument and to facilitate dead-time correction. The instrument is assembled in the form of a 20 cm cube, weighs 6.8 kg, and requires 1.6 watts of electrical power. The experiment is to be flown in mid-1964 on an Orbiting Geophysical Observatory which will spend a major portion of its time near the apogee height of 110,000 km, well outside the earth's magnetosphere. A somewhat simpler version capable of studying particles $Z < 3$ will be flown in late 1963 on an Interplanetary Monitoring Platform which will have an apogee height of 280,000 km.

A6-14 "Pulse Height Analyzer and Commutating Circuits for IMP E vs dE/dx Nuclear Abundance Experiment," NASA-GSFC, X-631-63-252, Oct. 1963.

A7 Solid-State Telescope

J.A. Simpson University of Chicago

A charged particle solid-state telescope was used to measure range and energy loss of galactic and solar cosmic rays. The experiment was designed to study particle energies (energy range is proportional to Z^2/A; for protons: 0.9 to 190 Mev, 6.5 to 190 Mev, 19 to 190 Mev, and 90 to 190 Mev) and charge spectra ($Z \leq 6$). The detector was oriented normal to the spacecraft spin axis. The detector accumulators for each energy interval were telemetered six times every 5.46 min. Each accumulation was about 40 sec long (initial spacecraft spin period was about 2 sec). The output from two 128-channel pulse height analyzers was obtained for one incident particle every 41 sec and read out along with the detector accumulations. From launch until October 15, 1964, a malfunction limited alpha studies to particles of $E > 30$ Mev. No useful information was received after October 15, 1964.

• Principal Investigator Group/Major Journals

A7-01 Fan, C.Y., G. Gloeckler, and J.A. Simpson, "Acceleration of Electrons Near the Earth's Bow Shock and Beyond," J. Geophys. Res., 71, 1837-1856, Apr. 1966.

See abstract under A5-15.

A7-02 Fan., C.Y., G. Gloeckler, and J.A. Simpson, "Cosmic Radiation Helium Spectrum Below 90 MeV Per Nucleon Measured on IMP 1 Satellite, J. Geophys. Res., 70, 3515-3527, 1965.

Measurement of the differential spectrum of primary helium nuclei over the energy range 30 to 90 Mev per nucleon in six energy intervals. The results are well represented by the power spectrum $dJ/dE = 1.15 \times 10^{-5} E^{1.4 \pm 0.2}$ $(m^2 \text{ sec ster Mev})^{-1}$, where J is the integral flux of He 3 and He 4, and E is the total kinetic energy. This is the time-averaged spectrum from Nov. 27, 1963, to May 1, 1964, near the minimum of the solar activity cycle. There is evidence that this helium spectrum is the low-energy extension of the modulated, interstellar spectrum of cosmic-ray helium: (1) the helium nuclei were continuously present over the 5-month period and not correlated with solar-flare phenomena; (2) this helium spectrum extends smoothly into the higher-energy spectrum for cosmic-ray helium measured in balloons by others in 1963 and known to be of galactic origin; (3) during this period the helium flux increased approximately 35% while the higher-energy cosmic radiation increased ~6%; this is the expected qualitative behavior for the solar modulation of an interstellar spectrum of helium during the decay phase of the interplanetary magnetic fields. Since the IMP 1 (Explorer 18) satellite had an apogee of 198,000 km, primary helium measurements were obtained over most of the orbital period. The experimental apparatus consisted of a solid-state, charged-particle telescope which measured the energy loss and total energy of protons, helium, and some components of higher charge. The novel use of semiconductor detectors, and their dynamic range, energy resolution, stability, and linearity as a function of particle charge are discussed.

A7-03 Fan, C.Y., G. Gloeckler, and J.A. Simpson, "Evidence for >30-kev Electrons Accelerated in the Shock Transition Region Beyond the Earth's Magnetospheric Boundary," Phys. Rev. Letters, 17, 149-153, Aug. 1964.

Measurements of electrons with energies >30 kev on Explorer 18 (IMP 1) are discussed. It is shown that these electrons are confined to peaks less than 5,000 kev wide and trace out a region in space which is compatible with the expected location of the shock front at a stand-off distance of approximately 15,000 to 20,000 kev beyond the boundary of the magnetosphere. The data discussed were obtained with the first gold-silicon surface-barrier charged particle detector of the University of Chicago cosmic-ray telescope.

A7-04 Gloeckler, G., "Solar Modulation of the Low-Energy Galactic Helium Spectrum as Observed on the IMP 1 Satellite," J. Geophys. Res., 70, 5333-5343, 1965.

Study of the time variations in the low energy cosmic-ray helium of galactic origin over the period from Nov. 27, 1963, to May 15, 1964. It is found that during this time the helium flux in the 30-to-90-Mev/nucleon energy interval increased by (65 ± 22)%, while the flux in the 250-to-500-Mev/nucleon energy range increase by (30 ± 8)%. It is shown from these observed increases that the modulation of the galactic cosmic radiation at these low energies is dependent on the velocity of the galactic particle rather than on its rigidity and that it is well described by the theory of Parker. The nature of the spectrum outside the solar system is discussed. It is found that the time-averaged modulated-galactic-helium spectrum in early 1964 can be approximated by $dJ/dE = 3 \times 10^{-6} E^{1.65}$ helium m^2-sec-ster-Mev, with total kinetic energy E measured in Mev, over the energy range from 7 to 90 Mev/nucleon. Evidence for helium of solar-system origin below ~50 Mev/nucleon in the "27-day" recurrent regions is reported.

A7-05 Gloeckler, G., and J.R. Jokipii, "Low-Energy Cosmic-Ray Modulation Related to Observed Interplanetary Magnetic Field Irregularities," Phys. Rev. Letters, 17, 203-207, 1966.

The diffusion coefficient describing the motion of cosmic-ray particles in the interplanetary magnetic field is determined from the power spectrum of magnetic irregularities observed on space probes, and is found to be proportional to $R\beta$ (R = particle magnetic rigidity, β = particle velocity). Near minimum solar activity, only this dependence of the diffusion coefficient on R and β can account for the observed long-term intensity variations of cosmic-ray protons and helium nuclei down to 10 Mev per nucleon in energy. Thus, the motion of cosmic rays in interplanetary space may be quantitatively related to the observed magnetic field.

A7-06 Jokipii, J.R., "Correlation of E >30 keV Electron Pulses and Magnetic Fields in the Magnetosheath and Beyond," J. Geophys. Res., 73, 931-942, 1968.

See abstract under A1-49.

A7-07 Murayama, T., "Spatial Distribution of Energetic Electrons in the Geomagnetic Tail," J. Geophys. Res., 71, 5547-5557, 1966.

Counting rates from a solid-state detector in the experiment of Fan, Gloeckler, and Simpson on the IMP 1 satellite have been analyzed to investigate the spatial distribution of electrons with energies >30 kev in the geomagnetic tail and in the magnetosheath region surrounding the tail out to ~30 earth radii. The counting rates range from the background cosmic-ray level (~3 sec^{-1}) up to 10^3 sec^{-1} and have a positive correlation with the K_p geomagnetic field disturbance index. A multiple correlation analysis was made to investigate the spatial distribution of the electrons. Within the tail, the particle flux is a decreasing function of Z_n, the distance from the neutral sheet as

determined by magnetic field observations on the same satellite by Ness, Scearce, and Seek. Z_n is found to be a better parameter for describing the electron distribution than the distance from either the ecliptic plane or the geomagnetic equatorial plane. The radial dependence of the electron flux reported earlier by Anderson is shown to be due mostly to the spurious correlation between the radial distance and Z_n. For a given constant Z_n, the flux is higher near the dawnside magnetospheric boundary than near the center of the tail. In the magnetosheath beyond the boundary of the tail, the electron flux decreases only gradually with increasing distance from the solar magnetospheric equatorial plane. The implications of these observations are discussed mainly in connection with the origin of the energetic electrons in the tail.

- Principal Investigator Group/Conference Proceedings

A7-08 Fan, C.Y., G. Gloeckler, B. McKibben, and J.A. Simpson, "The 'Quiet Time' Fluxes of Protons and α-Particles in the Energy Range of 2-20 MeV/Nucleon in 1967," Acta Physica Academiae Scientiarum Hungaricae, 29, Supplement 2, 261-267, 1970. (Proceedings of the 11th International Conference on Cosmic Rays, Budapest, Hungary, 1969.)

The quiet time fluxes and differential spectra of protons and alpha particles in the energy range 2-20 MeV/nucleon were measured in 1967 with cosmic ray detectors on the OGO-3 satellite. These measurements are the continuation of similar studies, begun in 1964, of the temporal variation of the spectra of these particles. The results obtained from the period 1964 to 1966 indicated that these particles were a mixture of particles of galactic and solar origin. The 1967 measurements show that, despite an increase in solar activity and modulation of relativistic cosmic rays, the 2 to 20 MeV fluxes of protons and alpha particles remained relatively unchanged. The implications of this result are discussed.

A7-09 Fan, C.Y., G. Gloeckler, and J.A. Simpson, "Acceleration of Particles in the Earth's Shock Transition Region and Beyond," Proceedings of the 9th International Conference on Cosmic Rays, 1, 105-108, 1966. (Proceedings held in London, England, Sept. 6-17, 1965. Institute of Physics and the Physical Society, London, England.)

Pulses of high energy electrons were observed in the vicinity of the bow shock of the terrestrial magnetosphere with both the Au-Si surface barrier solid state detector (the front detector of the cosmic ray telescope of the University of Chicago) and the GM counter (University of California) on board the IMP-1 satellite. These particle pulses were also detected inside the shock transition region with GM counters in earlier satellites. There is experimental evidence that these electrons are accelerated in the shock transition region. By comparing the counting rates of the solid state detector and that of the GM counter on board IMP-1, the energy spectrum of the electrons may be estimated. If the integral spectrum is expressed as $F = F_0E^{-\gamma}$, the value of γ varies from +2.5 to +4.5. Beyond the shock transition region up to the apogee of the IMP-1 satellite (200,000 km), pulses of high energy particles were also observed with the Au-Si solid state

detector prior to the arrival of the 27-day recurrent solar plasma of enhanced velocity. It is suggested that these are particles accelerated in space by multiple shock waves associated with the co-rotating shock front.

A7-10 Fan, C.Y., G. Gloeckler, and J.A. Simpson, "Protons and Helium Nuclei within Interplanetary Magnetic Regions which Co-Rotate with the Sun," Proceedings of the 9th International Conference on Cosmic Rays, 1, 109-111, 1966. (Proceedings held in London, England, Sept. 6-17, 1965. Institute of Physics and the Physical Society, London, England.)

From IMP-1 measurements we showed in 1964 that fluxes of protons of greater than 1-Mev energy appeared for several days in a sequence of six consecutive 27-day intervals. We concluded that these protons were confined within a region corotating with the sun which modulates the galactic cosmic radiation at the orbit of earth with the same 27-day recurrence period. This region has persisted for more than 20 solar rotations and was observed with the IMP-1 magnetometer by Ness and Wilcox to possess special characteristics. The energy spectrum of the protons in the leading and trailing sides of the corotating region was measured. A helium component continuously associated with the protons has been found with an energy spectrum of the form proportional to E^{-2} Mev/nucleon in the energy range 2 to 30 Mev/nucleon. Evidence from the OGO 1 satellite indicates that the proton and helium fluxes are not only present within corotating regions, but are also present at lower intensity and with different spectra at all times throughout a 2-1/2 month period. The source for continual acceleration of these protons and helium nuclei is discussed.

A7-11 Fan, C.Y., G. Gloeckler, and J.A. Simpson, "Solar Modulation of the Galactic Helium Spectrum Above 30 MeV Per Nucleon," Proceedings of the 9th International Conference on Cosmic Rays, 1, 380-382, 1966. (Proceedings held in London, England, Sept. 6-17, 1965. Institute of Physics and the Physical Society, London, England.)

Time variations in the differential energy spectrum and flux of primary helium nuclei in the energy range 30 to 90 Mev/nucleon have been studied over the time period from Dec. 1963 to Jan. 1965. Continuous measurements over most of the 1-yr period were made using (dE/dx,E) type solid state, charged-particle telescopes which were flown on two satellites (IMP 1 and IMP 2) which had highly eccentric orbits. The helium spectra obtained are well represented by a power dependence of the type $\alpha\ E^{+\gamma}$ where E is the particle total kinetic energy. The exponent γ changed from 1.75 to 1.3 in the 1-yr period while the flux of helium increased by about 75% in the same time interval. Since in addition to this observed modulation, the helium nuclei were continuously present and since the spectrum extends smoothly into the higher energy spectrum measured on balloons, we are convinced that we are observing the low-energy extension of the modulated local galactic helium spectrum. From the measured fractional helium intensity increases with time we are able to deduce that the modulation depends predominantly on the particle velocity.

- Principal Investigator Group/Other Publications

A7-12 Bridge, H.S., G.P. Serbu, N.F. Ness, J.A. Simpson, F. McDonald, K.A. Anderson, and J.H. Wolfe, "Initial Results from the First Interplanetary Monitoring Platform (IMP 1)," IG Bulletin No. 84, June 1964. (Reprinted in Transactions of the American Geophys. Union, 45, 501-520, 1964.)

See abstract under A-01.

A7-13 Fan, C.Y., G. Gloeckler, L.A. Littleton, and J.A. Simpson, "University of Chicago Data Formats for Library Magnetic Tapes for Satellites IMP-1, IMP-2, and IMP-3," University of Chicago, EFINS-66-02, 1966.

- Not Principal Investigator Group/Other Publications

A7-14 "Explorer 18 (1963 46A) Solar and Galactic Protons Experiment," National Space Science Data Center, NSSDC 67-37, Aug. 1967.

B5 Ion Chamber and GM Counters

K.A. Anderson University of California at Berkeley

This experiment, designed to measure fluxes of geomagnetically trapped particles, consisted of a 7.6-cm-diameter Neher type ionization chamber and two Anton 223 Geiger-Mueller tubes. The ion chamber responded to electrons and protons with E > 1 and 17 Mev, respectively. Both GM tubes were mounted parallel to the spacecraft spin axis. GM tube A detected electrons with E > 45 kev scattered off a gold foil. The acceptance cone for these electrons had a full angle of 61°, and its axis of symmetry made an angle of 59.5° with the spacecraft spin axis. GM tube A responded omnidirectionally to electrons and protons with E > 6 and 52 Mev, respectively. GM tube B looked directly into space through a hole in the spacecraft skin. The acceptance cone for GM tube B had a full angle of 38°, and its axis of symmetry was parallel to the spacecraft spin axis. Omnidirectionally, GM tube B responded to electrons and protons with E > 6 and 52 Mev, respectively. Directionally, GM tube B responded to electrons and protons with E > 40 and 500 kev, respectively. Pulses from the ion chamber were accumulated for 326.08 sec and read out once every 327.68 sec. Counts from GM tube A were accumulated for 39.36 sec and read out six times every 327.68 sec. Counts from GM tube B were accumulated for 39.36 sec and read out five times every 327.68 sec. This experiment performed normally from launch through October 13, 1965, the date of the last data transmission.

- Principal Investigator Group/Major Journals

B5-01 Anderson, K.A., J.H. Binsack, and D.H. Fairfield, "Hydromagnetic Disturbances of 3- to 15-Minute Period on the Magnetopause and Their Relation to Bow Shock Spikes," J. Geophys. Res., 73, 2371-2386, 1968.

See abstract under B1-01.

B5-02 Lin, R.P., and K.A. Anderson, "Periodic Modulations of the Energetic Electron Fluxes in the Distant Radiation Zone," J. Geophys. Res., 71, 1827-1835, 1966.

See abstract under A5-08.

- Principal Investigator Group/Conference Proceedings

B5-03 Anderson, K.A., "Energetic Electron Spikes in and Beyond the Transition Region," Proceedings of the 9th International Conference on Cosmic Rays, 1, 520-527, 1965. (Proceedings held at Imperial College of Science and Technology, London, England, Sept. 6-17, 1965.)

See abstract under A5-09.

B5-04 Anderson, K.A. "Wave-Energetic Particle Associations in the Magnetosphere," Earth's Particles and Fields, 429-439, 1968. (Proceedings of the NATO Advanced Study Institute, Freising, West Germany, July 31 - August 11, 1967. Ed., B.M. McCormac, Reinhold Book Corp., New York.)

See abstract under A5-10.

- Principal Investigator Group/Other Publications

B5-05 Anderson, K.A., "Energetic Particles in the Earth's Magnetic Field," Annual Rev. Nuclear Sci., 16, 291-344, 1966.

See abstract under A5-11.

B5-06 "Final Report for Energetic Particle Studies on the First Interplanetary Monitoring Satellites (July 1, 1962 to June 30, 1967)," University of California, Unnumbered, 1967.

See abstract under A5-14.

• Not Principal Investigator Group/Major Journals

B5-07 Rothwell, P., and C. Lynam, "Plasmapause, the Plasma Sheet, and Energetic Trapped Electrons in the Earth's Magnetosphere," Planetary Space Sci., 17, 447-454, 1969.

Observations from the IMP 2 satellite show that much of the energetic trapped radiation observed near the equatorial plane lay beyond the plasmapause, which therefore cannot be the boundary between 'open' and 'closed' field lines in the Earth's magnetosphere. The position of peak intensity for electrons >45 keV generally lay just beyond the plasmapause, while the position of peak intensity for electrons >1.6 MeV lay just inside it. The 'slot', the position of minimum intensity between inner and outer radiation belts lay well inside the plasmapause for both 1.6 MeV and 45 keV electrons.

The boundary between the stable trapping zone and the 'distant' radiation zone of highly fluctuating particle fluxes which also lay beyond the plasmapause, near 10 R_E during quiet times moved as close to the Earth as 6 R_E shortly after onset of magnetic bays; these positions are close to those reported for the inner boundary of the plasma sheet.

It is suggested that:

(1) The plasmapause is the limiting magnetic shell at which most terrestrial plasma of ionospheric origin can remain trapped, if there is an electric field across the magnetosphere.

(2) The inner boundary of the plasma sheet is the limiting distance to which the more energetic interplanetary plasma can penetrate into the Earth's field under the action of the same magnetospheric electric field.

B5-08 Rothwell, P., and V. Wallington, "Polar Substorm and Electron 'Islands' in the Earth's Magnetic Tail," Planetary Space Sci., 16, 1441-1451, 1968.

The behaviour of energetic electrons in the distant magnetosphere near the midnight meridian during polar substorms has been studied for the period March 5th - April 4th, 1965, using data from two end window Geiger counters flown on the IMP 2 satellite (apogee 15.8 Earth radii) and magnetic records from a chain of auroral zone stations around the world at magnetic latitudes equivalent to L = 7.4 ± 2.0.

When the satellite was in the distant radiation zone or in the plasma sheet which extends down the Earth's magnetic tail, sudden decreases in the horizontal magnetic field component at ground stations near the midnight meridian (negative magnetic bays) were followed by sudden increases in 40 keV electron fluxes (electron islands) at the satellite. When the satellite was at high latitudes in the magnetic tail 'bays' often were not followed by 'islands.' When the satellite was near the centre of the plasma sheet, energetic electron fluxes were observed even during magnetically quiet periods. The time delay between the sharp onset of magnetic bays in the auroral zone and the corresponding rapid increase in energetic electron intensity at the satellite, typically some tens of minutes, was least when the satellite was close to the Earth and increased with its increasing radial distance from the Earth. The delay was also a function of distance of the satellite from the centre of the plasma sheet, and of the magnitude of the intensity

increase (smaller delays for larger intensity increases). We deduce that the disturbance producing the magnetic bays and associated particle acceleration originates fairly deep in the magnetosphere and propagates outward to higher L values, and down the plasma sheet in the Earth's magnetic tail on the dark side of the Earth. It is unlikely that the accelerated electrons are themselves drifting away from the Earth, because the apparent velocity with which the islands move away from the Earth decreases with increasing distance from the Earth.

It is suggested that the polar substorm and the associated particle acceleration are part of an impulsive ejection mechanism of magnetospheric energy into the ionosphere, rather than an impulsive injection mechanism of solar wind energy into the magnetosphere.

B6 Scintillator and GM Telescopes

F.B. McDonald NASA/Goddard Space Flight Center

This experiment consisted of two detector systems. The first was a dE/dx vs E telescope with thin and thick CsI scintillators (one each) and an anticoincidence plastic scintillation counter. The telescope axis was normal to the spacecraft spin axis. Counts of particles penetrating the thin CsI scintillator and stopping in the thick CsI scintillator were accumulated during one 39.36-sec interval every 5.46 min. The relative contribution to the count rate of various species (electrons between 3 and 12 Mev, ions with charge = 1, 2, atomic mass = 1, 2, 3, 4, and energy between 18.7 and 81.6 Mev/nucleon) and energy spectral information were determined by 512-channel pulse height analysis performed simultaneously on the output of both CsI scintillators six times every 5.46 min. The second detector system consisted of two Geiger-Mueller tube telescopes oriented parallel and perpendicular to the spacecraft spin axis. Each telescope consisted of two colinear GM tubes. The parallel and perpendicular telescopes measured the sum of counts due to protons with $E > 70$ Mev and electrons with $E > 65$ Mev and the sum of counts due to protons with $E \geq 65$ Mev in electrons with $E > 6$ Mev, respectively. Counts registered in any one of the four GM tubes were also accumulated. These omnidirectional counts were due to protons with $E > 50$ Mev plus electrons with $E \geq 4$ Mev. The parallel, perpendicular, and omnidirectional count rates were obtained for one 40-sec accumulation interval during successive normal 81.9-sec telemetry sequences. Thus, any one count rate was measured for 40 sec once each 5.46 min. Both detector systems worked well from launch until March 2, 1965.

- Principal Investigator Group/Major Journals

B6-01 Balasubrahmanyan, V., E. Boldt, and R.A.R. Palmeira, "Solar Modulation of Galactic Cosmic Rays," J. Geophys. Res., 72, 27-36, 1967.

See abstract under A6-01.

B6-02 Cline, T.L., and F.B. McDonald, "Relativistic Electrons from Solar Flares," Solar Phys., 5, 507-530, 1968.

See abstract under A6-05.

- Principal Investigator Group/Conference Proceedings

B6-03 Balasubrahmanyan, V., D.E. Hagge, G.H. Ludwig, and F.B. McDonald, "Galactic Cosmic Rays at Solar Minimum, 1965," Proceedings of the 9th International Conference on Cosmic Rays, 1, 427-436, 1966. (Proceedings held at the Imperial College of Science and Technology, London, England, Sept. 6-17, 1965.)

See abstract under A6-07.

B6-04 Balasubrahmanyan, V., D.E. Hagge, and F.B. McDonald, "Solar Modulation of Galactic Cosmic Rays Near Solar Minimum (1965)," Can. J. Phys., 46, No. 10, S887-S891, May 1968. (Proceedings of the 10th International Conference on Cosmic Rays, Calgary, Alberta, Canada, June 19-30, 1967. Ed., M.D. Wilson, National Research Council of Canada.)

Continuing study of the time variation of the integral intensity of low-intensity cosmic rays and the differential spectra of protons and He nuclei in order to understand solar modulation and the interplanetary space conditions that determine the propagation of cosmic rays in the solar system. The results are reported of continuous monitoring of the intensity of cosmic rays (of 50-MeV energy) with identical G-M counter telescopes flown on satellites IMP 1, 2, and 3 and OGO-1. The spectrum studies also used data from balloon flights at Fort Churchill. It is shown that a comparison of the time behavior of the G-M counter data with Deep River neutron monitor data suggests the presence of a "hysteresis" time of behavior due to spectral changes occurring near the solar minimum.

B6-05 Balasubrahmanyan, V., and D. Venkatesan, "Spectral Variations in Short Term (Forbush) Decreases and in Long Term Changes in Cosmic Ray Intensity," Acta Physica Academiae Scientiarum Hungaricae, 29, Supplement 2, 327-336, 1970. (Proceedings of the 11th International Conference on Cosmic Rays, Budapest, Hungary, 1969.) (Also, NASA-GSFC, X-611-69-413, Sept. 1969.)

See abstract under A6-09.

B7 Solid-State Telescope

J.A. Simpson University of Chicago

A charged particle solid-state telescope was used to measure range and energy loss of galactic and solar cosmic rays. The experiment was designed to study particle energies (energy range is proportional to Z^2/A; for protons: 0.9 to 190 Mev, 6.5 to 19 Mev, 19 to 90 Mev, and 90 to 190 Mev) and charge spectra ($Z \leq 6$). The detector was oriented normal to the spacecraft spin axis. The detector accumulators for each energy interval were telemetered six times every 5.46 min. Each accumulation was about 40 sec long (initial spacecraft spin period was about 4.1 sec). The output from two 128-channel pulse height analyzers was obtained for one incident particle every 41 sec and read out along with the detector accumulations. Useful data were obtained from launch until April 5, 1965. Data coverage was intermittent throughout the life of the spacecraft due to frequent spacecraft shutoffs and sporadic failure of some detectors.

- Principal Investigator Group/Major Journals

B7-01 Gloeckler, G., and J.R. Jokipii, "Low-Energy Cosmic-Ray Modulation Related to Observed Interplanetary Magnetic Field Irregularities," Phys. Rev. Letters, 17, 203-207, 1966.

See abstract under A7-05.

B7-02 O'Gallagher, J.J., "Heliocentric Longitude Intensity Profile of 15 MeV Protons from the February 5, 1965, Solar Flare," J. Geophys. Res., 75, 1163-1171, 1970.

Simultaneous observations of 15-Mev protons from the solar flare of February 5, 1965, on Mariner 4 and IMP 2 show that the particle intensity decays faster near earth than at Mariner. It is shown that, if the longitudinal intensity profile for energetic flare particles is represented by a Gaussian in heliocentric longitude, then corotation of such a distribution past the two separated points of observation will account for this behavior. Furthermore, these observations provide a measure of the longitudinal scale of the distribution. In particular it is shown that the ratio of intensity at IMP 2 to that at Mariner 4 will be described by $R_{IM}(t) = R_0 \exp(-t/\tau_R)$ where τ_R is related directly both to Ψ, the half-width at 1/e times maximum of the assumed Gaussian distribution, and to the longitudinal separation of the two points of observation. The observations are well described by such an exponential relationship for the first 32 hours after the flare and yield for the half-width $\Psi = 15.3 \pm 1.0°$ throughout this period. The quoted limits on Ψ correspond to a limit on $K_\perp$, the diffusion coefficient perpendicular to the average spiral field, of $K_\perp \lesssim 1.2 \times 10^{19}$ cm^2/sec. On the other hand, the magnitude of Ψ early in the flare requires a diffusion coefficient of $K_\perp \simeq 1.4 \times 10^{20}$ cm^2/sec if this initial width is to be explained by invoking only anisotropic diffusion from the immediate locality of the flare on the sun. The implications of this discrepancy are discussed with respect to the predictions of anisotropic diffusion and the random walk of magnetic field lines.

- Principal Investigator Group/Conference Proceedings

B7-03 Fan, C.Y., G. Gloeckler, B. McKibben, and J.A. Simpson, "The 'Quiet Time' Fluxes of Protons and α-Particles in the Energy Range of 2-20 MeV/Nucleon in 1967," Acta Physica Academiae Scientiarum Hungaricae, 29, Supplement 2, 261-267, 1970. (Proceedings of the 11th International Conference on Cosmic Rays, Budapest, Hungary, 1969.)

See abstract under A7-08.

B7-04 Fan, C.Y., G. Gloeckler, and J.A. Simpson, "Protons and Helium Nuclei within Interplanetary Magnetic Regions which Co-Rotate with the Sun," Proceedings of the 9th International Conference on Cosmic Rays, 1, 109-111, 1966. (Proceedings held in London, England, Sept. 6-17, 1965. Institute of Physics and the Physical Society, London, England.)

See abstract under A7-10.

B7-05 Fan, C.Y., G. Gloeckler, and J.A. Simpson, "Solar Modulation of the Galactic Helium Spectrum Above 30 MeV Per Nucleon," Proceedings of the 9th International Conference on Cosmic Rays, 1, 380-382, 1966. (Proceedings held in London, England, Sept. 6-17, 1965. Institute of Physics and the Physical Society, London, England.)

See abstract under A7-11.

- Principal Investigator Group/Other Publications

B7-06 Fan, C.Y., G. Gloeckler, L.A. Littleton, and J.A. Simpson, "University of Chicago Data Formats for Library Magnetic Tapes for Satellites IMP-1, IMP-2, and IMP-3," University of Chicago, EFINS-66-02, 1966.

C5 Ion Chamber and GM Counters

K.A. Anderson University of California at Berkeley

This experiment, designed to measure fluxes of geomagnetically trapped particles, consisted of a 7.6-cm-diameter Neher type ionization chamber and two Anton 223 Geiger-Mueller tubes. The ion chamber responded to electrons and protons with E > 1 and 17 Mev, respectively. Both GM tubes were mounted parallel to the spacecraft spin axis. GM tube A detected electrons with E > 45 kev scattered off a gold foil. The acceptance cone for these electrons had a full angle of 61°, and its spin axis of symmetry made an angle of 59.5° with the spacecraft spin axis. GM tube A responded omnidirectionally to electrons and protons with E > 6 and 52 Mev, respectively. GM tube B looked directly

into space through a hole in the spacecraft skin. The acceptance cone for GM tube B had a full angle of 38°, and its axis of symmetry was parallel to the spacecraft spin axis. Omnidirectionally, GM tube B responded to electrons and protons with E > 6 and 52 Mev, respectively. Directionally, GM tube B responded to electrons and protons with E > 40 and 500 kev, respectively. Pulses from the ion chamber were accumulated for 326.08 sec and read out once every 327.68 sec. Counts from GM tube A were accumulated for 39.36 sec and read out six times every 327.68 sec. Counts from GM tube B were accumulated for 39.36 sec and read out five times every 327.68 sec. This experiment performed normally from launch through May 11, 1967, the date of the last useful data transmission.

- Principal Investigator Group/Major Journals

C5-01 Akasofu, S.I., E.W. Hones, and C.-I. Meng, "Simultaneous Observations of an Energetic Electron Event in the Magnetotail by the Vela 3A and IMP-3 Satellites (II)," J. Geophys. Res., 75, 7296-7298, 1970.

It is found that the plasma sheet in the magnetotail thickens (or expands) during the magnetospheric substorm and the expansion speed is about 20 km/sec and the subsequent contraction speed is only about 4 km/sec, based on a few energetic electron events detected almost simultaneously by both IMP-3 and Vela satellites.

C5-02 Anderson, K.A., "Energetic Electrons of Terrestrial Origin Behind the Bow Shock and Upstream in the Solar Wind," J. Geophys. Res., 74, 98-106, 1969.

Energetic electron fluxes associated with the earth's bow shock are found to be present about as often on the dawn side of the sun-earth line as on the dusk side. The peak fluxes attained by these spikes also show no dawn-dusk asymmetry. Upstream electron events, on the other hand, are predominantly found to the dawn side of the sun-earth line. Both phenomena have the same temporal character with characteristic times of 30 to 150 sec. Both have characteristic energies of about 15 keV, but the upstream electron fluxes are much weaker. The upstream events are interpreted to be of secondary origin with the bow shock spikes representing the primary acceleration event. This local acceleration process evidently is of no consequence to the problem of the Van Allen belts and auroral processes.

C5-03 Anderson, K.A., "Energetic Electrons of Terrestrial Origin Upstream in the Solar Wind," J. Geophys. Res., 73, 2387-2397, 1968.

Fluxes of energetic electrons of terrestrial origin are frequently found beyond the bow shock on the sunward side of the earth. The duration of individual events is from less than a minute up to several minutes, but they tend to occur in clusters lasting as long as several hours. Their flux is usually a few hundred cm^{-2} sec^{-1}, but occasionally it reaches 3×10^4 cm^{-2} sec^{-1} for electrons >40 kev. The upstream electron spikes are associated with rapid motion of the bow shock. The best interpretation of upstream spikes is that they are simply electrons

moving up interplanetary field lines from the magnetosheath just behind the shock where they originated as bow shock spikes.

C5-04 Anderson, K.A., and R.P. Lin, "Observations on the Propagation of Solar-Flare Electrons in Interplanetary Space," Phys. Rev. Letters, 16, 1121-1124, June 1966.

See abstract under A5-04.

C5-05 Kahler, S.W., "Comparison of Energetic Storm Protons to Halo Protons," Solar Phys., 8, 166-185, 1969.

Satellite observations of solar proton events with a 'halo' structure or an energetic storm proton event and an SSC are studied. It is pointed out that some SSC events are associated with a decrease in the few MeV cosmic ray fluxes while most are associated with a flux increase. The properties of halo protons and energetic storm protons are compared. It is hypothesized that the two events are similar in origin. The propagation mode of storm particles is discussed. Evidence is presented for a solar, rather than interplanetary origin of storm protons.

C5-06 Lin, R.P., "The Emission and Propagation of ~40 keV Solar Flare Electrons I: The Relationship of ~40 keV Electron to Energetic Proton and Relativistic Electron Emission by the Sun," Solar Phys., 12, No. 2, 266-303, May 1970.

Observations of prompt ~ 40 keV solar flare electron events by the IMP series of satellites in the period August, 1966 to December, 1967 are tabulated along with prompt energetic solar proton events in the period 1964-1967. The interrelationship of the various types of energetic particle emission by the sun, including relativistic energy electrons reported by Cline and McDonald (1968) are investigated. Relativistic energy electron emission is found to occur only during proton events. The solar optical, radio and X-ray emission associated with these various energetic particle emissions as well as the propagation characteristics of each particle species are examined in order to study the particle acceleration and emission mechanisms in a solar flare. Evidence is presented for two separate particle acceleration and/or emission mechanisms, one of which produces ~ 40 keV electrons and the other of which produces solar proton and possibly relativistic energy electrons. It is found that solar flares can be divided into three categories depending on their energetic particle emission: (1) small flares with no accompanying energetic phenomena either in particles, radio or X-ray emission; (2) small flares which produce low energy electrons and which are accompanied by type III and microwave radio bursts and energetic (~ 20 keV) X-ray bursts; and (3) major solar flare eruptions characterized by energetic solar proton production and type II and IV radio bursts and accompanied by intense microwave and X-ray emission and relativistic energy electrons.

C5-07 Lin, R.P., and K.A. Anderson, "Evidence for the Connection of Geomagnetic Tail Lines to the Interplanetary Field," J. Geophys. Res., 71, 4213-4217, 1966.

Solar ~40 keV electrons are observed to gain rapid access into the geomagnetic tail. These electron events are compared with events observed in the interplanetary medium, and it is found that they are essentially identical in all respects. It is argued that such rapid access of these low rigidity particles into the magnetotail must be the result of direct connection of the geomagnetic tail field lines to the interplanetary field. Electric field drift and diffusion of particles are shown to be unlikely mechanisms for entry into the tail.

C5-08 Lin, R.P., S.W. Kahler, and E.C. Roelof, "Solar Flare Injection and Propagation of Low-Energy Protons and Electrons in the Event of 7-9 July 1966," Solar Phys., 4, 338-360, 1968.

Simultaneous satellite observations of the solar particle event on July 7 to 9, 1966 are utilized to show that large spatial gradients are present in the fluxes of 0.5 to 20 MeV protons and $\gtrsim$45 keV electrons. The event is divided into three parts: the ordinary diffusive component, the halo, and the core. The core corotates with the interplanetary field, and therefore it and the surrounding halo are interpreted as spatial features which are connected by the interplanetary magnetic field lines to the vicinity of the flare region. Upper limits to the interplanetary transverse diffusion coefficient for 4 to 20 MeV protons at 1 AU are derived from the width of the halo. These are at least two orders of magnitude less than the parallel diffusion coefficient for the same energy particles. It is argued that the observed flux variations cannot be explained by an impulsive point source injection for any physically reasonable diffusion model. The geometry of the injection mechanism is discussed and it is suggested that some temporary storage of the flare particles occurs near the sun.

C5-09 Meng, C.-I., and S.I. Akasofu, "Magnetospheric Substorm Observations Near the Neutral Sheet," J. Geophys. Res., 76, 4679-4684, 1971. (Letter)

C5-10 Meng, C.-I., and K.A. Anderson, "Energetic Electrons in the Plasma Sheet Out to 40 R_E," J. Geophys. Res., 76, 873-882, 1971.

The flux time profiles and correlation with the local magnetic fields of energetic electrons (<40 keV) in the magnetospheric tail have been studied using four months of IMP-3 data.

The following results were obtained:

a) Fluxes of 10^2 to 8×10^5 cm^{-2} sec^{-1} have been measured beyond $X_{se} = -20$ R_e.

b) The energetic electrons are confined to the plasma sheet and this general character is closely the same as at the VELA orbit (~ 18 R_e).

c) The electrons are almost always present throughout the entire plasma sheet, including the evening side of the magnetospheric tail.

d) There is evidence that the energetic electrons are magnetically confined in much the same way as electron fluxes nearer the Earth in the skirt and cusp regions. These regions are recognized to be part of the plasma sheet.

e) Electron island fluxes are clearly recognized as due to expansion of the plasma sheet beyond its normal boundary as suggested by Axford (1967).

C5-11 Meng, C.-I., E.W. Hones, and S.I. Akasofu, "Simultaneous Observations of an Energetic Electron Event in the Magnetotail by the Vela 3A and IMP-3 Satellite (I)," J. Geophys. Res., 75, 7294-7295, 1970.

It is found that the plasma sheet in the magnetotail thickens (or expands) during the magnetospheric substorm and the expansion speed is about 20 km/sec and the subsequent contraction speed is only about 4 km/sec, based on a few energetic electron events detected almost simultaneously by both IMP-3 and Vela satellites.

- Principal Investigator Group/Conference Proceedings

C5-12 Anderson, K.A., "Relation of Energetic Particles in the Plasma Sheet to the Auroral Zone," Atmospheric Emissions, Eds., B. McCormac, A. Ombert, Van Nostrand Reinhold Pub. Co., 327-336, 1969.

A review is presented on the observational evidence for a relationship between plasma and energetic particle phenomena in the geomagnetic tail and for precipitation of particles into the auroral zone. The properties of the plasma and energetic particles in the geomagnetic tail are summarized along with the properties of the particles accelerated in the plasma sheet. Figures are included to show (1) the spatial extent of the plasma sheet as determined by Vela and OGO spacecraft; (2) examples of energetic electron fluxes in the plasma sheet 60 R_e into the tail; and (3) comparisons of particle fluxes observed in the geomagnetic tail with riometer records, and of particle fluxes 60 R_e into the magnetotail with ground level measurements. It is pointed out that electron precipitation into the auroral zone during sub-storms shows the same temporal behavior as island fluxes, and that the peak flux of plasma sheet acceleration events decreases with radial distance.

C5-13 Lin, R.P., "Correlations of Solar-Flare Electron Events with Radio and X-Ray Emission from the Sun," Can. J. Phys., 46, No. 10, S757-S760, May 1968. (Proceedings of the 10th International Conference on Cosmic Rays, Calgary, Alberta, Canada, June 19-30, 1967. Ed., M.D. Wilson, National Research Council of Canada.)

The >40 keV solar-flare electrons observed by the IMP III and Mariner IV satellites are shown to be closely correlated with solar radio and X-ray burst emission. In particular, intense type III radio bursts are observed to accompany solar electron-event flares. The energies of the electrons, the total number of electrons, and the size of the electron source at the sun can be inferred from radio observations. The characteristics of the electrons observed in the interplanetary space are consistent with these radio observations. Therefore these electrons are identified as the exciting agents of the type III emission. It has been noted that the radio and X-ray bursts are part of the flash phase of flares. The observations indicate that a striking feature of the flash phase is the production of electrons of 10-100 keV energies.

C5-14 Lin, R.P., "The Emission and Propagation of ~40 keV Solar Electrons," Acta Physica Academiae Scientiarum Hungaricae, 29, Supplement 2, 669-677, 1970. (Proceedings of the 11th International Conference on Cosmic Rays, Budapest, Hungary, 1969.)

Since the first spacecraft observations of ~40 keV solar electrons in 1965 over 130 such electron events have been detected by the essentially continuous monitoring of the IMP (Interplanetary Monitoring Platform) satellites. These impulsive ~40 keV electron events are closely associated with solar flares and are the most common type of energetic solar particle emission. Studies of the relationship of these electron events to other solar phenomena, in particular solar proton and relativistic energy solar electron events, indicate that the acceleration and emission of ~40 keV solar electrons is a phenomenon distinct from the production of solar protons and relativistic electrons. A close correlation is evident between ~40 keV electron events and flash phase phenomena such as X-ray and radio bursts. For the small flares commonly associated with ~40 keV electron events the production of such particles must constitute a major flare process. The propagation of ~40 keV eletrons has been studied. The transit time, rise time to maximum and decay time all show no solar longitude dependence. These results indicate that these electrons are released over a large area of the sun and that subsequently the propagation of these electrons can best be described in terms of a *cone of propagation* defined by the interplanetary magnetic field lines which thread the electron production and/or storage region at the sun.

- Principal Investigator Group/Other Publications

C5-15 "Final Report for Energetic Particle Studies on the First Interplanetary Monitoring Satellites (July 1, 1962 to June 30, 1967)," University of California, Space Science Lab. Ser. 8, Iss. 107, 1967.

See abstract under A5-14.

C5-16 Lin, R.P., "Observations of Solar Flare Electrons in Interplanetary Space," University of Calif., Aug. 1967. (Ph.D. Thesis)

The observations of >40 keV solar flare electrons by the IMP-III and Explorer 33 satellites are used to study the emission of such

electrons from the sun and their propagation in the interplanetary medium. It is found that there is very little diffusion transverse to the interplanetary magnetic field lines for these electrons in their propagation from the sun to the earth, and that the angular extent of the cone of propagation in interplanetary space filled with electrons reflects the angular size of the source at the sun. This size is typically about 30° solar longitude, but ranges up to 90° for electron events which occur at the time that a type I radio noise storm is covering a similar angular extent of the solar disc. The time behavior of the solar electron fluxes does not fit well to the power law decay predicted by the model of impulsive point source injection into an infinite diffusing medium, but rather exhibits an exponential decay in time as would be expected for the injection of these particles into a bounded diffusing medium. The large enduring pitch angle anisotropies which are often observed for these electron fluxes indicates that the electrons are essentially escaping beyond 1 A.U., and therefore the diffusing medium must be bounded inside 1 A.U. The diffusion of solar electrons may occur close to the sun. Comparisons of solar proton and electron onset times for mixed events indicates that the electrons are injected into the interplanetary medium earlier than the protons. Moreover, the proton fluxes on occasion show highly structured spatial variations which are not evident in the simultaneously observed electron fluxes. It is suggested that the solar protons and electrons are produced in different regions of the solar atmosphere; electrons in the upper chromosphere or lower corona and protons in the strong magnetic field regions in the lower chromosphere. The electron events are found to be accompanied by type III radio emission and impulsive centimeter and X-ray emission, all of which appear to be associated with the optical flash phase which occurs for many flares. The electron, radio, and X-ray emission by the flare can all be accounted for by the production of packets of 10^{35} electrons of 10-100 keV energies. The characteristics of the electron streams which produce type III radio emission as they escape the sun are completely consistent with the characteristics of the solar flare electrons observed by the satellites. The solar flare electrons observed by satellite are therefore tentatively identified as the same electrons which generate type III bursts at the sun.

- Not Principal Investigator Group/Other Publications

C5-17 George, M.J., "New Measurements on the Absolute Cosmic Ray Ionization from Sea Level to 1540 Kilometers Altitude," California Institute of Technology, 1969. (Ph.D. Thesis)

C5-18 Lindgren, S.T., "Solar and Galactic Cosmic Rays and the Interplanetary Magnetic Field 28 January - 25 February 1967," Acta Physica Academiae Scientiarum Hungaricae, 29, Supplement 2, 401-407, 1970. (Proceedings of the 11th International Conference on Cosmic Rays, Budapest, Hungary, 1969.)

See abstract under D2-20.

C6 Scintillator and GM Telescopes

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This experiment consisted of two detector systems. The first was a dE/dx, E telescope with thin and thick CsI scintillators (one each) and an anticoincidence plastic scintillator counter. The telescope axis was normal to the spacecraft spin axis. Counts of particles penetrating the thin CsI scintillator and stopping in the thick CsI scintillator were accumulated during one 39.36-sec interval every 5.46 min. The relative contribution to the count rate of various species (electrons between 3 and 12 Mev, ions with charge = 1, 2, atomic mass = 1, 2, 3, 4, and energy between 18.7 and 81.6 Mev/nucleon) and energy spectral information were determined by 512-channel pulse height analysis performed simultaneously on the output of both CsI scintillators six times every 5.46 min. The second detector system consisted of two Geiger-Mueller tube telescopes oriented parallel and perpendicular to the spacecraft spin axis. Each telescope consisted of two colinear GM tubes. The parallel and perpendicular telescopes measured the sum of counts due to protons with E > 70 Mev and electrons with E > 6.5 Mev and the sum of counts due to protons with E > 65 Mev and electrons with E > 6 Mev, respectively. Counts registered in any one of the four GM tubes were also accumulated. These omnidirectional counts were due to protons with E > 50 Mev plus electrons with E > 4 Mev. The parallel, perpendicular, and omnidirectional count rates were obtained for one 40-sec accumulation interval during successive normal 81.9-sec telemetry sequences. Thus, any one count rate was measured for 40 sec once each 5.46 min. Both detector systems worked well from launch until May 11, 1967.

- Principal Investigator Group/Major Journals

C6-01 Balasubrahmanyan, V., E. Boldt, and R.A.R. Palmeira, "Solar Modulation of Galactic Cosmic Rays," J. Geophys. Res., 72, 27-36, 1967.

See abstract under A6-01.

C6-02 Balasubrahmanyan, V., D.E. Hagge, G.H. Ludwig, and F.B. McDonald, "Multiply Charged Primary Cosmic Radiation at Solar Minimum, 1965." J. Geophys. Res., 71, 1771-1780, 1966.

The primary cosmic-ray charge and energy spectra have been obtained for helium through oxygen during the recent period when solar modulation effects were at a minimum. These spectra represent a synthesis of preliminary experimental results from cosmic-ray experiments flown on OGO 1, IMP 3, and high-altitude Skyhook balloon flights. The He energy spectrum is given from 35 to 750 Mev/nucleon. The energy spectrum for lithium-oxygen covers the interval ~40-1200 Mev/nucleon. Integral flux values >1200 Mev are obtained for He through Ne. L/M ratios of 0.29 ± .07 at 100 Mev/nucleon and 0.30 ± .03 above 600 Mev/nucleon are found. The C/He ratio of 0.023 ± .005 at 100 Mev/nucleon is significantly less than the same integral ratio of 0.036 ± .004 above 600 Mev/nucleon, indicating the effects of ionization losses during propagation through the interstellar gas under the assumption of similar source spectra.

C6-03 Cline, T.L., and F.B. McDonald, "Relativistic Electrons from Solar Flares," Solar Phys., 5, 508-530, 1968.

See abstract under A6-05.

- Principal Investigator Group/Conference Proceedings

C6-04 Balasubrahmanyan, V., D.E. Hagge, G.H. Ludwig, and F.B. McDonald, "Galactic Cosmic Rays at Solar Minimum, 1965," Proceedings of the 9th International Conference on Cosmic Rays, 1, 427-436, 1966. (Proceedings held at the Imperial College of Science and Technology, London, England, Sept. 6-17, 1965.)

See abstract under A6-07.

C6-05 Balasubrahmanyan, V., D.E. Hagge, and F.B. McDonald, "Solar Modulation of Galactic Cosmic Rays Near Solar Minimum (1965)," Can. J. Phys., 46, No. 10, S887-S891, May 1968. (Proceedings of the 10th International Conference on Cosmic Rays, Calgary, Alberta, Canada, June 19-30, 1967. Ed., M.D. Wilson, National Research Council of Canada.)

See abstract under B6-04.

C6-06 Balasubrahmanyan, V., E.C. Roelof, R.P. Bukata, and R.A.R. Palmeira, "Co-Rotating Modulations of Cosmic Ray Intensity Detected by Spacecraft Separated in Solar Azimuth," Acta Physica Academiae Scientiarum Hungaricae, 29, Supplement 2, 31-36, 1970. (Proceedings of the 11th International Conference on Cosmic Rays, Budapest, Hungary, 1969.) (Also, NASA-GSFC, X-611-69-413, Sept. 1969.)

See abstract under A6-08.

C6-07 Balasubrahmanyan, V., and D. Venkatesan, "Spectral Variations in Short Term (Forbush) Decreases and in Long Term Changes in Cosmic Ray Intensity," Acta Physica Academiae Scientiarum Hungaricae, 29, Supplement 2, 327-336, 1970. (Proceedings of the 11th International Conference on Cosmic Rays, Budapest, Hungary, 1969.) (Also, NASA-GSFC, X-611-69-413, Sept. 1969.)

See abstract under A6-09.

C6-08 Cline, T.L., and F.B. McDonald, "Interplanetary and Solar Electrons of Energy 3 to 12 MeV, Can. J. Phys., 46, No. 10, S761-S765, May 1968. (Proceedings of the 10th International Conference on Cosmic Rays, Calgary, Alberta, Canada, June 19-30, 1967. Ed., M.D. Wilson, National Research Council of Canada.)

Observations of 3 to 12-MeV solar-flare electrons detected in interplanetary space with the IMP 1, 2, and 3 satellites, and review of the progress in the study of solar modulation of these low-energy relativistic electrons. It is shown that the electrons detected have kinetic energies nearly two orders of magnitude higher than any previously studied. Solar events of July 7 and Sept. 14, 1966, are detailed. The electron time histories are shown to have delayed onsets, and are similar in form to those of high-energy protons. Energy spectra are described and illustrated. Characteristics of the electron-intensity time variations are outlined, and they are shown to be consistent with the hypothesis of the primary cosmic-ray nature of these particles and with a strong dependence on the local field conditions.

C6-09 McDonald, F.B., "Satellite Observations of Solar Cosmic Rays," Intercorrelated Satellite Observations Related to Solar Events, 34-52, 1970. (Proceedings of the 3rd ESLAB/ESRIN Symposium, Noordwijk, Netherlands, Sept. 16-19, 1969. Eds., V. Manno, D.E. Page, D. Reidel Publishing Company, Dordrecht, Holland.)

C6-10 McDonald, F.B., D.E. Hagge, and J.P. Meyer, "Measurements and Interpretation of the Isotopic Composition of Hydrogen and Helium Cosmic-Ray Nuclei Below 75 MeV/Nucleon," Can. J. Phys., 46, No. 10, S503-S506, May 1968. (Proceedings of the 10th International Conference on Cosmic Rays, Calgary, Alberta, Canada, June 19-30, 1967. Ed., M.D. Wilson, National REsearch Council of Canada.)

Measurement of hydrogen and helium isotopic abundance ratios and examination of the results of a propagation calculation studying the bearing of different source and propagation models on the two ratios. The creation of deuterons and ^{3}He through fragmentation of cosmic-ray and interstellar ^{4}He nuclei, and proton-proton reactions are investigated in order to understand the energy dependence of the hydrogen and helium ratios. A Monte Carlo technique is used to propagate the cosmic-ray protons and ^{4}He nuclei from the source to earth. Ionization loss, energy dependence of the cross sections, and reaction kinematics are taken into account, but elastic scattering, acceleration in space, and solar modulation are not. It is concluded that the present results completely rule out a total-energy, and favor a kinetic-energy source of power spectrum.

C6-11 Simnett, G.M., T.L. Cline, and F.B. McDonald, "Time Variations of the 4 to 12-MeV Interplanetary Electron Intensity Between 1963 and 1968," Acta Physica Academiae Scientiarum Hungaricae, 29, Supplement 1, 151-158, 1970. (Proceedings of the 11th International Conference on Cosmic Rays, Budapest, Hungary, 1969.) (Also, NASA-GSFC, X-611-69-413, Sept. 1969.)

See abstract under A6-11.

- Principal Investigator Group/Other Publications

C6-12 Kinsey, J.H., "Study of Low Energy Cosmic Rays at 1 A.U.," NASA-GSFC, X-611-69-396, Sept. 1969. (Ph.D. Thesis.)

The results from the two scintillator >E versus E - >E scopes on IMP-3 and IMP-4 and the solid state telescope on IMP-4 are analyzed and the resulting proton and alpha particle fluxes presented. A comparison of the quiet time spectra of both proton and alpha particles is made. It is shown that the results after solar minimum in 1965 do not agree with currently accepted theory in the low energy region of the spectrum considered. Further, it is shown that the reason for this may be because of a hysteresis in the particle fluxes with respect to energy. It is found that there is a fairly flat ratio of He^3 to He^3 to $He^3 + He^4$ energy range considered with a value of about 7%. Further evidence is presented for the existence of recurrence events with 27 day periods which are related to large calcium plage regions on the sun and co-rotating regions which produce discrete proton events observed at earth. These observations serve further to establish the source of protons with MeV energies.

C7 Solid-State Telescope

J.A. Simpson University of Chicago

A charged particle solid-state telescope was used to measure range and energy loss of galactic and solar cosmic rays. The experiment was designed to study particle energies (energy range is proportional to Z^2/A; for protons: 0.9 to 190 Mev, 6.5 to 19 Mev, 19 to 90 Mev, and 90 to 190 Mev) and charge spectra ($Z \leq 6$). The detector was oriented normal to the spacecraft spin axis. The detector accumulators for each energy interval were telemetered six times every 5.46 min. Each accumulation was about 40 sec long (initial spacecraft spin period was about 3.3 sec). The output from two 128-channel pulse height analyzers was obtained for one incident particle every 41 sec and was read out along with the detector accumulations. The experiment performed normally until April 21, 1966, after which several problems with the instrumentation developed, causing spikes in the count rate data, especially in the lowest energy channel. The date of transmission of the last useful information was April 29, 1967.

- Principal Investigator Group/Major Journals

C7-01 Fan, C.Y., and G. Gloeckler, "Galactic Deuterium and Its Energy Spectrum Above 20 MeV/Nucleon," Phys. Rev. Letters, 70, 329-333, 1966.

Measurement of the fluxes and energy spectra of deuterium, protons, and helium on the IMP-III satellite at a time near minimum solar activity. The deuterium differential energy spectrum in the range 17-63 Mev/nucleon is a $\alpha\ E^{\pm 2}$ and, at 60 Mev/nucleon, the relative abundance ratios are $H^2/He^4 = 0.15$ and $H^2/H^1 = 0.05$. If present values of experimental cross sections for the production of H^2 from nucleon interaction with He^4 are used, the observed deuterium abundance may be accounted for by the traversal of He^4 through 4 to 6 g/cm^2 of matter in cosmic-ray sources and the interstellar medium.

C7-02 Fan, C.Y., G. Gloeckler, K.C. Hsieh, and J.A. Simpson, "Isotopic Abundances and Energy Spectra of ^{3}He and ^{4}He Above 40 MeV/Nucleon From the Galaxy," Phys. Rev. Letters, 16, 813-817, May 1966.

Description of satellite measurements of the primary energy spectra of He 3 in the energy range ~40 to 110 Mev/nucleon, and of He 4 in the energy interval of 13 to 90 Mev/nucleon. It is shown that, although there is good agreement among three independent measurements for the absolute flux of He 3 + He 4 above 80 Mev/nucleon, there is a discrepancy of a factor of 2 between the He 3 differential flux obtained and that obtained by Hofmann and Winckler in the energy interval 80 to 100 Mev/nucleon. It is found that this discrepancy cannot be explained by the variation introduced by solar modulation in the time period between the two measurements.

C7-03 Fan, C.Y., G. Gloeckler, J.A. Simpson, and S.D. Verma, "Primary Cosmic Ray Electron Energy Spectrum From 10 MeV to 40 MeV," Astrophys. J., 151, 737-741, Feb. 1968.

Measurement of the differential energy spectrum of primary cosmic-ray electrons in the range from 10 to 40 Mev on the IMP 3 satellite during the period of minimum solar modulation for galactic cosmic rays. The average flux was found to be 3 $\pm$ 2 electrons/(m^2-sec-ster-Mev), and the differential energy spectrum joins previous measurements made at lower and higher energies.

C7-04 Gloeckler, G., and J.R. Jokipii, "Low-Energy Cosmic-Ray Modulation Related to Observed Interplanetary Magnetic Field Irregularities," Phys. Rev. Letters, 17, 203-207, 1966.

See abstract under A7-05.

C7-05 Gloeckler, G., and J.R. Jokipii, "Solar Modulation and the Energy Density of Galactic Cosmic Rays," Astrophys. J., 148, L41-L48, 1967.

Evaluation of the upper limit of the undetermined constant η of solar modulation of cosmic rays by considering the local interstellar cosmic-ray energy density. It is demonstrated that the local interstellar energy density of cosmic rays is a very sensitive function of η. Consideration of the effect of cosmic rays on the interstellar medium then allows to place an upper bound of about 1 GV on the parameter η. An equation is given for local interstellar energy density in terms of proton and helium nucleus particle velocity and kinetic energy. The energy density in ev/cm^3 was evaluated from the observed spectra and is plotted as a function of η. The energy density of cosmic rays is seen to increase rapidly with η above $\eta \gtrsim 0.7$ GV, and exceeds 10 ev/cm^3 for $\eta \gtrsim 1.3$ GV. Arguments based on the dynamics of the interstellar gas strongly suggest than W_{CR} (energy density) $\lesssim 2$ ev/cm^3 which in turn places a firm upper limit on η.

C7-06 Hsieh, K.C., "Study of Solar Modulation of Low-Energy Cosmic Rays Using Differential Spectra of Protons, ^{3}He and ^{4}He at E $\lesssim$ 100 MeV/Nucleon During the Quiet Time in 1965 and 1967," Astrophys. J., 159, 61-76, Jan. 1970.

The differential spectra of galactic cosmic-ray protons, ^{3}He, and ^{4}He at energies between ~20 and 100 MeV per nucleon have been measured during quiet periods between 1967 July and October. The differential spectra of ^{3}He and ^{4}He between 30 and 100 MeV per nucleon measured during solar minimum, 1965 May-September, have been revised and compared with the results of higher-energy measurements made by balloon experiments. These satellite measurements, shown to be free of detectable solar contamination, are used for a study of solar modulation of low-energy cosmic rays. A simple diffusion-convection model with the diffusion coefficient having a functional form that is constant in time fails to explain our observations; however, the same model with the diffusion coefficient having a time-dependent functional form (e.g., Jokipii's extension of the model) can account for our observations. Further, we find that a combined process of diffusion-convection *and* deceleration can also explain our observations. This latter alternative is more likely to be the appropriate model of modulation of low-energy cosmic rays.

C7-07 O'Gallagher, J.J., and J.A. Simpson, "Heliocentric Intensity Gradients of Cosmic-Ray Protons and Helium During Minimum Solar Modulation," Astrophys. J., 147, 819-827, Feb. 1967.

Preliminary results of an experiment that measures the diffusion coefficient of the inward diffusion of particles which is balanced by the outward convection of the particles by magnetic irregularities carried in the solar wind. The diffusion coefficient is said to depend on charged-particle parameters and the characteristics of the interplanetary medium. The problem of whether or not residual solar modulation exists is resolved.

- Principal Investigator Group/Conference Proceedings

C7-08 Fan, C.Y., G. Gloeckler, B. McKibben, and J.A. Simpson, "The 'Quiet Time' Fluxes of Protons and α-Particles in the Energy Range of 2-20 MeV/Nucleon in 1967," Acta Physica Academiae Scientiarum Hungaricae, 29, Supplement 2, 261-267, 1970. (Proceedings of the 11th International Conference on Cosmic Rays, Budapest, Hungary, 1969.)

See abstract under A7-08.

C7-09 Fan, C.Y., G. Gloeckler, and J.A. Simpson, "Satellite Measurements of Low-Energy Cosmic-Ray Li,Be,B,C,N,O,F, Nuclei and Their Implications," Can. J. Phys., 46, No. 10, S548-S552, May 1968. (Proceedings of the 10th International Conference on Cosmic Rays, Calgary, Alberta, June 19-30, 1967. Ed., M.D. Wilson, National Research Council of Canada.)

The differential energy spectrum and chemical abundance of individual elements from the lithium to fluorine have been measured near minimum solar modulation (June 1965 to March 1966) in interplanetary space on the IMP 3 satellite. The spectra for Li, Be, and B are found to increase with decreasing energy below ~60 MeV/nucleon. The consequences of these results on the propagation and lifetimes of cosmic-ray particles are discussed.

- Principal Investigator Group/Other Publications

C7-10 Fan, C.Y., G. Gloeckler, L.A. Littleton, and J.A. Simpson, "University of Chicago Data Formats for Library Magnetic Tapes for Satellites IMP-1, IMP-2, and IMP-3," University of Chicago, EFINS-66-02, 1966.

D5 Ion Chamber and GM Counters

K.A. Anderson University of California at Berkeley

This experiment consisted of a 10.2-cm Neher type ionization chamber and two Geiger-Mueller tubes. The ion chamber responded omnidirectionally to electrons with E > 0.7 Mev and protons with E > 12 Mev. Both GM tubes were mounted perpendicular to the spacecraft spin axis. GM tube A detected electrons with E > 45 kev which were scattered off a gold foil. The acceptance cone for these electrons had a full angle of 61° and axis of symmetry which was perpendicular to the spacecraft spin axis. GM tube B responded to electrons and protons with E > 22 and 300 kev, respectively, in an acceptance cone of 45° full angle with axis of symmetry perpendicular to the spacecraft spin axis. Both GM tubes responded omnidirectionally to electrons and protons with E > 2.5 and 35 Mev, respectively. Pulses from the ion chamber and counts from each GM tube were accumulated for 39.72 sec and read out every 40.96 sec. In addition, the time between the first two ion chamber pulses in an accumulation period was telemetered. On August 1, 1967, GM tube B began to behave erratically and on August 9, 1967, it stopped counting. GM tube A stopped counting a few days later. The ion chamber operated normally from launch through September 2, 1966. Between September 2, 1966, and October 20, 1967, the date of last usable data, the ion chamber operated at a lower threshold voltage.

- Principal Investigator Group/Major Journals

D5-01 Anderson, K.A., "Electrons and Protons in Long-Lived Streams of Energetic Solar Particles," Solar Phys., 6, 111-132, 1969.

In 1966 and 1967 many long-lived streams of low energy solar electrons and protons were observed near Earth. These streams were sometimes associated with bright flares which occurred many hours earlier and sometimes no individual flare could be found. In the latter case the particles are evidently to be associated in a general way with solar active centers as Fan et al (196) have done. The long-lived solar events discussed here include energetic storm particles, delayed events and fluxes associated with solar active regions. It is suggested here that these are all probably the same basic phe-

nomena viewed in somewhat different ways depending on the age of the region and its location on the solar disc. These events are usually associated with a depression in the sea-level neutron intensity and one or more sudden commencements of sudden impulses. Both electrons and protons are present in these events but in several cases electrons were not detected. The most unusual feature is that when both particle species are present, the electron flux is centered several hours before the proton flux.

D5-02 Dodson, H.W., E.R. Hedeman, S.W. Kahler, and R.P. Lin, "Solar Particle Event of July 16-19, 1966, and its Possible Association with a Flare on the Invisible Solar Hemisphere," Solar Phys., 6, 294-303, 1969.

An energetic solar proton and electron event was observed by particle detectors aboard Explorer 33 (AIMP-1) and OGO-3 during the period July 16-19, 1966. Optical and radio observations of the sun suggest that these particles were produced by a flare which may have occurred on July 16 near the central meridian of the invisible hemisphere. The active region to which the flare is assigned is known to have produced the energetic particle events of July 7 and 28, 1966. The propagation of the particles in the July 16-19 event over the ~180° extent of solar longitude from the flare to the earth is discussed, and it is concluded that there must exist a means of rapidly distributing energetic particles over a large area of the sun. Several possible mechanisms are suggested.

D5-03 Kahler, S.W., "Comparison of Energetic Storm Protons to Halo Protons," Solar Phys., 8, 166-185, 1969.

See abstract under C5-05.

D5-04 Lin, R.P., S.W. Kahler, and E.C. Roelof, "Solar Flare Injection and Propagation of Low-Energy Protons and Electrons in the Event of 7-9 July, 1966," Solar Phys., 4, 338-360, 1968.

See abstract under C5-08.

D5-05 Lindgren, S.T., "Solar Particle Events of May 23 and May 28, 1967," Solar Phys., 5, 382-409, 1968.

Description of two solar-particle events, which began on May 23 and May 28, 1967, respectively, and of related solar and terrestrial phenomena. The first of these two events was associated with one or ~~two~~ flares at 25 to 28°E. Not until 36 hours after the onset did the particle flux reach its maximum at energies >12 MeV. It is noted that particle maxima observed 1 to 2 days after the onset of an event are not associated exclusively with eastern flares.

- Principal Investigator Group/Other Publications

D5-06 Lin, R.P., "Observations of Solar Flare Electrons in Interplanetary Space," University of California, Aug. 1967. (Ph.D. Thesis)

See abstract under C5-16.

- Not Principal Investigator Group/Other Publications

D5-07 Lindgren, S.T., "Solar and Galactic Cosmic Rays and the Interplanetary Magnetic Field, 28 January - 25 February 1967," Acta Physica Academiae Scientiarum Hungaricae, 29, Supplement 2, 401-407, 1970. (Proceedings of the 11th International Conference on Cosmic Rays, Budapest, Hungary, 1969.)

See abstract under D2-20.

D6 Solid-State and GM Counters

J.A. Van Allen University of Iowa

Three EON type 6213 Geiger-Mueller tubes (GM1, GM2, and GM3) and a silicon solid-state detector (SSD) provided measurements of solar X rays (GM tubes only, between 2 and 12 A) and of solar, galactic, and magnetospheric charged particles. The GM tubes measured electrons of E > 45 to 50 kev and protons of E > 730 to 830 kev. The SSD output was discriminated at four thresholds: (1) pn1, which detected protons with $.31 \leq E \leq 10$ Mev and alphas with $.59 \leq E \leq 225$ Mev; (2) pn2, which detected protons with $.50 \leq E \leq 4$ Mev and alphas with $.78 \leq E \leq 98$ Mev; (3) pn3, which detected protons with $.82 \leq E \leq 1.9$ Mev and alphas with $1.13 \leq E \leq 46$ Mev; and (4) pn4, which detected alphas with $2.1 \leq E \leq 17$ Mev. GM1 and the SSD were oriented perpendicular to the spacecraft spin axis, GM2 was oriented parallel to the spin axis, and GM3 was oriented antiparallel to the spin axis. Data from GM1 and pn1 were divided into data from quadrants oriented with respect to the sun (sectors I, II, III, and IV centered 180°, 270°, 0°, and 90° from the sun, respectively). Data were read out in either 82- or 164-sec intervals. An intermittent, recognizable electronic failure occurred in the SSD starting about September 15, 1966. Accumulator failures occurred on July 21, 1967, and September 24, 1967. A limited amount of usable data was collected through the date of final spacecraft transmission (May 31, 1971).

- Principal Investigator Group/Major Journals

D6-01 Armstrong, T.P., and S.M. Krimigis, "Observations of Protons in the Magnetosphere and Magnetotail with Explorer 33," J. Geophys. Res., 73, 143-152, 1968.

Protons in the magnetosphere and magnetotail were observed with a silicon detector on Explorer 33. Detectable fluxes of protons Ep >0.31 Mev were measured to 10.4 R_E on the sunward side of the earth and, for the first time with the present experiment, to 80 R_E in the magnetotail.

The small proton fluxes ($\gtrsim 5$ per cm^2-sec-ster) measured in the magnetotail were usually anisotropic, with the largest flux apparently flowing down the tail, away from the earth. When proton bursts occurred in the tail, there was usually increased high-latitude magnetic bay activity at the earth. Durably trapped proton fluxes were observed to have intensities and spectra in agreement with previous measurements. A diurnal variation (in the L coordinate system) was observed in the 0.31- to 10-Mev trapped protons for L >6.6 R_E.

D6-02 Drake, J.F., "Soft Solar X-ray Burst Characteristics," Solar Phys., 16, 152, 1971.

The burst component of the solar x-ray flux in the soft wavelength range 2 A < λ < 12 A observed from Explorer 33 and Explorer 35 from July 1966 to September 1968 were analyzed. In this period 4028 burst peaks were observed.

The differential distributions of the temporal and intensity parameters of the bursts revealed no separation into more than one class of bursts. The most frequently observed value for rise time was 4 minutes and for decay time was 12 minutes. The distribution of the ratio of rise-to-decay time can be represented by an exponential with exponent -2.31 from a ratio of 0.3 to 2.7; the maximum in this distribution occurred at a ratio of 0.3. The values of the total observed flux, divided by the background flux, at burst maximum, can be represented by a power law with exponent -2.62 for ratios between 1.5 and 32. The distribution of peak burst fluxes can be represented by a power law with exponent -1.75 over the range 1 - 100 milli-erg $(cm^2\ sec)^{-1}$. The flux time integral values are given by a power law with exponent -1.44 over the range 1 - 50 erg cm^{-2}.

The distribution of peak burst flux as a function of Hα importance revealed a general trend for larger peak x-ray fluxes to occur with both larger Hα flares. The heliographic longitude dependence of soft x-ray bursts indicated no significant dependence of x-ray burst occurrence on heliographic longitude; the emission thus lacks directivity.

The theory of free-free emission by a thermal electron distribution was applied to a quantitative explanation of both hard x-ray fluxes (data from Arnoldy, Kane, and Winckler [1968]; Kane and Winckler [1969]; and Hudson, Peterson, and Schwartz [1969] and soft x-ray fluxes during solar x-ray bursts. Using bursts in three different energy intervals, covering a total range of 1 - 50 keV, temperatures of 12 - 39 x 10^6 °K and emission measures of 3.6 x 10^{47} to 2.1 x 10^{50} cm^{-3} were derived. The emission measure was found to vary from event to event. The peak time of hard x-ray events was found to occur an average of 3 minutes before the peak time of the corresponding soft x-ray bursts. Thus a changing emission measure during the event is also required. A free-free emission process with temperatures of 12 - 39 x 10^6 °K and with an emission measure in the range 3.6 x 10^{47} to 2.1 x 10^{50} cm^{-3} which varies both from event to event and within an individual event is required by the data examined.

D6-03 Drake, J.F., J. Gibson, and J.A. Van Allen, "Iowa Catalog of Solar X-ray Flux (2-12 Angstroms)," Solar Phys., 10, 433-459, 1969.

The absolute x-ray flux from the whole disc of the sun in the wave length range 2 to 12 A has been observed for a prolonged period by University of Iowa equipment on the earth-orbiting satellite Explorer 33 and the moon-orbiting satellite Explorer 35, both of the Goddard Space Flight Center of the National Aeronautics and Space Administration. The observations are continuing at the date of writing (July 1969). A comprehensive catalog of the flux F(2-12 A) is being produced. The observational technique and the scheme of reducing data are described herein. Sample tabulations and plots are given. A catalog of tabular and graphical data with a time resolution of either 81.8 of 163.6 sec has been completed for the following periods: from Explorer 33, 2 July 1966 to 27 July 1967; from Explorer 35, 26 July 1967 to 18 September 1968.

D6-04 Gibson, J., and J.A. Van Allen, "Correlation of X-ray Radiation (2-12 Angstroms) with Microwave Radiation (10.7 cm) from the Non-Flaring Sun," Astrophys. J., 161, No. 3, Part 1, 1135-1146, Sept. 1970.

Absolute values of the x-ray flux in the 2 - 12 Å range, F(2 - 12 Å), from the whole disc of the non-flaring sun are reported for 734 days during the period 1 July 1966 to 25 December 1968. The data came from University of Iowa equipment on the earth-orbiting satellite Explorer 33 and the moon-orbiting satellite Explorer 35. It is found that F(2 - 12 A) is essentially constant over time periods of the order of one day (flares excluded) but varies by a factor as great as 6 over time periods of the order of one month. During the entire observing period of about 29 months the quiet sun flux lies between upper and lower bounds of 0.4 and 6.8 milli-erg $(cm^2\ sec)^{-1}$, respectively, and the monthly minima increase gradually from 0.4 to 1.0 milli-erg $(cm^2\ sec)^{-1}$ as the solar activity cycle progresses.

A correlation study of F and the radio power density flux P at 10.7 cm (Algonquin Radio Observatory) rejects a linear relationship on both empirical and physical considerations but suggests a relationship of the form

$$F = a \exp\left(-\frac{b}{P}\right).$$

A least squares fit to the observed body of data yields a = 27.3 and b = 385.2, when F is in milli-erg $(cm^2\ sec)^{-1}$ and P is in units of 10^{-22} watt $(m^2\ Hz)^{-1}$.

On the basis of a simple, moderately realistic physical model, the foregoing relationship is found to be theoretically plausible for an emitting volume of hot plasma at electron temperature T, optically thin for x rays, and optically thick for radio waves. Inferred temperatures T are in the range 2.3 to 6.8 x 10^6 °K and emission measures $\int N_e^2\, dV$ in the range 7.6 to 33.5 x 10^{48} cm^{-3}. It appears that the effective horizontal area of radio emission is ~10 times that of the x-ray emitting region.

D6-05 Gleeson, L.J., S.M. Krimigis, and V.I. Axford, "Low Energy Cosmic Rays Near Earth," J. Geophys. Res., 76, 2228-2235, 1971.

Observations of protons with kinetic energy > 0.31 Mev in interplanetary space during quiet times made from the spacecraft Explorer 33 show that there is an anisotropy of ~ 15 percent with the maximum flux directed approximately radially outward from the sun. This observation, and the corresponding radial gradient results reported by Krimigis (1970) are shown to be in very good agreement with those expected from a model in which the observed protons are convected outward at the solar wind speed. It is concluded that these particles have come from an interior region and that the most probable source is the sun, but the possibility that they are of galactic origin, although remote, cannot be positively excluded.

D6-06 Haskell, G.P., "Anisotropic Fluxes of Energetic Particles in the Outer Magnetosphere," J. Geophys. Res., 74, 1740-1748, 1969.

Study of anisotropic fluxes of energetic particles (electrons, E $\gtrsim$ 50 keV; protons, E $\gtrsim$ 830 keV) encountered by the satellite Explorer 33 in, and immediately adjacent to, the distant trapping region. Attention is given to their location in the frame of reference provided by measurements of the local field. On the day side, the flux is peaked at right angles to the field, whereas on the night side it is peaked along the field. Two exceptions to this rule were found, and fluxes of "streaming" particles were found in the magnetosheath, immediately adjacent to the magnetopause. The observations are compared with previous ones and are discussed in the light of current theory.

D6-07 Krimigis, S.M., J.A. Van Allen, and T.P. Armstrong, "Simultaneous Observations of Solar Protons Inside and Outside the Magnetosphere," Phys. Rev. Letters, 18, 1204-1207, June 1967.

Discussion of the results of simultaneous observations of low-energy (~ 0.5 Mev) protons emitted in a solar flare of July 7, 1966, using detectors on board the earth satellites Explorer 33 and Injun 4, located outside and inside the earth's magnetosphere, respectively. It is found that such protons have full and essentially immediate access from interplanetary space to the polar caps of the earth.

D6-08 Van Allen, J.A., "Corrected Absolute Flux of the July 7, 1966, Solar X-ray Flare," J. Geophys. Res., 73, 6863, 1968.

Determination of curves of the relative geometric obliquity factor versus α (the angle between the spin axis of the satellite and the satellite sun line) for the three X-ray detectors on Explorer 33 and a detector on Explorer 35. This has been achieved by means of the simultaneous masses of flight data from the two spacecraft, using, of course, the actual solar spectrum and the actual spread of the solar beam.

D6-09 Van Allen, J.A., "On the Electric Field in the Earth's Distant Magnetotail," J. Geophys. Res., 75, 29-38, 1970.

Analysis of satellite observations of solar electrons with energy greater than 50 keV in order to determine the nature of electric and

magnetic fields in the earth's magnetotail at distances greater than 64 earth radii. During the prolonged solar electron event of Nov. 10 to 22, 1967, simultaneous observations were made with the earth orbiting satellite Explorer 33 in interplanetary space and with the moon-orbiting satellite Explorer 35 as the latter crossed the magnetotail. The intensity of electrons was nearly identical at successive pairs of observational points during a wide range of geomagnetic conditions. It appears that the magnetic topology of the distant magnetotail is an open one (dynamic interconnection with the interplanetary field), and that there are no closed electrical equipotential surfaces beyond 64 earth radii.

D6-10 Van Allen, J.A., "Solar X-ray Flare of July 7, 1966," J. Geophys. Res., 72, 5903-5911, 1967.

By means of a mica window Geiger-Muller tube on earth satellite Explorer 33, a major solar X-ray flare was observed with 81.8-sec. time resolution on July 7, 1966. The flare had its onset at 0023, its maximum intensity at 0042, and a total duration of about 200 min. The maximum energy flux was 3×10^{-2} erg/cm^2-sec, and the time integrated flux was 97 erg/cm^2 ($2 < \lambda < 12$ A). Assuming equal intensity over 2π ster at the sun, the total emission in this wavelength band was 1.4×10^{29} ergs, and the maximum surface luminosity of the sun was 2.9×10^6 erg/cm^2-sec or 4.5×10^{-5} of the whole radiant luminosity of the average solar surface. Charged particles began to arrive at the satellite at 0058, or 35 min after the first detection of the X-ray enhancement, and remained in the interplanetary system for at least 10 days thereafter. The intensity-time curve of the soft X-rays is compared with those of 2700-MHz solar radio noise flux and of ionospheric absorption at 22 MHz as observed at Penticton.

D6-11 Van Allen, J.A., "Solar X-ray Flares on May 23, 1967," Astrophys. J., 152, L85-L86, May 1968.

Results from a determination of the absolute flux of soft X rays (2 to 12 Å) from a sequence of three solar flares on May 23, 1967, as a function of time, with a resolution of 163.6 sec. The maximum flux F at 2 to 12 Å equals 0.65 erg/cm^2-sec occurred at 1846 UT. It is thought that this is the most intense solar X-ray flux yet observed.

D6-12 Van Allen, J.A., J.F. Fennell, and N.F. Ness, "Asymmetric Access of Energetic Solar Protons to the Earth's North and South Polar Caps," J. Geophys. Res., 76, 4262-4275, July 1971.

See abstract under E1-14.

D6-13 Van Allen, J.A., and N.F. Ness, "Observed Particle Effects of an Interplanetary Shock Wave on July 8, 1966," J. Geophys. Res., 72, 935-942, 1967.

See abstract under D1-11.

D6-14 Van Allen, J.A., and N.F. Ness, "Particle Shadowing by the Moon," J. Geophys. Res., 74, 71-93, 1969.

See abstract under D1-12.

D6-15 Van Allen, J.A., and C.D. Wende, "On the Solar Flare of 8 July 1968," J. Geophys. Res., 74, 3046-3048, 1969.

Absolute solar x-ray flux in the wavelength range 2 to 12A is reported for the 3B flare of 8 July 1968. The measurements were made with satellites Explorer 33 and 35. Also given is the solar radio flux density at 15,375 MHz as observed by the North Liberty Radio Observatory.

D6-16 Wende, C.D., "Correlation of Solar Microwave and Soft X-ray Radiation 1. The Solar Cycle and Slowly Varying Components," J. Geophys. Res., 74, 4649-4660, 1969.

An analysis of the solar cycle variation and the quiet sun component is presented. The integral solar X-ray flux between 2-12 A was measured by the spacecrafts Injun 1, Injun 3, Explorer 33, and Explorer 35. The integral flux between 2-9 A was observed by the Mariner V spacecraft. The data from Injuns 1 and 3 and Explorers 33 and 35, averaged in monthly intervals, show a long term variation in activity of at least a factor of five between 1961 and 1969. A slowly varying component which tracks the 10 cm radio flux is observed in the X-ray flux. This X-ray flux variation, about a factor of ten, is correlated with the appearance of major active regions on the solar disc. This slowly varying componet is shown to correlate well with radio fluxes at frequencies greater than about 1 GHz and less well with radio fluxes at lower frequencies. The X-ray spectrum, obtained by comparing the 2-9 A flux with the 2-12 A flux, hardens during periods of high solar activity.

D6-17 Wende, C.D., "Correlation of Solar Microwave and Soft X-ray Radiation 2. The Burst Component," J. Geophys. Res., 74, 6471-6481, 1969.

A study is presented of the histories of solar flares observed at 2 cm and observed at X-ray wavelengths with Mariner V (2-9 A) and Explorers 33 and 35 (2-12 A) that shows post-burst increase and gradual rise and fall events are concurrent microwave and soft X-ray phenomena. The correlation between the X-ray flux and the radio flux is high but non-linear. The character of the correlation is consistent with a thermal flare theory in which the volume emissivity at X-ray wavelengths is of the spectral form $(dE/d\gamma) \approx \exp(-h\mu/kT)$ and the radio flux is from the same region which is optically thick with a temperature T. The correlation yields the peak flare temperature, T_p, and the flare solid angle in terms of the fractional increase in temperature relative to the peak temperature.

- Principal Investigator Group/Conference Proceedings

D6-18 Van Allen, J.A., "Energetic Particle Phenomena in the Earth's Magnetospheric Tail," Particles and Fields in the Magnetosphere, 111-121, 1970. (Proceedings of the Symposium of the Summer Advanced Study Institute, Santa Barbara, Calif., Aug. 4-15, 1969. Ed., B.M. McCormac, D. Reidel Publishing Co., Dordrecht, Holland.)

- Principal Investigator Group/Other Publications

D6-19 Armstrong, T.P., "Several Observations of Proton Bursts in the Magnetotail Associated with Polar Magnetic Substorms," University of Iowa, Unnumbered, Apr. 1968.

Several observations of intense, highly anisotropic bursts of energetic protons (> 0.32 MeV) in the magnetotail are reported. The bursts observed occurred during the recovery phases of polar magnetic substorms and are thought to be caused by the transport of magnetic field lines containing trapped protons from the near magnetosphere into the tail. Strong evidence, based on the absence of protons moving toward the earth, is found that the magnetotail is open for $\geq$ .32 MeV protons. Arguments are advanced that the magnetic field in the tail is smooth on a scale of a proton gyroradius (8×10^4 km), but fluctuating on a scale of an electron gyroradius (70 km).

D6-20 Armstrong, T.P., S.M. Krimigis, and J.A. Van Allen, "Observations of the Solar Particle Event of 7 July 1966 with University of Iowa Detectors," Annals of the IQSY, 3, 313-328, 1969.

Nearly complete time histories (from July 7 to July 17) of the intensities of 0.31-10 MeV protons and of 2.1 - 17 MeV alpha particles emitted from the solar flare of 0023 UT on July 7, 1966, have been obtained with particle detectors on Explorer 33. The peak intensity of 3.5×10^3 $(cm^2 \text{ sec sr MeV})^{-1}$ of 0.82 - 1.9 MeV protons occurred between 1000 and 1100 UT on July 8, approximately 34 hr after the flare. At the same time, the peak intensity of 2.1 - 17 MeV alpha particles was 190 $(cm^2 \text{ sec sr})^{-1}$. The abundance ratio of protons to alpha particles has been measured for the first time in the energy range from 0.5 to 4 MeV/nucleon and is found to range from 28 to 55 in this event. The time profiles of protons and alpha particles are complex, and rapid variations of proton intensities are observed to occur in times as small as 82 sec, the interval between data samples.

D6-21 Krimigis, S.M., J.A. Van Allen, and T.F. Armstrong, "Solar Particle Observations Inside the Magnetosphere During the 7 July 1966 Proton Flare Event," Annals of the IQSY, 3, 395-407, 1969.

Observations of protons emitted by the 7 July 1966 solar flare at N34,W47 with the low altitude high latitude satellite Injun IV show the following: (1) high energy (Ep $\approx$ 27 MeV) protons arrive promptly over the earth's polar caps and decay in a manner consistent with diffusive propagation; (2) the counting rate due to protons in the interval 0.52

$\leq$ Ep $\leq$ 4 MeV and moving normal to the magnetic vector shows a double plateau as the satellite moves over the polar caps; (3) the position of the knee for protons in the above energy interval varies from L ≈ 7.5 to L ≈ 6.3 at magnetic local times of ≈ 4.5 hours and ≈ 11.5 hours, respectively; (4) after the sudden commencement the latitude gap between trapped protons and solar protons disappears, suggesting that some solar protons may become trapped in the earth's radiation belts; and (5) simultaneous observations with similar detectors inside the magnetosphere (Injun IV) and outside the magnetosphere (Explorer 33) show that low energy (≈ 0.5 MeV) protons have essentially immediate access from the interplanetary space to the polar caps of the earth. Theoretical implications of these results are discussed.

D6-22 Sengupta, P.R., "Effect of 1 λ <10 A Solar X-rays on the Ionosphere Between 60 and 100 km," Journal of the Institution of Telecommunication Engineers, (India), 15, No. 5, 305-328, 1969. (Also, University of Iowa Report 68-17, Mar. 1968.)

Computations were made in order to evaluate the ionospheric effects caused by the observed 2 < λ < A X-ray quiescent flux and flare flux. Of seventy-two solar X-ray flares having F(2-12 A) greater than 3 X 10^{-3} erg/cm^2 sec as recorded by Explorer 33, sixty-seven are found to be accompanied by reported S.I.D's in which the electron density of the ionosphere between 60 to 100 km undergoes a rapid increase during a few minutes. These rapid increases in electron density are presumably caused by the enhanced X-ray flux in the wavelength range 1 < λ < 10 A because softer X-rays would be completely absorbed above 100 km and harder X-rays would penetrate below 60 km without significant attenuation at higher altitudes. The altitudes for peak electron production range from 99 km for 10 Å X-rays down to 58 km for 1 Å X-rays. The electron production rate equations were solved using a quiescent X-ray energy spectrum and a mean flare flux X-ray energy spectrum.

D6-23 Sengupta, P.R., "Solar X-ray Control of the D-Layer of the Ionosphere," EASCON '68 Record, 357-363, 1968. (Proceedings of the Institute of Electrical and Electronics Engineer, Electronics and Aerospace Systems Conventions, Washington, D.C., September 9-11, 1968, Institute of Electrical and Electronics Engineers, Inc., New York.)

Evaluation of solar X-ray control of the D layer of the ionosphere, based on data recorded on Explorer 33 during the period from July 1966 to September 1967. Electron production rates due to typical values of the X-ray flux are computed. The relative importance of X-ray ionization is estimated by comparing these with total D-layer electron production rate and also with computed electron production rates due to Lyman alpha and cosmic rays. It is concluded that the 1 to 10 Å solar X-ray flux, which varies with daily solar activity and varies by a factor of about 100 over a sunspot cycle, contributes up to 80% of the total D-layer ionization, depending on the solar activity.

D6-24 Strein, E.W., and J.E. Russell, "AIMP D & E Trapped Radiation Experiment," University of Iowa, July 1966.

This report provides a technical description of the University of Iowa Lunar Orbiting Radiation Experiment which is part of the Anchored Interplanetary Monitoring Platform (AIMP) satellite. The Geiger counter detectors and the solid-state detectors are described along with the accompanying electronics, hardware, and test procedures. The report is fully illustrated with both photographs and schematic drawings.

D6-25 Van Allen, J.A., and M.N. Oliven, "Paucity of Energetic Electron Clouds on the Sunward Side of the Magnetospheric Shock Front," University of Iowa, UI 68-19, Apr. 1968. (Also presented as a talk at the AGU Meeting, April 1968.)

By means of Explorers 33 and 35, a comprehensive study is being made of the occurrence of clouds of energetic electrons ($E_e \geq 45$ keV) in the vicinity of the earth out to a geocentric radial distance of 80 earth radii (R_E). In this preliminary statistical report the incidence of electron clouds is given as the percentage of 36-minute time intervals during which one or more 25.565-second samples each 81.808 seconds exhibited an electron intensity greater than 30 $(cm^2 \text{ sec sterad})^{-1}$ on any one of three Geiger tube detectors. The total useful period of observation comprises 11,378 hours at a sampling duty cycle of 31%. The percentage incidence of clouds is exhibited in 10 R_E by 10 R_E cells in an X_{SE}-Y_{SE} projection and an X_{SM}-Z_{SM} projection, ignoring all other parameters (e.g., K_p, auroral substorms, etc). During over 3000 useful hours in the region on the sunward side of the average magnetospheric shock front and at sun-earth-probe angles less than 70° only two bursts of brief time duration (~5 minutes) and of marginal intensity and validity have been observed. Thus, the occurrence of detectable clouds (or islands) or energetic electrons is far less common in this region than in the region interior to the average shock front surface.

We conclude that the ejection of clouds of electrons from the interior of the magnetosphere through the shock front is an extremely uncommon and perhaps non-existent phenomenon.

D6-26 Wende, C.D., "Correlation of Solar Microwave and Soft X-ray Radiation," University of Iowa, UI 68-57, Aug. 1968. (Ph.D. Thesis)

Solar x-ray measurements made with the Mariner V, Explorer 35, Explorer 33, Injun III, and Injun I spacecraft were correlated with solar microwave emissions. Soft x-ray ($2A<\lambda<12A$) counterparts to the quiet sun component, slowly varying component, and burst component of microwave emissions were found with the exception of a counterpart to impulsive radio bursts with time scales of seconds to minutes. Twenty cases of a high positive correlation between the magnitude of fluxes of soft x-ray flares and of microwave events (of the post burst increase or gradual rise and fall types) observed at a wavelength of 1.95 cm at the North Liberty Radio Observatory operated by the University of Iowa were found. From the correlation, assuming a common source, an x-ray spectrum of the form $\exp(-h\nu/kT)$, and that the flare was optically thick at a wavelength of 1.95 cm and optically thin at x-ray wavelengths, minimum angular sizes and maximum peak temperatures of flares can be found. The alternative assumption that the optical depth at $\lambda = 1.95$ cm is less than unity is inconsistent with observations. Assuming that

free-free emission was dominant at both wavelengths, typical flare diameters were found to be about 32 arc seconds and typical peak flare temperatures about 4 million degrees Kelvin. Limiting values of diameter and peak temperatures differed by a factor of 2 from typical values. Electron densities required by the above assumptions were the order of 10^{11} cm^{-3}.

- Not Principal Investigator Group/Major Journals

D6-27 Hewitt, L.W., "Ionization Increases Associated with the Small Solar Proton Events of 5 February 1965 and 16 July 1966," Can. J. Phys., 47, No. 2, 131-134, 1969.

Observations of partial reflections from the ionosphere at vertical incidence at 2.66 MHz have been made at Resolute Bay, geographic latitude 74.7°N, since September 1963. By measuring the amplitudes of the ordinary and extraordinary backscattered waves information is obtained about electron number densities in the lower ionosphere. The results presented in this paper show that the partial reflection technique is more sensitive than most other ground-based experiments for the detection of D-region ionization increases associated with small solar proton events. Results obtained by the partial reflection experiment during the events of 5 February 1965 and 16 July 1966 are presented and compared with VLF and satellite observations.

D6-28 Ohki, K., "Directivity of Solar Hard X-ray Bursts," Solar Phys., 7, 260-267, 1969.

Solar hard X-ray bursts (>10 keV) seem to show a center-to-limb variation, while softer X-ray bursts show no directivity. This effect on hard X-ray bursts may be due to the directivity of the emission itself. As the cause of the directivity, two possibilities are suggested. One is the inverse Compton effect, and the other is the bremsstrahlung from anisotropic electrons.

D6-29 Westin, H., "Some Statistical Properties of Surges," Solar Phys., 7, 393-416, 1969.

Statistical study of all surges observed at the Swedish Astrophysical Station in Anacapri from July 1, 1957 until Dec. 31, 1967. In 1958 the southern hemisphere was most active in producing surges, but thereafter the northern hemisphere has dominated the activity with increasing rate. The average for the whole period shows that the northern part of the sun has been twice as active as the southern part. The latitude distribution for surges has varied with the solar cycle with a pattern similar to the butterfly diagram for sunspots. The polar surges were most frequent in the beginning of the new cycle. The importance distribution is also dependent on the solar cycle, as a higher percentage of surges of importance 1 are found during the solar minimum. Surges of higher importance tend to have longer durations and are more often associated with flares. The association rate between surges and radio emission is dependent on both the solar cycle and the importance of the surge. During years with high activity, more than 20% of all surges were followed within 5 min from their start by radio emission,

compared to 4% during solar minimum. A total of 17% of surges of importance 2 are closer related to radio emission, but only 10% of surges of importance 1. On the whole, 11% of the surges occurred almost simultaneously with radio bursts. Bursts in discrete frequencies were registered in connection with 8% of the surges, while 11% were followed within 5 min from their start by burst in spectral observations. All these surges were isolated - i.e., no flares have been reported to occur during their lifetimes. This is also the case for the 18 surges covered by X-ray observations, three of which were related to X-ray bursts.

- Not Principal Investigator Group/Other Publications

D6-30 Bostrom, C.O., "Entry of Low Energy Solar Protons into the Magnetosphere," Intercorrelated Satellite Observations Related to Solar Events, 229-238, 1970. (Proceedings of the 3rd ESLAB/ESRIN Symposium, Noordwijk, Netherlands, Sept. 16-19, 1969. Eds., V. Manno, D.E. Page, D. Reidel Publishing Company, Dordrecht, Holland.)

Some aspects of the temporal and spatial variations of low energy solar protons are examined by comparing data from the polar orbiting satellite 1963 38C with measurements in interplanetary space by Explorers 33 and 34. Selected periods during the events of September 1966 and May 1967 are used to show a variety of features in the polar region latitude profiles. The proton intensity in the low latitude "rim" of the polar region appears to track the interplanetary flux of solar protons more readily than does the polar intensity. The rim straddles the energetic electron trapping boundary, and the rim intensity is frequently greater than the polar plateau flux. The intersatellite comparisons and latitude profiles are discussed in terms of model requirements.

D6-31 Pinter, S., "Solar-Flare X-ray Emission Producing Geomagnetic Pulsations," Bulletin Astron. Instit. of Czech., 19, 97-99, 1968.

Study of geomagnetic pulsations occurring during solar flares, which were recorded during the period from 1958 to 1966. The investigation is based mostly on records of geomagnetic pulsations recorded at the Japanese observatories of Kanoya (ϕ = 31°25'N, λ = 130°53'E) and Memabetsu (ϕ = 43°55'N, λ = 144°12'E). It is suggested that intense solar flares are in some cases accompanied by irregular geomagnetic pulsations of the pi 2 type with periods in the range from 40 to 90 sec at midlatitudes. These pulsations occur on the sunlit side of the earth. The geomagnetic pulsations in question begin simultaneously with sudden ionospheric disturbances at the time of the impulsive development of X-ray radiation with a wavelength range of 0.1 to 10 Å.

D6-32 Pinter, S., "Some Relations Between 3-cm Solar Radio Bursts, Flares, X-rays and Geomagnetic Crochets," Bulletin Astron. Instit. of Czech., 20, 151-156, 1969.

Examination of the geoactivity of solar flares and of the relations between geomagnetic crochets and X rays, solar radio bursts, and flares.

Time relations of soft and hard X-ray emission, centimeter radio bursts, and expansive and Y phases of flares with geomagnetic crochets are investigated. It is shown that not all flares are equally geoactive and that their wave geoactivity depends on the height at which they begin to expand in the solar atmosphere.

E5 Ion Chamber and GM Counters

K.A. Anderson University of California at Berkeley

This experiment consisted of a 10.2-cm Neher type ionization chamber and two Geiger-Mueller tubes. The ion chamber responded omnidirectionally to electrons with E > 0.7 Mev and protons with E > 12 Mev. Both GM tubes were mounted parallel to the spacecraft spin axis. GM tube A detected electrons with E > 45 kev which were scattered off a gold foil. The acceptance cone for these electrons had a 70° full angle and axis of symmetry which was 20° off the spacecraft spin axis. GM tube B responded to electrons and protons with E > 22 and 300 kev respectively, in an acceptance cone of 70° full angle centered at the spacecraft spin axis. Both GM tubes responded omnidirectionally to electrons and protons of energies with E > 2.5 and 50 Mev, respectively. Pulses from the ion chamber and counts from each GM tube were accumulated for 39.72 sec and read out every 40.96 sec. In addition, the time between the first two ion chamber pulses in an accumulation period was telemetered. This experiment performed well initially. On November 20, 1968, the ion chamber failed. On May 9, 1969, GM tube B failed. GM tube A is still operating normally and returning usable information (February 22, 1971).

- Principal Investigator Group/Major Journals

E5-01 Anderson, K.A., "Electrons and Protons in Long-Lived Streams of Energetic Solar Particles," Solar Phys., 6, 111-132, 1969.

See abstract under D5-01.

E5-02 Anderson, K.A., "Energetic Electrons of Terrestrial Origin Behind the Bow Shock and Upstream in the Solar Wind," J. Geophys. Res., 74, 95-106, 1969.

See abstract under C5-02.

E5-03 Anderson, K.A., "Method to Determine Sense and Magnitude of Electric Field from Lunar Particle Shadows," J. Geophys. Res., 75, 2591-2594, 1970.

The effect of an electric field across the magnetotail on the formation of energetic particle shadows near the moon is considered: Methods of finding the direction and magnitude of the electric field are outlined.

E5-04 Anderson, K.A., and R.P. Lin, "Observation of Interplanetary Field Lines in the Magnetotail," J. Geophys. Res., 74, 3953-3968, 1969.

Description of a method of finding the topology of magnetic field lines in the magnetotail using solar electrons as field line tracers. The method depends on the presence of a large absorber such as the moon. Applying this method to spacecraft data, it is found that most of the field lines in the magnetotail at 60 earth radii geocentric distance are connected to the interplanetary field. On one occasion, field lines of interplanetary character were found at the center of the magnetotail at a geocentric distance of about 60 earth radii. One interpretation of this observation is that the reconnection region must have been at a geocentric distance less than 60 earth radii.

E5-05 Anderson, K.A., and C.-I. Meng, "Layer of Energetic Electrons (>40 keV) Near the Magnetopause," J. Geophys. Res., 75, 1827-1836, 1970.

See abstract under A5-05.

E5-06 Kahler, S.W., "Comparison of Energetic Storm Protons to Halo Protons," Solar Phys., 8, 166-185, 1969.

See abstract under C5-05.

E5-07 Lin, R.P., "Observations of Lunar Shadowing of Energetic Particles," J. Geophys. Res., 73, 3066-3071, 1968.

Determination of the effect of the close presence of the moon on energetic particle fluxes, by comparing observations from the lunar-orbiting satellite AIMP 2 with simultaneous observations by an identical experiment aboard the earth-orbiting satellite IMP 4. The following conclusions are drawn from satellite records showing some lunar-associated decreases in the electron flux during solar-flare electron events observed in interplanetary space: (1) most of the decreases occur at times when the sun-moon-satellite angle is at about the spiral field angle; (2) decreases occurs both with the satellite behind the moon with respect to the sun and with the satellite in front of the moon; (3) on many occasions the electron-flux decreases are much greater than 50%; and (4) these sharp decreases may occur even many hours after the beginning of the solar electron event. It is concluded that these decreases in the solar electron flux observed by AIMP 2 are due to the shielding by the moon of these particles along the field line.

E5-08 Lin, R.P., "The Emission and Propagation of ~40 keV Solar Flare Electrons I: The Relationship of ~40 keV Electron to Energetic Proton and Relativistic Electron Emission by the Sun," Solar Phys., 12, 226-303, May 1970.

See abstract under C5-06.

E5-09 Lin, R.P., "The Emission and Propagation of ~40 keV Solar Flare Electrons II: The Electron Emission Structure of Large Active Regions," Solar Phys., 15, No. 2, 453-478, Dec. 1970.

Electrons of ~ 40 keV energy observed at 1 AU are used as tracers to map the emission structure of a large active region, McMath plage 8905, which crossed the visible disk in July-August, 1967.

The acceleration of 10-100 keV electrons is found to be a property of active regions with a certain stage of development, and is signaled by the emission of $\gtrsim$ 20 keV X-rays. The emission of electrons into the interplanetary medium may be separate from the acceleration of the electrons. Type III radio emission at long wavelengths appears to indicate the escape of the electrons into the interplanetary medium.

The subsequent electron propagation in the interplanetary medium is essentially scatter-free, and the profile of the electron appears to be determined predominantly by transport/storage processes in the solar corona. The emission structure for active region McMath plage 8905 consists of (1) an open cone of ~ 70° extent in solar longitude where electrons have direct access to interplanetary field lines; (2) a cone of propagation of 100° width in solar longitude, surrounding and including the open cone in which impulsive electron events are observed; and (3) an overall ~ 200° extent of solar longitude over which low, non-impulsive fluxes from the active region are observed. A model is presented to account for the observed structure. This type of emission structure may be present in other electron-active regions.

E5-10 Lin, R.P., and H.S. Hudson, "10-100 keV Electron Acceleration and Emission from Solar Flares," Solar Phys., 17, No. 2, 412-435, Apr. 1971.

We present an analysis of spacecraft observations of non-thermal X-rays and escaping electrons for 5 selected small solar flares in 1967. OSO-3 multi-channel energetic X-ray measurements during the non-thermal component of the solar flare X-ray bursts are used to derive the parent electron spectrum and emission measure. IMP-4 and Explorer 35 observations of >22 keV and >45 keV electrons in the interplanetary medium after the flares provide a measure of the total number and spectrum of the escaping particles. The ratio of electron energy loss due to collisions with the ambient solar flare gas to the energy loss due to bremsstrahlung is derived. The total energy loss due to collisions is then computed from the integrated bremsstrahlung energy loss during the non-thermal X-ray burst. For >22 keV flare electrons the total energy loss due to collisions is found to be ~10^4 times greater than the bremsstrahlung energy loss and ~10^2 times greater than the energy loss due to escaping electrons. Therefore the escape of electrons into the interplanetary medium is a negligible energetic electron loss mechanism and cannot be a substantial factor in the observed decay of the non-thermal X-ray burst for these solar flares.

We present a picture of electron acceleration, energy loss and escape consistent with previous observations of an inverse relationship between rise and decay times of the non-thermal X-ray burst and X-ray energy. In this picture the acceleration of electrons occurs throughout the 10-100 sec duration of the non-thermal X-ray burst and determines the time profile of the burst. The average energy of the

accelerated electrons first rises and then falls through the burst. Collisions with the ambient gas provide the dominant energetic electron loss mechanism with a loss time of $\lesssim 1$ sec. This picture is consistent with the ratio of the total number of energetic electrons accelerated in the flare to the maximum instantaneous number of electrons in the flare region. Typical values for the parameters derived from the X-ray and electron observations are:

total energy in >22 keV electrons $\simeq$ total energy lost by collisions = $\sim 10^{28-29}$ erg,
total number of electrons accelerated above 22 keV = $\sim 10^{36}$,
total energy lost by non-thermal bremsstrahlung = $\sim 10^{24}$ erg,
total energy lost in escaping >22 keV electrons = $\sim 10^{26}$ erg
total number of >22 keV electrons escaping = $\sim 10^{33-34}$.

The total energy in electrons accelerated above 22 keV is comparable to the energy in the optical or quasi-thermal flare, implying a flare mechanism with particle acceleration as one of the dominant modes of energy dissipation.

The overall efficiency for electron escape into the interplanetary medium is ~0.1-1% for these flares, and the spectrum of escaping electrons is found to be substantially harder than the X-ray producing electrons.

E5-11 Meng, C.-I., "Energetic Electrons in the Magnetotail at $60R_E$," J. Geophys. Res., 76, 862-872, 1971.

Energetic electron (E_e > 22 keV and E_e > 45 keV) observations of the lunar orbiting Explorer 35 satellite from 15 magnetotail crossings at geocentric distances of about 60 R_e are presented. The longitudinal and latitudinal distributions are shown at two different flux intensities [low fluxes and high fluxes (cutoff $J(E_e > 22$ keV) > 345 electrons/cm^2 sec ster)]. At low fluxes with the counting rate threshold above the cosmic ray background, the occurrence frequency of energetic electrons is almost the same from the dawn side to the dusk side of the tail. The latitudinal distribution shows the occurrence frequency of energetic electrons to the highest near the solar magnetospheric equator and gradual falling off away from the equatorial plane. At high flux levels [$J(E_e > 22$ keV) > 345 electrons/cm^2 sec ster and $J(E_e > 45$ keV) > 278 electrons/cm^2 sec ster], the distributions are strongly dependent on longitude and latitude: the occurrence frequency is much higher in the dawn side and near the equator. The region where fluxes were found least frequently is in the northern part of the tail on the dusk side. This dawn to dusk asymmetry appears to increase with increasing flux threshold levels.

- Principal Investigator Group/Conference Proceedings

E5-12 Anderson, K.A., "Relation of Energetic Particles in the Plasma Sheet to the Auroral Zone," Atmospheric Emissions, Eds., B. McCormac, A. Omhalt, Van Nostrand Reinhold Publishing Co., 327-336, 1969.

See abstract under C5-12.

- Principal Investigator Group/Other Publications

E5-13 Anderson, K.A., "Energetic Particle Studies on the Lunar Anchored IMP Satellites," Space Science Laboratory Consolidated Progress Report, Ser., 9, Issue 50, 136-138, Oct. 1968.

The Explorer 33 satellite launched on 1 July 1966 was one of three spacecraft carrying University of California energetic particle experiments in operation during the large solar flare of 7 July 1966. The spacecraft were separated by about 600,00 km, and this made it possible to obtain information regarding propagation speeds and particle diffusion coefficients. These experiments, in fact, provide the only quantitative experimental information available on the transverse diffusion coefficient. Dr. Robert Lin presented these results at the Tenth International Conference on Cosmic Rays, Calgary, Canada, June 1967.

The second lunar anchored IMP satellite (Explorer 35) was launched on 19 July 1967 and was injected successfully into a selenocentric orbit on 22 July. This University of California experiment is essentially identical to the one on Explorer 33. The Explorer 35 spacecraft and all experiments have functioned properly for one month in orbit around the moon. To date no energetic particle effects associated with the moon have been found. This is not surprising since from the same spacecraft a lunar magnetic field was not detected. The upper limit to the lunar magnetic moment is set by Ness, et al at 10^{-5} of the earth's moment.

E6 Solid-State and GM Counters

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Three EON type 6213 Geiger-Mueller tubes (GM1, GM2, and GM3) and a silicon solid-state detector (SSD) provided measurements of solar X rays (GM1 only, between 2 and 12 Å), and charged particles in the vicinity of the moon. GM1 and GM3 measured electrons of $E > 48$ to 50 kev and protons of $E > 740$ to 820 kev, while GM2 was shielded by a cap approximately 1 g/cm^2 thick (limiting its response to protons of $E \geq 30$ Mev). The SSD output was discriminated at four thresholds: (1) pn1, which detected protons with $.32 \leq E \leq 6.3$ Mev, (2) pn2, which detected protons with $.48 \leq E \leq 3.0$ Mev, (3) pn4, which detected alphas with $2 \leq E \leq 10.2$ Mev, and (4) pn3, which was sensitive to particles of $Z > 3$, carbon 12 with $.58 \leq E \leq 9.5$ Mev/nucleon, nitrogen 14 with $.514 \leq E \leq 13.9$ Mev/nucleon, and oxygen 16 with $.466 \leq E \leq 18.8$ Mev/nucleon. GM1 the SSD were oriented perpendicular to the spacecraft spin axis, GM2 was oriented parallel to the spin axis, and GM3 was oriented antiparallel to the spin axis. Data from GM1, pn1, and pn4 were divided into data from quadrants oriented with respect to the sun (sectors I, II, III, and IV centered 180°, 270°, 0°, and 90° away from the sun, respectively). Data were read out every 82 or 164 sec, and the experiment performance was normal as of April 1971.

• Principal Investigator Group/Major Journals

E6-01 Armstrong, T.P., and S.M. Krimigis, "Statistical Study of Solar Protons, Alphas, and Z ≥3 Nuclei in 1967-68," J. Geophys. Res., 76, 4230-4244, 1971.

Comprehensive measurements of protons, alpha particles and Z ≥ 3 nuclei of E ≥ 0.5 Mev/nucleon obtained with the lunar-orbiting Explorer 35 spacecraft for the period 20 July 1967 to 14 May 1968 are reported. The major results which emerge from this study are the following: (a) Protons of E ≥ 0.5 Mev are present in the interplanetary medium at least 63% of the time. (b) Protons, alphas and Z ≥ 3 (medium) nuclei always appear together although in variable mixtures. (c) Events with harder proton spectrums have smaller p/α ratios. (d) The α/M nuclei ratio of 20 ± 10 characterizes most events. (e) The event-integrated p/α ratio varies from 10 to 150. (f) There exists a directional anisotropy in the p/α ratio, believed to be observed for the first time. (g) By combining Spectroscopic data of Lambert (1967) with the observed α/M ratio a value of ~ 50 for the p/α ratio at the sun is obtained. The data are discussed in the context of particle propagation and properties of the solar source region.

E6-02 Drake, J.F., "Soft Solar X-ray Burst Characteristics," Solar Phys., 16, 152, 1971.

See abstract under D6-02.

E6-03 Drake, J.F., J. Gibson, and J.A. Van Allen, "Iowa Catalog of Solar X-ray Flux (2-12 Angstroms)," Solar Phys., 10, 433-459, 1969.

See abstract under D6-03.

E6-04 Fennell, J.F., "Observations of Proton Bursts in the Magnetotail with Explorer 35," J. Geophys. Res., 75, 7048-7059, 1970.

Energetic proton bursts ($E_p \geq 0.32$ MeV) are observed at 60 R_E in the magnetotail by Explorer 35. The intensity is usually anisotropic. The net proton flow as measured in the ecliptic plane is found to be most often, but not always, nearly parallel or antiparallel to the local magnetic field, and is sometimes toward and sometimes away from the earth. The protons are usually observed during high-latitude magnetic bay activity at the earth. Companion observations outside the bow shock by Explorer 33 show that the proton bursts are not of solar origin. One observation evidences possible proton flow away from the earth, across the neutral sheet, and back toward the earth parallel to the field in the ecliptic plane. The proton bursts have spectral e-folding energies of 50-110 keV and peak intensities of 14-420 $(cm^2 \text{ sec ster})^{-1}$, values that are similar to those for protons near the outer-zone trapping boundary.

E6-05 Gibson, J., and J.A. Van Allen, "Correlation of X-ray Radiation (2-12 Angstroms) with Microwave Radiation (10.7 cm) from the Non-Flaring Sun," Astrophys. J., 161, No. 3, Part 1, 1135-1146, Sept. 1970.

See abstract under D6-04.

E6-06 Krimigis, S.M., E.C. Roelof, T.P. Armstrong, and J.A. Van Allen, "Low Energy ($\geq$ 0.3 MeV) Solar Particle Observations at Widely Separated Points (>0.1 AU) During 1967," J. Geophys. Res., 76, 5921-5946, 1971.

Simultaneous observations of solar particle events at low (< 1 Mev) energies have been obtained using intercalibrated solid state detectors on Mariner 5, Explorer 35 and Mariner 4 during days 200 to 271, 1967. An examination of the intensity time profiles, anisotropies, proton to alpha intensity ratios (j_p/j_α), alpha to Z $\geq$ 3 (M-nuclei) ratios (j_α/j_M), and the proton energy spectrums from several events has led to the following results: (a) There are finite differences in particle intensity onsets following flares even when spacecraft are located close to the same interplanetary magnetic field line. (b) When particle fluxes have reached a quasistationary state, identifiable features in the intensity profile can often be observed to be convected by the solar wind past widely separated (> 0.1 AU) spacecraft. (c) Several flare-associated and non-flare intensity peaks are found to corotate with the sun. (d) Anisotropies are largest during the onset phase of flare-associated events with the maximum intensity coming from the solar quandrant ($\pm$ 45° to the sun-spacecraft line). (e) The proton spectrum hardens during event onsets and becomes softer as the event progresses at both spacecraft. (f) The j_p/j_α time profile generally follows the proton profile and varies considerably during events; also j_p/j_α decreases as the proton spectrum hardens in accordance with Schatzman's (1963) model. (g) The j_α/j_m ratio is relatively less variable than the j_p/j_α ratio. (h) Few intensity increases can be reliably associated with specific flares on the sun. It is concluded that, in view of the observations, multi-spacecraft studies should allow the development of more sophisticated models for the understanding of low energy solar particle events.

E6-07 Van Allen, J.A., "On the Electric Field in the Earth's Distant Magnetotail," J. Geophys. Res., 75, 29-38, 1970.

See abstract under D6-09.

E6-08 Van Allen, J.A., J.F. Fennell, and N.F. Ness, "Asymmetric Access of Energetic Solar Protons to the Earth's North and South Polar Caps," J. Geophys. Res., 76, 4262-4275, 1971.

See abstract under E1-14.

E6-09 Van Allen, J.A., and N.F. Ness, "Particle Shadowing by the Moon," J. Geophys. Res., 74, 71-93, 1969.

See abstract under D1-12.

E6-10 Van Allen, J.A., and B.A. Randall, "Evidence for Direct Durable Capture of 1 to 8 MeV Solar Alpha Particles onto Geomagnetically Trapped Orbits," J. Geophys. Res., 76, 1830-1836, 1971.

E6-11 Van Allen, J.A., and C.D. Wende, "On the Solar Flare of 8 July 1968," J. Geophys. Res., 74, 3046-3048, 1969.

See abstract under D6-15.

E6-12 Wende, C.D., "Correlation of Solar Microwave and Soft X-ray Radiation 1. The Solar Cycle and Slowly Varying Components," J. Geophys. Res., 74, 4649-4660, 1969.

See abstract under D6-16.

E6-13 Wende, C.D., "Correlation of Solar Microwave and Soft X-ray Radiation 2. The Burst Component," J. Geophys. Res., 74, 6471-6481, 1969.

See abstract under D6-17.

- Principal Investigator Group/Conference Proceedings

E6-14 Van Allen, J.A., "Energetic Particle Phenomena in the Earth's Magnetospheric Tail," Particles and Fields in the Magnetosphere, 111-121, 1970. (Proceedings of the Symposium of the Summer Advanced Study Institute, Santa Barbara, Calif., Aug. 4-15, 1969. Ed., B.M. McCormac, D. Reidel Publishing Co., Dordrecht, Holland.)

- Principal Investigator Group/Other Publications

E6-15 Armstrong, T.P., "Several Observations of Proton Bursts in the Magnetotail Associated with Polar Magnetic Substorms," University of Iowa, Unnumbered, Apr. 1968.

See abstract under D6-19.

E6-16 Strein, E.W., and J.E. Russell, "AIMP D & E Trapped Radiation Experiment," University of Iowa, July 1966.

See abstract under D6-24.

E6-17 Van Allen, J.A., and M.N. Oliven, "Paucity of Energetic Electron Clouds on the Sunward Side of the Magnetospheric Shock Front," University of Iowa, UI 68-19, Apr. 1968. (Also presented as a talk at the AGU meeting, April 1968.)

See abstract under D6-25.

E6-18 Venkatarangan, P., D. Venkatesan, and J.A. Van Allen, "Solar Flare Increases in Cosmic Ray Intensity on November 18, 1968, February 25, 1969, and March 30, 1969," University of Iowa, UI 69-47, Undated.

Flare type increases in cosmic ray intensity were registered by high latitude neutron monitors on November 18, 1968; February 25, 1969; and March 30, 1969. Data were also available for these events from various detectors of the University of Iowa, on board the satellite Explorer 35. Analyses of intensity time profiles for the events are presented pertaining to protons, alpha particles, and heavy ions ($Z > 2$). The results exhibit considerable differences from event to event. The implications of the observations are discussed.

E6-19 Wende, C.D., "Correlation of Solar Microwave and Soft X-ray Radiation," University of Iowa, UI 68-57, Aug. 1968. (Ph.D. Thesis)

See abstract under D6-26.

E6-20 Yeh, R.S., and J.A. Van Allen, "Alpha Particle Emissivity of the Moon--An Observed Upper Limit," Science, 166, 370-372, Oct. 1969.

By the observations with the moon-orbiting spacecraft Explorer 35 during 1967-1968, it is unlikely that the alpha particle emissivity of the moon is greater than 0.064 $(cm^2\ sec\ sr)^{-1}$ and exceedingly unlikely that it is greater than 0.128, these values being respectively 0.1 and 0.2 of provisional estimates by Kraner et al in 1966. This result implies that the abundance $_{92}U^{238}$ in the outer crust (≈ a few meters in thickness) of the moon is very much less than that typical of the earth's lithosphere, though it is consistent with the abundance of $_{92}U^{238}$ in terrestrial basalt or in chrondritic meteorties.

- Not Principal Investigator Group/Major Journals

E6-21 Feix, G., "Correlation of the Impulsive Component of MM-Bursts and the Gradual Rise of Soft X-ray Emission," Astronomy and Astrophysics 9, No. 2, 239-244, Nov. 1970.

From a survey of high resolution measurements of the sun a mm-wavelengths it has been found that the impulsive maximum occurs before the maximum of the associated soft X-ray burst. These observations appear to be consistent with well known cm-observations. It can be clearly seen from the mm-observations that the impulsive radio component is being released explosively after a gradual heating of the flaring region.

- Not Principal Investigator Group/Other Publications

E6-22 Marks, C.L., "Solar X-ray Data for Three 1968 Flares, July 8, September 29, November 2," National Space Science Data Center, NSSDC 70-05, Mar. 1970.

F4 Ion Chamber and GM Counters

K.A. Anderson University of California at Berkeley

The instrumentation for this experiment consisted of a 10.2-cm Neher type ionization chamber and two Geiger-Mueller tubes. The ion chamber responded omnidirectionally to electrons with E > 0.7 Mev and protons with E > 12 Mev. Both GM tubes were mounted parallel to the spacecraft spin axis. GM tube A detected electrons with E > 45 kev that were scattered off a gold foil. The acceptance cone for these electrons had a 70° full angle and an axis of symmetry that was 20° off the spacecraft spin axis. GM tube B responded to electrons and protons with E > 22 and 300 kev, respectively, in an acceptance cone of 70° full angle centered at the spin direction. Both GM tubes responded omnidirectionally to electrons and protons of E > 2.5 and 50 Mev, respectively. Pulses from the ion chamber and counts from each GM tube were accumulated for 9.92 sec and read out every 10.24 sec. The time between the first two ion chamber pulses in an accumulation period was also telemetered. This experiment performed normally from launch through May 3, 1969, when IMP F reenter- the earth's atmosphere.

- Principal Investigator Group/Major Journals

F4-01 Anderson, K.A., "Electrons and Protons in Long-Lived Streams of Energetic Solar Particles," Solar Phys., 6, 111-132, 1969.

See abstract under D5-01.

F4-02 Kahler, S.W., "Comparison of Energetic Storm Protons to Halo Protons," Solar Phys., 8, 166-185, 1969.

See abstract under C5-05.

F4-03 Lin, R.P., "Observations of Lunar Shadowing of Energetic Particles," J. Geophys. Res., 73, 3066-3071, 1968.

See abstract under E5-07.

F4-04 Lin, R.P., "Observations of Scatter-Free Propagation of 40-keV Solar Electrons in the Interplanetary Medium," J. Geophys. Res., 75, 2583-2586, 1970.

A number of ~40-kev solar flare electron events of short duration

have been observed by the University of California experiment aboard the IMP 4 satellite. These events have almost equal rise and decay times of 5-10 min, and transit times of these particles from the sun to the earth are ~25 min. The most probable distance traveled for these electrons is only ~1.5 AU, compared with typically ~10 for protons and 1.2 for the length of a smooth spiral interplanetary field line from the sun to the earth. The bulk of the electrons travel <2.0 AU. We conclude that the electrons have experienced little or no scattering in their propagation through the interplanetary medium.

F4-05 Lin, R.P., "The Emission and Propagation of ~40 keV Solar Flare Electrons I: Relationship of ~40 keV Electron to Energetic Proton and Relativistic Electron Emission by the Sun," Solar Phys., 12, No. 2, 266-303, May 1970.

See abstract under C5-06.

F4-06 Lin, R.P., "The Emission and Propagation of ~40 keV Solar Flare Electrons II: The Electron Emission Structure of Large Active Regions," Solar Phys., 15, No. 2, 453-478, Dec. 1970.

See abstract under E5-09.

F4-07 Lin, R.P., and H.S. Hudson, "10-100 keV Electron Acceleration and Emission from Solar Flares," Solar Phys., 17, No. 2, 412-435, April 1971.

See abstract under E5-10.

F4-08 Lindgren, S.T., "Solar Particle Events of May 23 and May 28, 1967," Solar Phys., 5, 382-409, 1968.

See abstract under D5-05.

- Principal Investigator Group/Conference Proceedings

F4-09 Lin, R.P., "The Emission and Propagation of ~40 keV Solar Electrons," Acta Physica Academiae Scientiarum Hungaricae, 29, Supplement 2, 669-677, 1970. (Proceedings of the 11th International Conference on Cosmic Rays, Budapest, Hungary, 1969.)

See abstract under C5-14.

- Principal Investigator Group/Other Publications

F4-10 Anderson, K.A., "Energetic Particle Studies on the Interplanetary Monitoring Platform Satellites," Space Sci. Lab. Consolidated Progress Report, Ser. 9, Issue 50, 140-141, Oct. 1968.

The IMP 1, 2, and 3 data have been used by the University of California to obtain simultaneous measurements of particle fluxes at different points in space. A technical description of the University of California experiments on IMP 1, 2, and 3 is given along with calibration curves for the ionization chambers. The document describes the data tape format and summarizes the computer programs that were developed to process the data from the experiments. References to additional reports based on the IMP spacecraft are included.

F5 Solar Proton Monitor

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The solar proton monitoring experiment utilized four separate detectors, each of which used one or more solid-state sensors. Three detectors measured the omnidirectional fluxes of protons and alpha particles with energy per nucleon values above 10, 30, and 60 Mev. Alpha particle contributions to the total count rates were generally less than 10%. The 10-Mev channel was sampled for two 19.2-sec intervals every 163.8 sec, and the 30- and 60-Mev channels were sampled for one 19.2-sec interval every 163.8 sec. Resultant hourly averaged fluxes have been published in Solar-Geophysical Data (NOAA, Boulder) on a rapid basis. The fourth detector had a 60° full angle normal to the spacecraft spin axis. Each of two discrimination levels was sampled for two 19.2-sec intervals every 163.8 sec. Fluxes of 1- to 10-Mev protons were measured in the lower discrimination state, and fluxes of particles depositing more than 3.6 Mev were measured in the upper discrimination state. Data were obtained from the first three detectors between launch and May 3, 1969. Data from the fourth detector were obtained between launch and June 12, 1968.

- Principal Investigator Group/Major Journals

F5-01 Ogilvie, K.W., and J.F. Arens, "Acceleration of Protons by Interplanetary Shocks," J. Geophys. Res., 76, 13-20, 1971.

See abstract under F1-17.

F5-02 Williams, D.J., and C.O. Bostrom, "Proton Entry into the Magnetosphere on May 26, 1967," J. Geophys. Res., 74, 3019-3036, 1969.

Low energy proton observations over the polar cap and in the interplanetary and magnetosheath regions are compared during May 26, 1967. The results indicate that at this time the entry of low energy solar protons into the magnetosphere was controlled by a diffusion process. It also appears that the protons had access to the entire figure-8

current pattern in the geomagnetic tail and diffused into the two approximately circular cylinders containing the field lines from the northern and southern polar caps. A first approximation value of 10^{15} to $10^{16} cm^2 sec^1$ is obtained for the radial diffusion coefficient, D_{rr} in the tail. No value can be derived for the diffusion coefficient along the field line, D_{zz}, with the present data. Consequently, in the present case, only a rough upper limit of $L^C \leq (420 \text{ to } 2400)R_E$ is obtained for the distance to the region where low energy protons are diffused into the tail.

- Principal Investigator Group/Conference Proceedings

F5-03 Bostrom, C.O., "Entry of Low Energy Solar Protons into the Magnetosphere," Intercorrelated Satellite Observations Related to Solar Events, 229-238, 1970. (Proceedings of the 3rd ESLAB/ESRIN Symposium, Noordwijk, Netherlands, Sept. 16-19, 1969. Eds., V. Manno, D.E. Page, D. Reidel Publishing Company, Dordrecht, Holland.)

See abstract under D6-30.

F5-04 Williams, D.J., "Solar Proton Observations 1-10 MeV," Proceedings of the Seminar on the Study of Interplanetary Space Physics Using Cosmic Rays, 87-115, 1969. (Proceedings held at the Physical Technical Institute, USSR Academy of Sciences, Leningrad, USSR, June 4-7, 1969. Ed., A.I. Ioffe.) (Also, NASA-GSFC, X-612-69-258, June 1969.)

A brief resume of diffusion models and solar proton propagation in the interplanetary medium is given. Observations of solar protons from the Solar Proton Monitoring Experiment flown aboard the Explorer 34 satellite are then presented. Attention is focused on the 1-10 Mev proton intensities and their different behavioral characteristics as compared to higher energy (> few tens of Mev) solar protons. Observations of quasi-periodic variations in the 1-10 Mev proton intensities are presented. Power spectra are shown for both quiet and active periods. It is found that during the quiet periods analyzed, the 1-10 Mev proton intensity power spectra displayed an f^{-1} to $f^{-1.5}$ trend. Some mechanism is apparently ordering the proton intensities in the frequency domain. Active periods are shown in which prominent peaks in the power spectra are observed at 0.0125 cycles per minute ($2.1\ (10)^{-4}$ Hz; 80 minute period) and at 0.02 cycles per minute ($3.3\ (10)^{-4}$ Hz; 50 minute period). A summary of observations concerning the entry of low energy protons into the magnetosphere is given.

- Principal Investigator Group/Other Publications

F5-05 Arens, J.F., "Interplanetary Energetic Particle Diffusion Coefficient Determination Using Random Walk from Shock Waves," NASA-GSFC, X-646-70-226, June 1970. (Paper submitted to J. Geophys. Res.,)

A shock wave passing through the solar wind can apparently reflect

energetic protons to build up an enhanced intensity in front of the shock wave. Values of the diffusion coefficient in interplanetary space and the reflection efficiency of the particles can respectively be calculated from the distance the enhanced region extends in front of the shock wave and the increase in intensity from the undisturbed intensity. Values of ~ 10^{17}cm^2/sec and ~ 90% are found by fitting the data of Ogilvie and Arens (1970) and describe properties of 1 MeV protons with pitch angle ≈90° scattering through ≈20°.

F5-06 Kohl, J.W., "Solar Proton Monitoring," APL Tech. Digest, 8, 2-9, Sept.-Oct. 1968.

Instrumentation has been developed to provide data over long periods of time on the radiation environment near earth and in interplanetary space. A description is given of the particle detectors used and a few of the preliminary observations obtained with this instrumentation on board rockets and the IMP F satellite. Variations of particle flux and energy during periods of differing solar activity provide information on the magnetic configuration in space and near earth, and on particle interactions with the earth's magnetosphere. Future flights of similar instrumentation may improve understanding of solar-terrestrial relationships.

- Not Principal Investigator Group/Major Journals

F5-07 Fisk, L.A., "Increases in the Low Energy Cosmic Ray Intensity at the Front of Propagating Interplanetary Shock Waves, J. Geophys. Res., 76, 1662-1672, 1971.

A simple model is discussed which can account for many of the features observed in the pulse-like increases in the low energy cosmic ray intensity that occur at the front of propagating interplanetary shock waves. It is assumed that low energy particles are swept up by the shock, but because of extensive scattering by magnetic field irregularities remain near the shock front forming the pulse. It is found that the intensity can increase substantially at the shock as particles gain energy by making repeated collisions with the moving shock front. The behavior of particles which accumulate at the shock is illustrated with some solutions to the time-dependent Fokker-Planck equation which governs cosmic ray behavior allowing for convection, diffusion, and particle energy changes. The predicted pulse shapes agree reasonably well with the observations provided that the diffusion coefficient parallel to the magnetic field is ~ 10^{19}cm^{2}sec^{-1} for 1 MeV protons.

- Not Principal Investigator Group/Other Publications

F5-08 Driatsky, V.M., T.M. Krupitskaya, and A.V. Shiroshkov, "PCA Intensity Relationship to the Solar Cosmic Ray Energy Level and Flux Value," Unpublished, Unnumbered, Undated.

F6 Low Energy Solid-State Telescope

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A four-element solid-state telescope with an acceptance cone half angle of 20° was mounted normal to the spacecraft spin axis. During each 2.73-min interval, 9.82-sec accumulations were obtained in each of 16 distinct counting modes. These modes involved protons in five energy intervals covering 0.6 to 18 Mev, alpha particles in four intervals covering 1.7 to 80 Mev, and electrons, deuterons, tritons, and helium-3 nuclei in the intervals 0.3 to 3, 5 to 20, 5.5 to 25, and 11 to 72 Mev, respectively. Onboard calibration checks were performed every 6 hr. The experiment performed normally from launch to the spacecraft reentry date, May 3, 1969.

- Principal Investigator Group/Major Journals

F6-01 Graedel, T.E., and L.J. Lanzerotti, "Proton Excitation of Solar Radio Bursts. (Accepted for publication in J. Geophys. Res.,)

Beams of electrons moving at several tenths of the speed of light have long been invoked as the causative mechanism for Type III solar radio bursts. With the advent of charged-particle experiments aboard spacecraft, it has become possible to correlate Type III bursts directly with charged-particle fluxes. In the work reported here, radio burst data from OGO-III at 4-2 MHz are correlated with solar particle events observed on Explorer 34. During a four-month period of concurrent observations by the two experiments, a moderate, correlation is found between 600 keV proton ($\beta \equiv \frac{v}{c} = 0.025$) events and 4-2 MHz Type III bursts with $S_\nu \geq 1 \times 10^{-17}$ watt cm^{-2} Hz^{-1} (the OGO-III detection limit). In contrast, essentially no correlation exists between the Type III bursts and 300 keV ($\beta = 0.77$) electron events. A random number argument is used to suggest that neither result is statistically significant. Thus, for Type III solar radio bursts in the frequency range and with the flux density limit stated above, the results are not inconsistent with recent theoretical evidence for possible proton excitation of Type III bursts.

F6-02 Lanzerotti, L.J., "Discussion of Paper, 'A Comparison of Energetic Storm Protons to Halo Protons,'" Solar Phys., 11, 145-147, 1970.

F6-03 Lanzerotti, L.J., "Low-Energy Solar Protons and Alphas as Probes of the Interplanetary Medium, the May 28, 1967, Solar Event," J. Geophys. Res., 74, 2851-2868, 1969.

The low-energy solar protons and alpha particles detected during the May 28 (day 148), 1967, solar flare are used as 'probes' to investigate the properties of the interplanetary medium during the course of the event. The lower energy fluxes exhibit characteristics of particle storage either at the sun or in interplanetary space. The higher energy particle fluxes exhibit 'classical' west limb flare profiles and are fit both to a simple isotropic diffusion-with-boundary model and to a radial dependent scattering center model. The diffusion coefficient model of Jokipii is used with the results of a fit to the exponential decay of the

event to predict an f^{-3} dependence of the power spectral density of the interplanetary magnetic field fluctuations (assuming a boundary location independent of rigidity). The ratio of particle fluxes before and after sudden, discontinuous flux decrease (attributed to a sector boundary) is found to be $\sim R^3$ for protons and $\sim R^6$ for alphas for particles with rigidities $\lesssim$ 200 Mv. Significant velocity dispersions are discovered in three of the flux modulations during the onset stage of the event. The velocity dispersions in one of these modulations could be interpreted as due to a modulating region located ~0.03 AU from the earth. It is speculated that this region was responsible for an sc at the earth some two hours later.

F6-04 Lanzerotti, L.J., "Penetration of Solar Protons and Alphas to the Geomagnetic Equator," Phys. Rev. Letters, 21, 929-933, Sept. 1968.

Simultaneous spectral observations of low-energy solar particles in interplanetary space and in the magnetosphere on the equator strongly imply that these particles have essentially free access to the outer magnetosphere through a very effective diffusion mechanism which preserves the spectra shapes and the flux magnitudes. These observations further imply that measurements of solar-particle arrival time over the polar caps are not sufficient to distinguish between open or closed magnetosphere models.

F6-05 Lanzerotti, L.J., M.D. Montgomery, and S. Singer, "Penetration of Solar Protons into the Magnetosphere and Magnetotail," J. Geophys. Res., 75, 3729-3734, 1970.

Three sets of satellite measurements are used to compare solar proton fluxes in the magnetotail, in the outer magnetosphere, at synchronous altitude, and in interplanetary space. Comparisons of the interplanetary and magnetosphere proton fluxes show that outer magnetosphere disturbances play a strong role in the initial access of near-90° pitch angle protons to synchronous altitude. One comparison of the magnetotail and synchronous altitude fluxes suggests that the synchronous altitude fluxes may not always result from a scattering of the protons in from the tail. The interplanetary magnetotail proton comparisons further confirm the results of Montgomery and Singer (1969), who found that delays in the proton access to the magnetotail were always present.

- Principal Investigator Group/Conference Proceedings

F6-06 Lanzerotti, L.J., "Access of Solar Particles to Synchronous Altitude," Intercorrelated Satellite Observations Related to Solar Events, 206-228, 1970. (Proceedings of the 3rd ESLAB/ESRIN Symposium, Noordwijk, Netherlands, Sept. 16-19, 1969, Eds., V. Manno, D.E. Page, D. Reidel Publishing Company, Dordrecht, Holland.)

When a source of solar-originated particles is present in interplanetary space, comparable fluxes of these particles with similar spectral characteristics are usually observed inside the magnetosphere

at synchronous altitudes. The temporal and spectral changes in the access of these solar protons and α particles to synchronous altitude are discussed and reviewed. Possible consequences of the presence of substantial fluxes of low energy solar protons deep inside the magnetosphere are also discussed.

- Principal Investigator Group/Other Publications

F6-07 Lanzerotti, L.J., "Calibration of a Semiconductor Detector Telescope for Space Experiments," Nuclear Instruments and Methods, 61, No. 1, 99-107, Apr. 1968.

A description of the procedures and results of the electron and proton calibrations of two identical satellite experiments is reported. The experiments each consisted of a six element solid state detector telescope and were designed to investigate the particle flux and population in the earth's magnetosphere.

F6-08 Lanzerotti, L.J., "Protons, Alpha Particles, and Electrons Resulting from the 18 November 1968 Solar Flare," Data on Cosmic Ray Event of November 18, 1968 and Associated Phenomena, Upper Atmosphere Geophysics UAG-9, World Data Center A, 34-39, Apr. 1970.

This report presents the data on the solar proton, alpha particles, and electron fluxes measured by an instrument on the Explorer 34 (IMP F) satellite following the extreme west hemisphere (N21 W87) 1B solar flare of November 18, 1968. The Bell Telephone Laboratories instrument on Explorer 34 has been previously reported in the literature [Lanzerotti et al., 1969]. The data measurements will be described below; a more complete discussion of the observations and their implications for solar particle propagation is in preparation [Lanzerotti and Graedel, to be published].

F6-09 Lanzerotti, L.J., "Solar Proton Radiation Damage of Solar Cells at Synchronous Altitudes," J. of Spacecraft and Rockets, 6, 1086-1087, Sept. 1969.

Discussion of solar proton radiation as a major source of damage to solar cells used in spacecraft flown at synchronous altitudes. Recent experimental measurements of low energy solar protons and alpha particles at the synchronous orbit are described, showing that the fluxes and the spectra of these particles are in general quite similar to the solar particle observations made simultaneously in interplanetary space. It is concluded that a solar cell shield of about 7-mil thickness may be considered to be sufficient for largely eliminating the damage from low intensity, low energy solar enhancements. With this thickness shield, only the protons from very high intensity, harder-spectra solar flare events will dominate the electron environment in producing radiation damage effects.

F6-10 Lanzerotti, L.J., "Solar Protons and Alphas from the May 23, 1967, Solar Flares," Data on Solar Event of May 23, 1967 and its Geophysical Effects, Upper Atmospheric Geophysics Report UAG-5, World Data Center A, 56-67, 1969.

Satellite observations of low energy solar protons and alpha particles emitted from the series of May 23, 1967, east limb solar flares are described. The propagation of the particles from the east limb of the sun to the earth during the onset phase is observed to be rigidity rather than velocity dependent. A distinct softening of both the solar proton and alpha spectra is observed during the time intervals around the May 24 and May 25 sudden commencements. Two large solar particle flux decreases after the May 25 SC were observed. The percentage flux decreases of the first of these are strongly rigidity dependent while the percentage flux decreases of the second are rigidity independent.

F6-11 Lanzerotti, L.J., H.P. Lie, and G.L. Miller, "Satellite Solar Cosmic Ray Spectrometer with On-Board Particle Identification," Transactions of the IEEE, NS-16, 343-350, Feb. 1969.

The design and calibration results of a satellite based solar-cosmic ray particle identifier system utilizing a field effect transistor analog multiplier for the IMP F and G spacecraft are described. A discussion is made of the effectiveness of particle separation by such a particle identifier used in on-board data processing.

F6-12 Lanzerotti, L.J., and M.F. Robbins, "Solar Flare Alpha to Proton Ratio Changes Following Interplanetary Disturbances," Bell Telephone Lab., Unnumbered, Undated. (Paper submitted to Solar Phys.)

A discussion is presented on the half hour averaged low energy solar alpha to solar proton flux ratios observed following the three large solar flares of May 23, 1967. One of the large changes observed in the particle ratios (following a sudden commencement (SC) storm observed on the earth) is interpreted as due to a source effect. The second large change, again observed following an SC, is observed in the equal velocity and equal rigidity ratios and not in the equal energy/charge ratios. This observation suggests that electric fields in an interplanetary disturbance may be the cause of the modulations.

F6-13 Lanzerotti, L.J., and C.M. Soltis, "Interplanetary Protons and Alphas, Days 300-313, 1968," Data on Solar Geophysical Activity October 24 - November 6, 1968, Upper Atmosphere Geophysics Report UAG-8, World Data Center A, 198-204, Mar. 1970.

The period in late October and early November, 1968, represented an interval of time when the interplanetary medium was quite disturbed and heavily populated with low energy solar protons. The solar flare-produced disturbances in the solar wind caused at least five large sudden commencements (SC) to be recorded in the earth during the seven days from October 26 through November 1.

The interplanetary measurements reported here were made by the Bell Laboratories experiment on the Explorer 34 (IMP F) satellite. Explorer 34 was a spin stabilized (with spin axis perpendicular to the ecliptic plane) satellite with an apogee of approximately 34 R_E. The BTL experiment consisted of a four element solid state telescope oriented perpendicular to the spin axis. The half angle of the detector telescope defining collimator was 20°; the flux measured by the experiment was the spin averaged flux of particles in the ecliptic plane. Protons and alphas up to an energy of approximately 4 Mev/nucleon were distinguished by the energy deposited in the first two detectors of the telescope and subsequently measured in a five channel analyzer. Particle species above this energy were distinguished by the use of an on-board pulse multiplier [Lanzerotti, Lie, and Miller, 1969].

- Not Principal Investigator Group/Major Journals

F6-14 Ogilvie, K.W., and J.F. Arens, "Acceleration of Protons by Interplanetary Shocks," J. Geophys. Res., 76, 13-20, 1971.

See abstract under F1-17.

F7 Low Energy Proton and Electron Differential Energy Analyzer

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This experiment was designed to measure low-energy electron and proton intensities separately inside the magnetosphere and in the interplanetary region. The detector system consisted of a curved plate, cylindrical, electrostatic analyzer (LEPEDEA - Low Energy Proton and Electron Differential Energy Analyzer) and Bendix continuous channel multiplier (Channeltron) array, and in addition, an Anton 213 GM tube designed to survey the intensities of electrons with E > 40 kev in the outer magnetosphere. The electrostatic analyzer was capable of measuring the angular distributions and differential energy spectra of proton (25 ev to 47 kev) and electron (33 ev to 57 kev) intensities, separately, within 15 contiguous energy intervals. The analyzer accumulators were read out four times every 20.48 sec. Each accumulation was about 480 msec long (spacecraft spin period was initially 2.6 sec). A complete scan of the spectrum for four directions in a plane perpendicular to the spacecraft spin axis required 307.2 sec. For each energy interval, the detector response for four approximately 60° segments of the angular distribution were telemetered. The instruments performed normally from launch until the satellite decayed on May 3, 1969.

- Principal Investigator Group/Major Journals

F7-01 Frank, L.A., "On the Presence of Low Energy Protons ($5 \leq E \leq 50$ keV) in the Interplanetary Medium," J. Geophys. Res., 75, 707-716, 1970.

A fortuitous set of observational conditions has allowed first measurements of low-energy proton ($5 \leq E \leq 50$ keV) distributions heretofore unobserved in the interplanetary medium. Salient features of

the two major enhancements of interplanetary proton ($5 \lesssim E \lesssim 50$ keV) intensities observed during the period 25 July through 13 August 1967 were (a) a broad differential energy spectrum of intensities over the energy range $5 \lesssim E \lesssim 50$ keV with peak intensities ~ 10 protons $(cm^2\text{-sec-sr-eV})^{-1}$ at ~ 20 keV, (b) peak number densities ~ 10^{-2} protons $(cm)^{-3}$, (c) peak energy densities ~ 300 $eV(cm)^{-3}$, (d) an anisotropy in the angular distributions in the ecliptic plane favoring intensities arriving from near-solar directions by factors ~ 2 or 3, (e) duration of these events ~ 1 day on 29 July and 11 August, and (f) the occurrence of a small geomagnetic storm immediately following each enhancement of proton intensities. These peak energy densities exceed the 'quiet-sun' ion and electron thermal energy densities by a factor ~ 10 and are comparable to or exceed these thermal energy densities during solar disturbances. Sufficient energy is carried by these interplanetary protons ($5 \lesssim E \lesssim 50$ keV) to account for the observed $D_{ST}(H)$ decreases during the two small geomagnetic storms if ~ 2% of these protons incident upon the sunlit hemisphere of the magnetopause are convected into the earth's magnetosphere.

• Principal Investigator Group/Other Publications

F7-02 Frank, L.A., "S.U.I. Experiment for the Interplanetary Monitoring Platforms (IMP) F and G," SUI 64-32, Aug. 1964.

Description of the instrumentation proposed for the University of Iowa experiment on IMPS F and G to study particle populations and behavior in the outer magnetosphere. The use of the Iowa Low Energy Proton and Electron Differential Energy Analyzer (LEPEDEA), in conjunction with a semiconductor electron multiplier (Channeltron) to measure differential energy spectra of electrons and protons over the range 100 to 50,000 ev is described. A summary of the characteristics and calibrations of the LEPEDEA and the accompanying Anton 213 Geiger-Mueller counter is given. The characteristics of the LEPEDEA are compared to those of a dc scintillator. Figures are included to show the operation of the instrument and the telemetry system and the response of the instruments in calibration.

F7-03 Frank, L.A., N.K. Henderson, and R.L. Swisher, "Degradation of Continuous-Channel Electron Multipliers in a Laboratory Operating Environment," Rev. Sci. Instrum., 40, 685-689, May 1969.

Measurements of the counting rates (~10^3 to 10^4 counts/sec) of continuous-channel electron multipliers mounted in an electrostatic analyzer responding to a monoenergetic beam of electrons, while operating in a vacuum chamber at a pressure ~3×10^{-6} Torr attained with an oil diffusion pump, display a degradation of their gain (fatigue) which is proportional to the accumulated counts. The useful lifetime of these devices when employed with fixed-threshold pulse amplifiers is defined here as the accumulated counts until gain degradation has produced a reduction of the counting rates to 15% of the initial responses at an operating bias voltage of 4000 V and constant stimuli. The lifetimes of these particle detectors in this laboratory environment are ~10^{10} counts or, for example, an average counting rate of 300 counts/sec for one year. Comparison of this laboratory lifetime with the responses of similar instrumentation which has been flown on the earth satellites OGO's 3, 4, and 5 and IMP 4 demonstrates that the expected lifetimes

for these electron multipliers in a spaceflight environment are several years. Efficiencies of an electron multiplier for counting monoenergetic electrons over an energy range ~60 to 50 000 eV are also presented.

- Not Principal Investigator Group/Major Journals

F7-04 Meng, C.-I., and S.I. Akasofu, "Study of Polar Magnetic Substorms, 2. Three-Dimensional Current System," J. Geophys. Res., 74, 4035-4053, 1969.

Three-dimensional current systems are constructed semi-quantitatively for different epochs of several polar magnetic substorms, mainly on the basis of the distribution of their magnetic fields on the earth's surface. In a representative case the current system consists of an asymmetric ring current belt in the day-evening sector, current along the field lines from the morning end of the ring current to the northern and southern ionospheres, ionospheric current along the auroral oval in the dark sector (the auroral electrojet), and current along the field lines from the western end of the auroral electrojet to the ring current. The distribution of asymmetric ring current particles thus deduced in a previous paper (Akasofu and Meng, 1969) and in this work is remarkably similar to that observed by Frank (1968).

F8 Cosmic Ray Anisotropy

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The experiment was designed to study solar particle anisotropy and its variation with time. A telescope, consisting of three aligned detectors (A - solid state, B - plastic scintillator, C - CsI scintillator) and a plastic scintillator anticoincidence shield (D), was used to measure protons from 0.8 to 7.0 Mev (counts in A but not in B) and from 35 to 110 Mev (coincident counts in B (dE/dx) and C (total E) but not in D). Pulse height analysis yielded six-point spectra within each of these two energy intervals. In addition, a proportional counter provided directional measurements of X rays with E > 2 kev and electrons with E > 70 kev. Counts in each particle counting mode were obtained in each of eight sectors in the ecliptic plane. X-ray counts were obtained in the solar sector. A complete set of count rates and spectral data was obtained every 81.9 sec. The proportional counter and telescope worked well from launch until March 1968 and May 3, 1969 (spacecraft reentry date), respectively.

- Principal Investigator Group/Major Journals

F8-01 Allum, F.R., U.R. Rao, K.G. McCracken, J.R. Harries, and R.A.R. Palmeira, "Degree of Anisotropy of Cosmic Ray Electrons of Solar Origin," Solar Phys., 17, 241-268, Mar. 1971.

Data obtained by the Explorer 34 satellite regarding the degree of anisotropy of $\gtrsim$ 70 keV electrons of solar origin are reported. It is shown that the anisotropies are initially field aligned, and that they decay to $\lesssim$ 10% in a time of the order of 1 hour. The decays of the concurrent ionic and electronic anisotropies for one well observed

event are in good agreement with the diffusive propagation model of Fisk and Axford. The data suggest parallel diffusion coefficients for both ions and electrons that are rigidity independent. From consideration of a long lived electron event, it is shown that the electronic fluxes exhibit "equilibrium" anisotropies at late times. These are interpreted as indicating that convective removal at the solar wind velocity is the dominant mechanism whereby solar cosmic ray electrons ($\simeq$ keV) leave the solar system. They also indicate that there is a positive electron density gradient at late times in a solar electron event. The data suggest that this was established prior to the establishment of a similar gradient for the cosmic ray ions.

F8-02 Bartley, W.C., K.G. McCracken, U.R. Rao, J.R. Harries, R.A.R. Palmeira, and F.R. Allum, "Instrument to Measure Anisotropies of Cosmic Ray Electrons and Protons for the Explorer 34 Satellite," Solar Phys., 17, 218-240, Mar. 1971.

An instrument to measure the anisotropy and energy spectra of cosmic-ray electrons and protons, and X-rays of solar and galactic origin is described. Such instruments were launched on May 24, 1967 and June 21, 1969 as component parts of the scientific payloads of the Explorer 34 and 41 satellites. A general description and the main characteristics of the detectors are presented and the stability of the instrument on Explorer 34 over its 23 months of operation is discussed. The method of analysis of the obtained angular distribution of solar cosmic ray particles in the ecliptic plane is given. It is shown that the anisotropy of low energy particles of solar origin decreases sharply to a very small value when the satellite penetrates the magnetosphere.

F8-03 Rao, U.R., K.G. McCracken, F.R. Allum, R.A.R. Palmeira, W.C. Bartley, and I. Palmer, "Anisotropy Characteristics of Low Energy Cosmic Ray Population of Solar Origin," Unpublished, Unnumbered, Undated. (To be published in Solar Phys.)

The anisotropy of solar protons in the energy range 0.7-55 MeV obtained by the Explorer 34 satellite is examined and compared with similar data on electrons from the Explorer and protons from Pioneer spacecrafts. It is shown that the large field aligned anisotropies which are observed during the rise time of a flare event change to an equilibrium anisotropy coming radially from the sunward direction due to the convective removal of the solar particles. At very late times during the decay ($T \geq 4$ days) the anisotropy is observed to be from a direction ~45° east of the satellite-sun line and is parallel to $\vec{E} \times \vec{B}$ drift. The equilibrium anisotropy clearly indicates that convection is the determining process in the escape of the solar cosmic rays from the interplanetary medium. The easterly anisotropy at late times is interpreted as indicative of positive density gradient of solar cosmic ray population. The dependence of the equilibrium anisotropy on the energy and the velocity of the particles and on plasma velocity are shown to be in agreement with the theoretical predictions. Both the radial and easterly equilibrium anisotropies show an inverse dependence with the particle velocity in agreement with the theory. The amplitude of the large field aligned anisotropies observed during the rise time of the flare event, prior to the setting up of equilibrium anisotropy, seems to vary with time t as $(Vt)^{-1}$ in accordance with Fisk and Axford theory.

Interplanetary magnetic sector crossings during a flare event, cause abrupt reversals in the non-equilibrium anisotropy phases and a drastic reduction in the anisotropy amplitude. If the sector crossing occurs when the equilibrium anisotropy is established, no significant effect is observed in the anisotropy phase.

The time intensity profiles at very low energies show complicated structures unlike those at higher energies, particularly during the decay phase of the flare events. The decay time constant in a flare effect is shown to be a function of convective removal of particles and the azimuthal density gradient of particles. Depending on whether the observer is located east or west with respect to the centroid of the flare population, the azimuthal drift will either aid or cancel the effect due to convective evacuation resulting in a steeper or a slow decay of the particle flux. The decay time constant at higher energies is shown to be usually much smaller than at lower energies which is attributable to the much lower influence of the azimuthal gradient at these energies.

- Principal Investigator Group/Conference Proceedings

F8-04 Rao, U.R., F.R. Allum, W.C. Bartley, R.A.R. Palmeira, J.A. Harries, and K.G. McCracken, "Measurement of Cosmic Ray Anisotropy of Solar Origin by Explorer 34 Satellite," Solar Flares and Space Res., Unnumbered, 267-276, 1969.

The Explorer 34 (IMP F) spacecraft was launched into a highly eccentric orbit, of apogee 2.15 X 10^5 km at 1400 UT on May 24, 1967. This paper provides a preliminary survey of the phenomena observed by the cosmic ray anisotropy detectors during the period from May to December, 1967. Detailed studies of these and other phenomena will be published elsewhere at a later date.

F9 GSFC Solid-State Telescope

F.B. McDonald NASA/Goddard Space Flight Center

This experiment used a dE/dx vs E telescope with one thin and two thick surface barrier solid-state detectors and an anticoincidence plastic scintillator counter. The two thick detectors acted together as one detector. The telescope axis was perpendicular to the spacecraft spin axis. Counts of particles penetrating the thin detector and stopping in a thick detector were accumulated for two 4.48-sec intervals every 2.73 min. The relative contributions to the count rate of protons and alpha particles with $4.2 \leq E \leq 19.1$ Mev/nucleon and energy spectral information were determined by 1024-channel pulse height analysis, which was performed simultaneously on the output of the solid-state detectors eight times every 2.73 min. Separation of counting rates into two modes (proton and alpha particle), distinguished by the amount of energy deposited in the thin detector, was not achieved as planned. Protons stopping in the thin detector (and particles penetrating it) were measured by passing the output signal through an eight-level energy threshold discriminator. The eight corresponding proton energies ran from 1.1 Mev to about 4 Mev. Data from any one level were transmitted once every 2.73 min. The anticoincidence scintillator failed in March 1968. This resulted in somewhat higher background count rates, which rendered isotopic (but not charge) sepa-

ration more difficult. Except as already noted, the experiment performed well from launch until May 3, 1969 (spacecraft reentry date).

- Principal Investigator Group/Major Journals

F9-01 Arens, J.F., "Interplanetary Energetic Particle Diffusion Coefficient Determination Using Random Walk from Shock Waves," NASA-GSFC, X-646-70-226, June 1970. (Paper submitted to J. Geophys. Res.)

See abstract under F5-05.

F9-02 Baity, W.H., B. Teegarden, J.A. Lezniak, and W.R. Webber, "Intensities of Low-Energy Cosmic-Ray ^{2}H and ^{3}He Nuclei Measured in 1967-1968," Astrophys. J., 164, 521-527, Mar. 1971.

Measurements of the intensities of ^{2}H and ^{3}He made by two different instruments carried respectively on the Pioneer 8 and IMP IV spacecraft are presented. The results from these two quite different instruments were found to be in good agreement. The ^{3}He results are consistent with published results of other observers. We find the ^{2}H results consistent with measurements at solar minimum when modulation is taken into account. The values for the ^{2}H intensity, however, disagree with those of Hsieh and Simpson taken in late 1967. We are at present unable to explain this discrepancy. The implications of these results with respect to the solar modulation and galactic propagation of cosmic rays are discussed.

F9-03 Fisk, L.A., "Increase in the Low Energy Cosmic Ray Intensity at the Front of Propagating Interplanetary Shock Waves," J. Geophys. Res., 76, 1662-1672, 1971.

See abstract under F5-07.

F9-04 Kinsey, J.H., "Identification of a Highly Variable Component in Low-Energy Cosmic Rays at 1 A.U.," Phys. Rev. Letters, 24, No. 5, 246-249, Feb. 1970.

Evidence is given for the existence of two distinct populations of cosmic-ray protons and alpha particles in the energy range of 4 to 80 MeV/nucleon: (1) a highly variable component with an inverse energy dependence and (2) a quasi-steady residual component which shows a positive dependency on energy. The analysis based on a series of four-day energy spectra obtained from the cosmic-ray experiments aboard IMP 4 during the time interval from May 24, 1967 to Aug. 20, 1968. It is suggested that the highly variable component is probably entirely of solar origin. The residual component is most likely of galactic origin, although below 10 MeV it may also contain some solar particles.

F10 Scintillator Telescope

F.B. McDonald NASA/Goddard Space Flight Center

This experiment used a dE/dx vs E telescope with thin and thick CsI scintillators (one each) and an anticoincidence plastic scintillation counter. The telescope axis was parallel to the spacecraft spin axis. Counts of particles penetrating the thin CsI scintillator and stopping in the thick CsI scintillator were accumulated for a 4.48-sec interval twice every 2.73 min. The relative contribution to the count rate of various species (electrons with $2.7 \leq E \leq 21.5$ Mev, nuclei with charge = 1, 2, atomic mass = 1, 2, 3, 4, and with $18.7 \leq E \leq 81.6$ Mev/nucleon) and energy spectral information were determined by 1024-channel pulse height analysis performed simultaneously on the output of both CsI scintillators 16 times every 2.73 min. Separation of counting rates into two modes (proton and alpha particle) distinguished by the amount of energy deposited in the thin detector was not achieved as planned. Counts of electrons with $0.3 \leq E \leq 0.9$ Mev stopping in the thin scintillator were also obtained once each 2.73 min. Except as noted above, the experiment performed well from launch to May 3, 1967 (spacecraft reentry date).

- Principal Investigator Group/Major Journals

F10-01 Kinsey, J.H., "Identification of a Highly Variable Component in Low-Energy Cosmic Rays at 1 A.U.," Phys. Rev. Letters, 24, No. 5 246-249, Feb. 1970.

See abstract under F9-04.

F10-02 Ogilvie, K.W., and J.F. Arens, "Acceleration of Protons by Interplanetary Shocks," J. Geophys. Res., 76, 13-20, 1971.

See abstract under F1-17.

F10-03 Simnett, G.M., and F.B. McDonald, "Observations of Cosmic Ray Electrons Between 2.7 and 21.5 Mev," Astrophys. J., 157, 1435-1447, Sept. 1969.

Results are presented from the IMP-IV satellite on the 2.7-21.5 MeV electron intensity in interplanetary space between July 3rd and August 27th 1967. The measured electron intensity is believed to be uncontaminated by solar electrons. The analysis procedure for background subtraction and subsequent derivation of the electron spectrum is described. The results of electron accelerator calibrations are used extensively. The origin of the electrons is discussed, and the results are compared with the predicted intensity of knock-on electrons from proton-electron collisions in interstellar space. The measured electron spectrum is shown to be compatible with a sole origin in the galactic knock-on component if solar modulation of low energy electrons is insignificant. The electron energy spectrum obtained is well represented by a power law of the form $dJ/dE = 132\ E^{-1.75}$ electrons/m^2sec sr MeV between 2.7 and 21.5 MeV.

- Principal Investigator Group/Conference Proceedings

F10-04 Simnett, G.M., T.L. Cline, S.S. Holt, and F.B. McDonald, "Delayed Appearance of Relativistic Electrons 5 Days After a Solar Flare," Acta Physica Academiae Scientiarum Hungaricae, 29, Supplement 2, 649-656, 1970. (Proceedings of the 11th International Conference on Cosmic Rays, Budapest, Hungary, 1969.) (Also, NASA-GSFC, X-611-69-413, Sept. 1969.)

F10-05 McDonald, F.B., "Satellite Observations of Solar Cosmic Rays," Intercorrelated Satellite Observations Related to Solar Events, 34-52, 1970. (Proceedings of the 3rd ESLAB/ESRIN Symposium, Noordwijk, Netherlands, Sept. 16-19, 1969. Eds., V. Manno, D.E. Page, D. Reidel Publishing Company, Dordrecht, Holland.)

F10-06 Simnett, G.M., T.L. Cline, and F.B. McDonald, "Time Variations of the 4 to 12-MeV Interplanetary Electron Intensity Between 1963 and 1968," Acta Physica Academiae Scientiarum Hungaricae, 29, Supplement 1, 151-158, 1970. (Proceedings of the 11th International Conference on Cosmic Rays, Budapest, Hungary, 1969.) (Also, NASA-GSFC, X-611-69-413, Sept. 1969.)

See abstract under A6-11.

- Principal Investigator/Other Publications

F10-07 Kinsey, J.H., "Study of Low Energy Cosmic Rays at 1 A.U.," NASA-GSFC, X-611-69-396, Sept. 1969. (Ph.D. Thesis.)

See abstract under C6-12.

F11 Chicago Solid-State Telescope

J.A. Simpson University of Chicago

The experiment was designed to measure separately the contributions of solar nuclei and of galactic nuclei ($Z \leq 14$) using a solid-state cosmic-ray telescope designed for energy loss vs range or total energy measurements. The particle energy range was proportional to Z^2/A; for protons: 0.8 to 9.6 Mev, 9.6 to 18.8 Mev, 29.5 to 94.2 Mev, and 94.2 to 170 Mev and above. The detector viewing angle was perpendicular to the satellite spin axis. A second, smaller, solid-state telescope mounted parallel to the spacecraft spin axis was used to direct electrons in the range 80 to 130 kev and 175 to 390 kev. The electron detector was designed to provide information concerning the shape and intensity of the magnetospheric electon spectra. The detector accumulators for each energy interval were telemetered four times every 20.48 sec. Each accumulation was 4.8 sec long (spacecraft initial spin period was about

2.6 sec). The output from three 256-channel nuclear particle telescope pulse height analyzers was obtained for one incident particle every 5.12 sec and was telemetered along with the detector accumulators. Except for the failure of the electron detector 6 days after launch, the experiment performed normally until the satellite decayed on May 3, 1969.

- Principal Investigator Group/Major Journals

F11-01 Hsieh, K.C., "Study of Solar Modulation of Low-Energy Cosmic Rays Using Differential Spectra of Protons, ^{3}He, and ^{4}He at $E \lesssim 100$ MeV/Nucleon During the Quiet Time in 1965 and 1967," Astrophys. J., 159, 61-76, Jan. 1970.

See abstract under C7-06.

F11-02 Hsieh, K.C., and J.A. Simpson, "Galactic ^{3}He Above 10 MeV per Nucleon and the Solar Contributions of Hydrogen and Helium," Astrophys. J., 162, No. 3, Part 2, L197-L201, Dec. 1970.

The flux of ^{3}He between 10 and 30 MeV per nucleon has been measured in interplanetary space for the first time. The ^{3}He spectrum between 10 and 100 MeV per nucleon is compared with the proton and ^{4}He spectra. The ^{3}He flux is of galactic origin and is used as a tracer to identify the galactic spectrum of ^{1}H and ^{4}He between 10 and 30 MeV per nucleon in the presence of a quasi-steady solar component whose proton spectrum has a slope of opposite sign in this energy range. During the quietest periods on the Sun in 1967, the Sun contributed approximately 70 percent of the observed proton flux at 10 MeV, 30 percent at 15 MeV, 15 percent at 20 MeV, and a negligible flux at higher energies. These values are consistent with those obtained by using galactic ^{2}H as a tracer. The ^{3}He and ^{4}He spectra above 10 MeV per nucleon also provide evidence that adiabatic deceleration is operative as a mechanism in cosmic-ray modulation and that the local interstellar spectrum flattens toward low energies.

F11-03 Hsieh, K.C., and J.A. Simpson, "Isotopic Abundances and Energy Spectra of ^{2}H, ^{3}He, and ^{4}He of Cosmic-Ray Origin in the Energy Region ~10-100 MeV/Nucleon^{-1}," Astrophys. J., 158, Part 2, L37-L41, Oct. 1969.

The IMP-4 satellite carried an instrument capable of resolving the H and He isotopes. The differential energy spectrum of ^{2}H from 6 to 60 MeV nucleon^{-1}, along with simultaneous measurements of ^{3}He and ^{4}He, has been obtained during the 1967 solar quiet times in interplanetary space. These measurements show that (1) an ^{2}H flux exists whose magnitude is not accounted for by current ideas for cosmic-ray transport in the Galaxy; (2) by using the ^{2}H as a tracer for a component of galactic origin in interplanetary space it is found that the solar-proton component (1967) must be less than 15 percent of the interplanetary proton flux at 20 MeV; and (3) present forms of solar-modulation theory must be modified at low energies to account for the observations.

F11-04 Hsieh, K.C., and J.A. Simpson, "Relative Abundances and Energy Spectra of ^{3}He and ^{4}He from Solar Flares," Astrophys. J., 162, No. 3, Part 2, L191-L196, Dec. 1970.

The isotope ^{3}He from solar flares has been detected in interplanetary space with the University of Chicago charged-particle telescope on the IMP-IV satellite. The study included ^{1}H, ^{3}He, and ^{4}He nuclei in the energy range 10-100 MeV per nucleon from seven flares in 1967. The summed differential energy spectra obtained for ^{4}He and ^{3}He are $\propto E^{-3.0}$ and $\propto E^{-1.8}$, respectively. When one integrates over this energy range, the ratio ^{3}He/^{4}He = (2.1 ± 0.4) X 10^{-2}. For the entire energy span it is estimated that this ratio becomes ≤ 2 X 10^{-3}, which is below the optically observed upper limits of chromospheric ^{3}He/^{4}He and in agreement with calculated values. The measurements support the view that flare abundances of the isotopes are samples of the chromospheric abundances, but significant production of ^{3}He in nuclear interactions cannot be excluded.

- Principal Investigator Group/Conference Proceedings

F11-05 Garcia-Munoz, M., and J.A. Simpson, "Galactic Abundances and Spectra of Cosmic Rays Measured on the IMP-4 Satellite I. Helium and Medium, and the Very Heavy Nuclei," Acta Physica Academiae Scientiarum Hungaricae, 29, Supplement 1, 317-323, 1970. (Proceedings of the 11th International Conference on Cosmic Rays, Budapest, Hungary, 1969.)

The ratio ^{4}He/(C + N + O) has been obtained from the differential energy spectra of ^{4}He, C, N and O measured from 25 to 170 MeV per nucleon with a particle telescope on the IMP-4 satellite in 1967-1968. The results are in close agreement with earlier measurements at the time of solar minimum in 1965. They confirm both (1) the approximate independence of the relative abundances of He and C, N, O over a wide energy range, and (2) the presence of a significant decrease in the ratio at energies below ~70 MeV per nucleon. The quantitative constraints which these measurements place on a steady-state or equilibrium model for cosmic ray propagation in the Galaxy are examined. As a further test of cosmic ray propagation we have determined the relative abundances of the individual nuclei P, S, Cl, A, K, Ca, Sc, Ti, V, Cr, Mn and the group [Fe + Co + Ni] at 150 MeV/nucleon. We discuss the limitations which these results place on the steady state model. In addition we note the implications of the measured ratios S/Si = 0.20 and F/O = 1.6 X 10^{-2} at 150 MeV/nucleon.

F11-06 Garcia-Munoz, M., and J.A. Simpson, "Galactic Abundances and Spectra of Cosmic Rays Measured on the IMP-4 Satellite II. Li, Be, B and the Medium Nuclei," Acta Physica Academiae Scientiarum Hungaricae, 29, Supplement 1, 325-330, 1970. (Proceedings of the 11th International Conference on Cosmic Rays, Budapest, Hungary, 1969.)

The galactic cosmic ray spectra of the light (L) nuclei Li, Be, B and the medium (M) nuclei C, N, O have been measured in the range 20 MeV/nucleon to 150 MeV/nucleon by the University of Chicago cosmic ray telescope on board the IMP-4 satellite from May 1967 to May 1968. The

L/M ratio is equal to 0.22 ± 0.03 at 120 MeV/nucleon, 0.21 ± 0.04 at 80 MeV/nucleon and 0.23 ± 0.05 at 40 MeV/nucleon. Thus the ratio L/M is essentially constant in the measured energy range and equal to the corresponding ratios measured by other investigators in the range 1 to 22 GeV/nucleon. The individual ratios Li/M, Be/M and B/M are also essentially constant and equal to the high energy measurements previously reported. It is found that an equilibrium model with exponential distribution of path lengths and 10 g/cm^2 mean leakage path length can fit the experimental results. The fraction of ^{7}Be in beryllium in the interval 37 MeV/nucleon to 107 MeV/nucleon has been measured and found to be 0.3 ± 0.1.

- Principal Investigator Group/Other Publications

F11-07 Hsieh, K.C., G.M. Mason, E. Murphy, J.A. Simpson, and J.D. Sullivan, "Data Formats for Library Magnetic Tapes and Microfilm from the University of Chicago Charged Particle Experiments on the Satellites IMP-4 and IMP-5," University of Chicago, Laboratory for Astrophysics and Space Research, Preprint No. EFI 71-14, Mar. 1971.

We are submitting to the NSSDC the final processed data obtained from the University of Chicago instruments on the eccentric polar orbiting satellites IMP-4 and IMP-5. IMP-4 data coverage is from the launch date of May 24, 1967 through April 29, 1969. IMP-5 data coverage is from the launch date of June 21, 1969, and continues until the present time (March, 1971). These data are presented on microfilm and on magnetic tape. On microfilm are time-intensity plots for the averaged counting rates with each plot corresponding to a Bartel's Solar Rotation. There are four categories of magnetic tape:

1) Averaged counting rates,
2) Raw accumulator readouts,
3) Pulse height analysis readouts, and
4) Orbit parameters.

This document describes the instruments, the formats of the data and the relationship between the data and the physical parameters the instruments were recording. A reference list of scientific publications by the University of Chicago group based on the IMP-4 and IMP-5 data is attached.

F11-08 Lanzerotti, L.J., "Low Energy Solar Protons and Alphas as Probes of the Interplanetary Medium: The May 28, 1967, Solar Event," J. Geophys. Res., 74, 2851-2868, 1969.

The low-energy solar protons and alpha particles detected during the May 28 (day 148), 1967, solar flare are used as 'probes' to investigate the properties of the interplanetary medium during the course of the event. The lower energy fluxes exhibit characteristics of particle storage either at the sun or in interplanetary space. The higher energy particle fluxes exhibit 'classical' west limb flare profiles and are fit both to a simple isotropic diffusion-with-boundary model and to a radial dependent scattering center model. The diffusion coefficient model of Jokipii is used with the results of a fit to the exponential decay of the event to predict an f^{-3} dependence of the power spectral

density of the interplanetary magnetic field fluctuations (assuming a boundary location independent of rigidity). The ratio of particle fluxes before and after a sudden, discontinuous flux decrease (attributed to a sector boundary) is found to be $\sim R^3$ for protons and $\sim R^6$ for alphas for particles with rigidities $\lesssim 200$ Mv. Significant velocity dispersions are discovered in three of the flux modulations during the onset stage of the event. The velocity dispersions in one of these modulations could be interpreted as due to a modulating region located ~0.03 AU from the earth. It is speculated that this region was responsible for an sc at the earth some two hours later.

G6 Low Energy Solid-State Telescope

W.L. Brown — Bell Telephone Laboratories

A four-element solid-state telescope with an acceptance cone half angle of 20° was mounted normal to the spacecraft spin axis. During each 2.73-min interval, 9.82-sec accumulations were obtained in each of 16 distinct counting modes. These modes involved protons in five energy intervals covering 0.6 to 18 Mev, alpha particles in four intervals covering 1.7 to 80 Mev, and electrons, deuterons, tritons, and helium-3 nuclei in the intervals 0.3 to 3, 5 to 20, 5.5 to 25, and 11 to 72 Mev, respectively. Onboard calibration checks were performed every 6 hr. The experiment performed normally until January 30, 1970, when a GSFC power supply failure limited useful data gathered to low energy protons, electrons, and alphas. Information on these particles is not available after that date. The instrument is still about 30% operational (April 1971).

• Principal Investigator Group/Other Publications

G6-01 Lanzerotti, L.J., "Calibration of a Semiconductor Detector Telescope for Space Experiments," Nuclear Instruments and Methods, 61, No. 1, 99-107, Apr. 1968.

See abstract under F6-07.

G6-02 Lanzerotti, L.J., H.P. Lie, and G.L. Miller, "Satellite Solar Cosmic Ray Spectrometer with On-Board Particle Identification," Transactions of the IEEE, NS-16, 343-350, Feb. 1969.

See abstract under F6-11.

G7 Low Energy Proton and Electron Differential Energy Analyzer

J.A. Van Allen — University of Iowa

This experiment, which was similar to the University of Iowa experiment on IMP F, was designed to separately measure low-energy electron and proton intensities inside the magnetosphere and in the interplanetary region. The detector system consisted of a curved plate, cylindrical, electrostatic analyzer (LEPEDEA detector) and Bendix con-

tinuous channel multiplier (Channeltron) array, and an Anton 213 GM tube designed to survey the intensities of electrons with E > 40 kev in the outer magnetosphere. The electrostatic analyzer was capable of measuring the angular distributions and differential energy spectra of proton and electron intensities, separately, within 15 contiguous energy intervals over the energy ranges 25 ev to 47 kev and 33 ev to 57 kev. The analyzer accumulators were read out four times every 20.48 sec. Each accumulation was about 480 msec long (spacecraft spin period was initially 2.6 sec). A complete scan of the spectrum for four directions in a plane perpendicular to the spacecraft spin axis required 307.2 sec. For each energy interval, the detector response for four approximately 60° segments of the angular distribution was telemetered. The instruments were performing normally as of March 1971.

• Principal Investigator Group/Major Journals

G7-01 Frank, L.A., "Plasma in the Earth's Polar Magnetosphere," J. Geophys. Res., 76, 5202-5219, 1971.

First observations of the plasmas in the dayside polar magnetosphere were obtained with the earth-satellite Imp 5 during July-August 1969. Several of the more important observational results are the following. (1) The polar neutral 'points' that appear at the high-latitude magnetopause in mathematical models for the shape of the geomagnetic cavity formed by the interaction of the solar wind with the geomagnetic field are observationally 'bands' with width ~1 R_E across the dayside high-latitude magnetopause (one band in the northern hemisphere and presumably a second in the southern hemisphere). (2) These two bands, or regions of the magnetopause through which the magnetosheath plasma has direct access to the magnetosphere, and the corresponding extension of these bands from magnetopause to auroral altitudes have been designated herein as the 'polar cusps.' (3) At all other positions of the dayside magnetopause, the magnetopause appears to be an effective barrier against the direct entry of magnetosheath plasma. (4) During periods of relative magnetic quiescence the intersection of the dayside polar cusp with the auroral zone is positioned at invariant latitude $\Lambda = 79°$ (±1°) and its latitudinal width is 20 to 400 km projected onto the auroral zone. (5) During periods of the relative magnetic disturbance the position of the polar cusp moves equatorward by several degrees in invariant latitude without a large increase in its latitudinal width, i.e., by factors $\lesssim 2$. (6) The high-latitude termination of energetic trapped electron (E > 45 kev) intensities in the high-latitude dayside outer radiation zone occurs coincident with the polar cusp, albeit these intensities are small and of irregular profile with radial distance in this region. (7) No measureable intensities of energetic electrons (E > 40 kev) magnetosheath protons and electrons, and ring-current protons were observed at latitudes above the polar cusp, i.e., in the polar cap region. (8) The proton and electron differential energy spectrums as viewed in the solar direction in the distant polar cusp (within several earth radii of the magnetopause) are identical to those observed within the magnetosheath to within observational accuracy. (9) The bulk velocity of protons in the distant polar cusp as deduced from the angular distributions appears to be lower than that of the magnetosheath plasma near the magnetopause by factors ~2 or 3. (10) In the midaltitude polar cusp at ~4 to 5 R_E geocentric radial distances, the proton spectrum differs from that at the magnetosheath in that protons with energies $\lesssim 500$ ev are severely less than those observed in the magnetosheath. (11) The proton spectrums in the midaltitude polar cusp are similar to those in the distant plasma sheet with the exception that the proton number densities in the polar cusp are typically

larger by factors ~20 to 200. (12) The angular distributions of proton intensities in the midaltitude polar cusp are strongly peaked along the local magnetic field (i.e., down into the auroral zone); the dimensions of the atmospheric loss cone at these altitudes appear to be insufficiently large to account for the observed anisotropy; and (13) the magnetosheath plasma in the midaltitude polar cusp is observed to be separated into two thin sheets, one of magnetosheath proton intensities and the other populated with magnetosheath electrons; these sheets are immediately adjacent to each other with the electron sheet equatorward of the proton sheet; their latitudinal widths as projected into the auroral zone are roughly equal, ~10 to 200 km. These observations, along with recent measurements from other earth satellites, have been interpreted in terms of a proposed magnetospheric model with several new features, among which are the following. (1) Plasma sheet protons gain access to the magnetospheric field lines via the dayside polar cusps. (2) All magnetic field lines threading the distant plasma sheet beyond ~20 or 30 R_E were convected from the polar cusps. (3) Magnetic field lines in the polar cap region of the magnetotail do not merge or pass through the plasma sheet.

- Principal Investigator Group/Other Publications

G7-02 Frank, L.A., "Several Comments Concerning a Recently Proposed Magnetospheric Model," University of Iowa, UI 70-57, Nov. 1970.

G7-03 Frank, L.A., "S.U.I. Experiment for the Interplanetary Monitoring Platforms (IMP) F and G," SUI 64-32, Aug. 1964.

See abstract under F7-02.

G9 Cosmic Ray Anisotropy

K.G. McCracken University of Texas at Dallas

This experiment was designed to study solar particle anisotropy and its variations with time. A telescope, consisting of three aligned detectors (A - solid state, B - plastic scintillator, C - CsI scintillator) and a plastic scintillator anticoincidence shield (D), was used to measure protons from 0.8 to 7.0 Mev (counts in A but not in B) and from 35 to 110 Mev (coincident counts in B (dE/dx) and C (total E) but not in D). Pulse height analysis yielded six-point spectra within each of these two energy intervals. In addition, a proportional counter provided directional measurements of X rays with E ≥ 2 kev and electrons with E > 70 kev. Counts in each particle counting mode were obtained in each of eight sectors in the ecliptic plane. X-ray counts were obtained in the solar sector. A complete set of count rates and spectral data was obtained every 81.9 sec. The experiment was functioning normally as of March 1971.

- Principal Investigator Group/Major Journals

G9-01 Bartley, W.C., K.G. McCracken, U.R. Rao, J.R. Harries, R.A.R. Palmeira, and F.R. Allum, "Instrument to Measure Anisotropies of Cosmic Ray Electrons and Protons for the Explorer 34 Satellite," Solar Phys., 17, 218-240, Mar. 1971.

See abstract under F8-02.

G12 Solid-State Telescope

J.A. Simpson University of Chicago

This experiment was designed to measure separately the contributions of solar nuclei and of galactic nuclei ($Z \leq 14$) using a combination solid-state and Cerenkov counter cosmic-ray telescope detector. The detector was designed for energy loss vs range or total energy measurements for protons (differential measurements between 0.8 to 119 Mev and an integral measurement between 119 Mev and 1 Bev). Similar differential energy measurements of HE and higher Z nuclei were made between 3 Mev/nucleon and 1 Bev/nucleon. The detector was oriented perpendicular to the satellite spin axis. The detector accumulators were telemetered four times every 20.48 sec. Each accumulation was 4.8 sec long (spacecraft initial spin period was about 2.2 sec). The output from the three 256-channel pulse height analyzers was obtained for one incident particle every 5.12 sec and was telemetered along with the detector accumulators. The experiment was functioning normally as of March 1971.

- Principal Investigator Group/Major Journals

G12-01 Hsieh, K.C., G.M. Mason, and J.A. Simpson, "Cosmic Ray Deuterium from Satellite Measurements, 1965 to 1969," Astrophys. J., 166, 221-233, May 1971.

A new measurement of the ^2H flux of galactic origin and the $^2H/^4He$ ratio in the energy interval from 20 to 60 MeV per nucleon has been obtained from the University of Chicago experiment on the satellite IMP-5 in 1969. The results obtained are compared with satellite measurements made since 1965. The differential energy spectrum of ^2H is found to be much flatter than that measured at the time of the discovery of ^2H in 1965, due to the greater uncertainties in background correction in the 1965 measurements.

Other Experiments

E7 Micrometeorite Flux

J.L. Bohn Temple University

This experiment was designed to measure the ionization, momentum, speed, and direction of micrometeorites, using thin film charged detectors, induction devices, and microphones. The experiment continues to operate normally (March 1971).

- Principal Investigator Group/Conference Proceedings

E7-01 Alexander, W.M., C.W. Arthur, J.D. Corbin, and J. Lloyd Bohn, "Picogram Dust Particle Flux: 1967-1968 Measurements in Selenocentric, Cislunar and Interplanetary Space," Space Res. X, 252-259, 1970. (Proceedings of Open Meetings of Working Groups of the Twelfth Plenary Meeting of COSPAR, Prague, Czechoslovakia, May 11-24, 1969. Eds., T.M. Donahue, P.A. Smith, and L. Thomas, North-Holland Publishing Company, Amsterdam, Holland.)

During 1967 and 1968, dust particle measurements from Lunar Explorer 35, OGO III and Mariner IV determined the flux of picogram particles in selenocentric, cislunar and interplanetary space. The Lunar Explorer 35 measurement showed a mean cumulative particle flux of 1×10^{-3} m^{-2} sec^{-1} π $ster^{-1}$ with fluctuations of more than one order of magnitude. The chi-squared test for variance indicates that the time distribution of detected particles in selenocentric space varied significantly from a random distribution during periods of major meteor showers. For non-shower periods, the mean cumulative flux was 2.5×10^{-4} m^{-2} sec^{-1} π $ster^{-1}$. The OGO III dust particle measurement in cislunar space gave a mean cumulative flux of 9×10^{-3} m^{-2} sec^{-1} π $ster^{-1}$ for 0.1 picogram particles. The Mariner IV experiment indicated a mean cumulative flux of 7×10^{-5} m^{-2} sec^{-1} π $ster^{-1}$ for picogram particles near 1 AU. Comparing results of these experiments and employing linear regression curve fitting techniques, the cumulative flux is found to be proportional to $m^{-0.98}$ for masses between 0.1 picogram and 1 nanogram.

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