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High-Latitude Geophysical Studies with Satellite Injun 3

1. Description of the Satellite

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Abstract. We describe the satellite Injun 3 and its scientific payload, which has been used in geophysical studies reported in the accompanying papers. The satellite was launched on December 13, 1962, into an orbit with apogee altitude 2785 km, perigee altitude 237 km, orbital inclination 70.4°, and period 116 minutes. One axis is continually aligned to within a few degrees of the local geomagnetic field vector by a permanent magnet. Eight directional detectors point at right angles to this axis and therefore measure trapped, or Van Allen, radiation. There are three omnidirectional particle detectors. Six particle detectors point upward in the northern hemisphere and therefore detect particles that are being precipitated to cause auroras. Two photometers, with 5577 A and 3914 A filters, point down the axis to view these auroras in the northern hemisphere, while another 5577 A photometer serves the same purpose in the southern hemisphere. With a loop antenna, very-low-frequency electromagnetic radiation in the frequency range about 500 cps to about 10 kc/s is detected, and a frequency and amplitude analysis is performed. The characteristics of the proton detectors which cover the energy range ~50 kev to more than 100 Mev and the electron detectors which cover the range ~5 kev to ~5 Mev are discussed.

INTRODUCTION

High-latitude phenomena such as auroras and the outer radiation zone are so complex and variable, so uncontrollable and unreproducible, that their adequate experimental observation requires that a single event be studied with every piece of apparatus we can bring to bear on it. We devised the satellite Injun 3 to be a self-contained geophysical laboratory for such investigations.

In the following three papers preliminary studies with this satellite are presented. (Another paper by Laughlin et al. will be submitted to this Journal as part 2 in this series.) In this paper we briefly describe relevant features of Injun 3 so that the following papers can contain a minimum amount of technical detail. A more complete technical description of the satellite and relevant scientific aims as they existed before launch are given elsewhere [*O'Brien et al.*, 1962]. Here we discuss only those features of the satellite relevant to the more complete understanding of the physics of the following studies.

The Injun satellites are designed and built by staff and students of the State University of Iowa. The first satellite of this series, Injun 1, was launched on June 29, 1961, and operated successfully for more than eighteen months. Its initial scientific aims were partially frustrated by a launch malfunction that prevented its separation from another satellite. As a consequence, it could not achieve the orientation

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planned for it, and the field of view of its auroral photometer was blocked. The second satellite of the series, Injun 2, was destroyed in a missile malfunction on January 24, 1962.

Injun 3 was planned to be a replacement for Injun 2, and to contain a few new features. Initially it was to be a sixty-pound payload in a sphere of diameter twenty inches. However, partly as a consequence of the discovery of the July 9, 1962, artificial radiation belt by Injun 1,

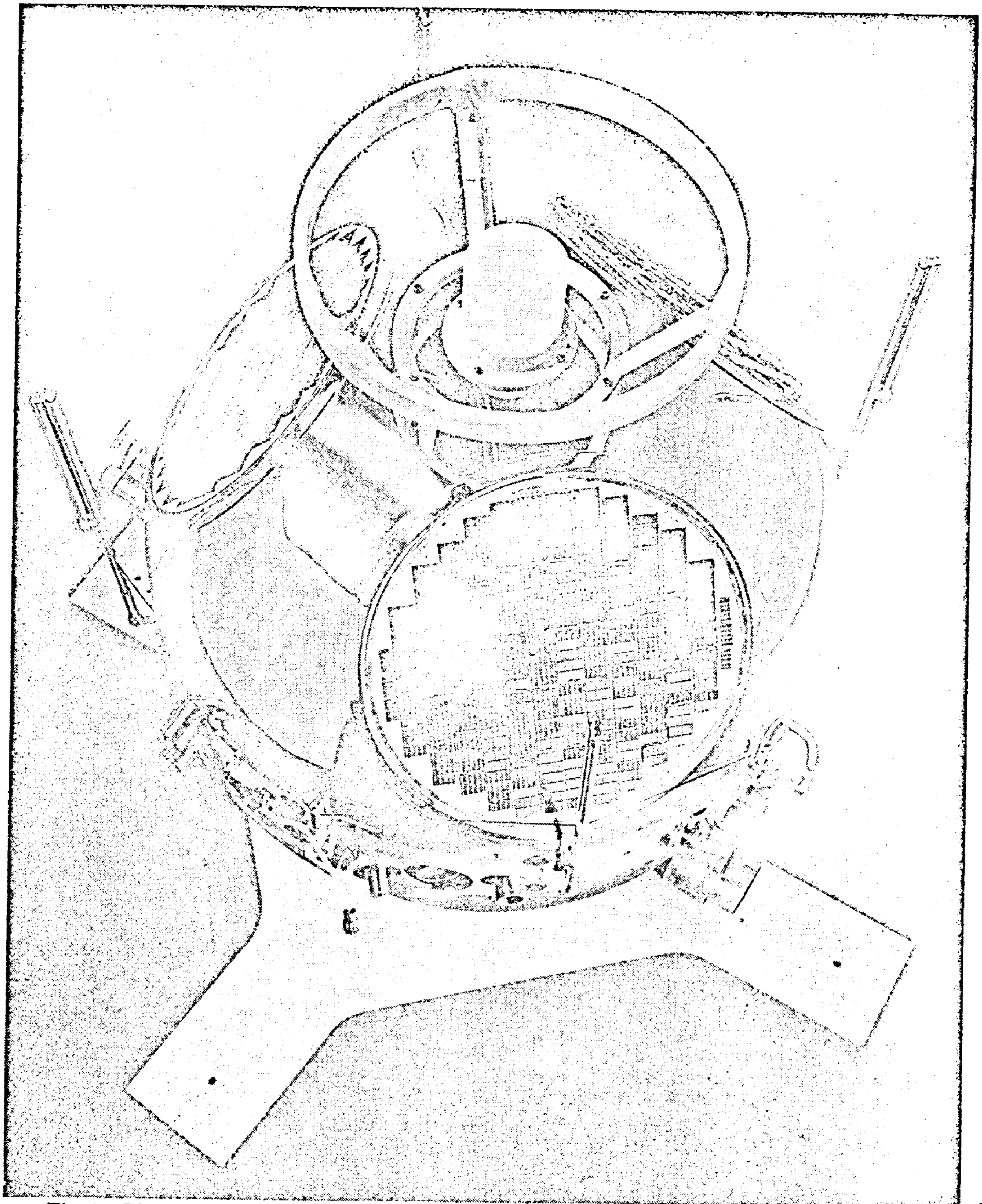

Fig. 1. The satellite Injun 3, weight 115 pounds, diameter 24 inches. The directional detectors all have their axes in the horizontal equatorial plane. The VLF antenna is visible on top.

we were provided in August 1962 with the opportunity to enlarge Injun 3 to a payload of one hundred and fifteen pounds in a sphere of diameter twenty-four inches. We took advantage of this opportunity.

Injun 3 was launched on December 13, 1962, into an orbit with initial apogee altitude of 2785 km, perigee altitude 237 km, orbital inclination 70.4°, and period 116 min. Its orbit nominally was to be circular at an altitude of about 950 km, and much of the payload was designed on the assumption that the nominal orbit would be achieved. The ellipticity of the orbit complicates analysis of such phenomena as diurnal or local time variations of the outer radiation zone and analysis of photometric data.

This complication is not a trivial one, introducing as it does another parameter (altitude) into studies already burdened with many variables. But the technical features of the payload such as the dynamic ranges of its detectors, its telemetry system, and so on are adequate to cope with the great differences between the actual and the nominal altitudes.

GENERAL

Injun 3 is shown in Figure 1. It contains eighteen particle detectors, three auroral and airglow photometers, and equipment to measure very-low-frequency (VLF) electromagnetic waves. Two magnetometers and five photodiodes provide information on the orientation of the satellite, which is magnetically aligned. There are two independent telemetry systems, one of which operates for seventeen minutes after reception of a properly coded command. One, system *A*, transmits two watts of RF power. The other, system *B*, transmits only 200 milliwatts.

Telemetry from the satellite is routinely acquired at the following stations: College, Alaska; St. Johns, Newfoundland; Winkfield, England; Mojave, USA; Quito, Ecuador; Lima, Peru; Santiago, Chile; Johannesburg, South Africa; and Woomera, Australia; all of which are operated by the National Aeronautics and Space Administration, and at the following privately organized stations: Ottawa (by the National Research Council of Canada); Prince Albert, Canada (by the Prince Albert Radar Laboratory); Kiruna, Sweden (by the Geophysical Laboratory); Salisbury, Southern Rhodesia (by a private group); Santos, Brazil (by the Applied Physics Laboratory of Johns Hopkins University); and Iowa City, USA.

Tracking of the satellite, production of definitive orbits, and so on are carried out by the Goddard Space Flight Center. All orbital data are routinely converted into suitable magnetic coordinates.

Data are transmitted as a series of binary bits arranged by one of the two data encoders (*A* and *B*) on board. The telemetry comprises the outputs of selected detectors (varied in flight on command from Iowa City), of two independent on-board clocks or frame counters, and of relevant aspect and housekeeping information. Data are decoded in Iowa City by IBM 7070 and 1401 computers and auxiliary electronics. Checking of the real time of each datum point is maintained by the on-board frame counters whose outputs are treated by the computer as an intrinsic part of the data. The frame counters are checked several times each day against standard time sources such as WWV and against each other. Each datum point can then be labeled in real time and in space along the orbital path to an accuracy of about one second or ten kilometers routinely.

Each detector has its own twelve-bit accumulator in system *A*, and eight of them have their own (different) twelve-bit accumulators in system *B*. The detectors are connected to their individual accumulators and activated when

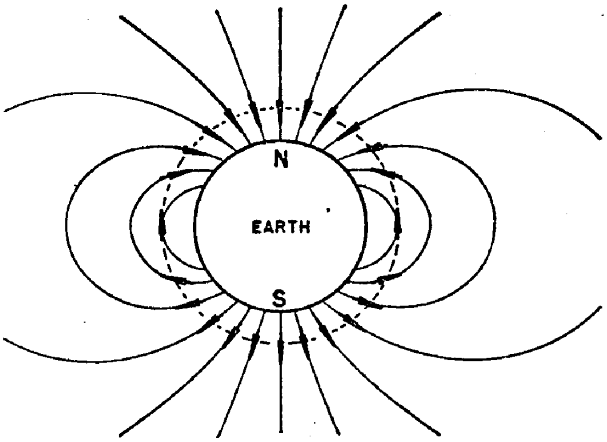

Fig. 2. Sketch illustrating continual alignment of a magnetically oriented satellite in a polar orbit.

the satellite is commanded on. The digital number transmitted for each detector in serial binary array is then the number of counts accumulated in its register since the previous sample was transmitted. This accumulation time varies from about one second to one-sixteenth second in system *A*, depending on the particular detector and on the mode of interrogation chosen by command from Iowa City, and in system *B* this time varies from about one second to about one-fifth second, depending on the detector. Each word has a parity-check bit transmitted by the satellite to enable the computer to check for noisy data in the later decoding.

In addition to the above digital data, the VLF amplifier modulates the telemetry carrier with the VLF signal detected between frequencies of about 500 cps and 7000 cps.

The telemetry is at 136.860 Mc/s, phase modulated in system *A* by 10.24 kc/s and by 14.3 kc/s, corresponding to a zero and a one bit, respectively. In system *B* the carrier is amplitude modulated at 3 kc/s and 4 kc/s (as was Injun 1), corresponding to a zero and a one bit, respectively.

Temperature control of the satellite is passive, and with an average absorptivity of 0.34 and an average emissivity of 0.38, it was designed to operate between −3°C in the minimum (65 per cent) sunlight exposure orbit and about 28°C in the maximum (100 per cent) exposure orbit. Actual temperatures in the first three months of operation ranged between 4°C and 30°C, in excellent agreement with predictions, considering that the orbit is somewhat more exposed than the nominal one. The temperature was kept low so as to reduce thermal noise and hence greatly improve the sensitivity of the four instruments using photomultipliers in a direct current mode.

Power for the satellite is from nineteen *F*-type nickel-cadmium cells and some smaller cells, trickle-charged by solar cells. The satellite is turned on for about 15 to 20 per cent of each day.

The satellite is magnetically oriented with an Alnico V bar magnet one inch square and twenty-two inches long, with a magnetic moment (M) of about 1.4×10^5 ergs/gauss. With a satellite moment of inertia (I) of about 10^7 g cm^2, the resultant natural period of oscillation (T) in the earth's field (B) of (say) 0.3 gauss is

$$T = 2\pi\sqrt{I/MB} \qquad \sim 2 \text{ min}$$

which is sufficiently fast to maintain alignment continuously even while the direction of the local geomagnetic field vector (**B**) changes (see Figure 2).

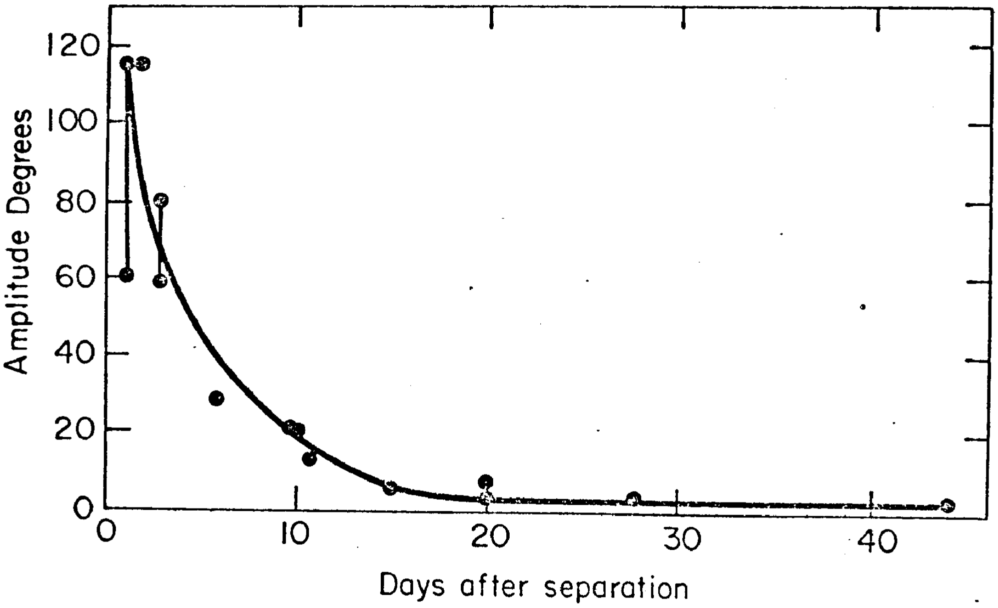

Fig. 3. Maximum deviation from magnetic alignment during early passes by Injun 3. The large difference in two measurements on one day is due to the large amplitude point being taken from a high-altitude, weak-field pass, and the smaller amplitude point from a low-altitude, strong-field pass. Damping of the early oscillations was accomplished with hysteresis losses in permalloy rods.

Soon after launch, the satellite angular motion had an amplitude of more than 100°. This initial angular kinetic energy was dissipated by hysteresis losses in twenty-two permalloy rods one-eighth inch in diameter and about eleven inches long mounted perpendicular to the axis of orientation. The progressive alignment is shown in Figure 3, and the equilibrium alignment in Figure 4. The alignment is measured by two Schonstedt flux-gate magnetometers which were calibrated in the Model Ships Magnetic Laboratory of the Naval Ordnance Laboratory.

Scientific Instrumentation

The scientific instruments are listed in Table 1. For convenience of viewing the physical parameters which each measures a summary sketch is shown in Figure 5. A plan view of the satellite shows the relative orientation and arrangement of the detectors in Figure 6.

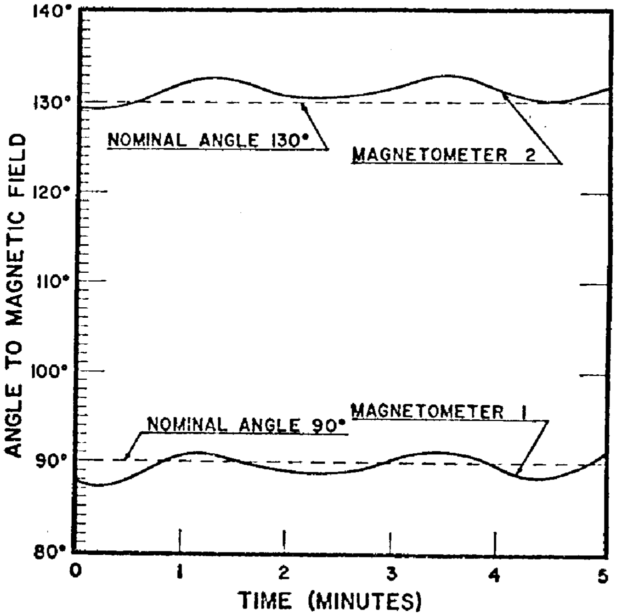

Fig. 4. Magnetic alignment of Injun 3 in the equilibrium condition; perigee pass, 45 days after separation. The detailed shape of the deviation from alignment changes somewhat from pass to pass.

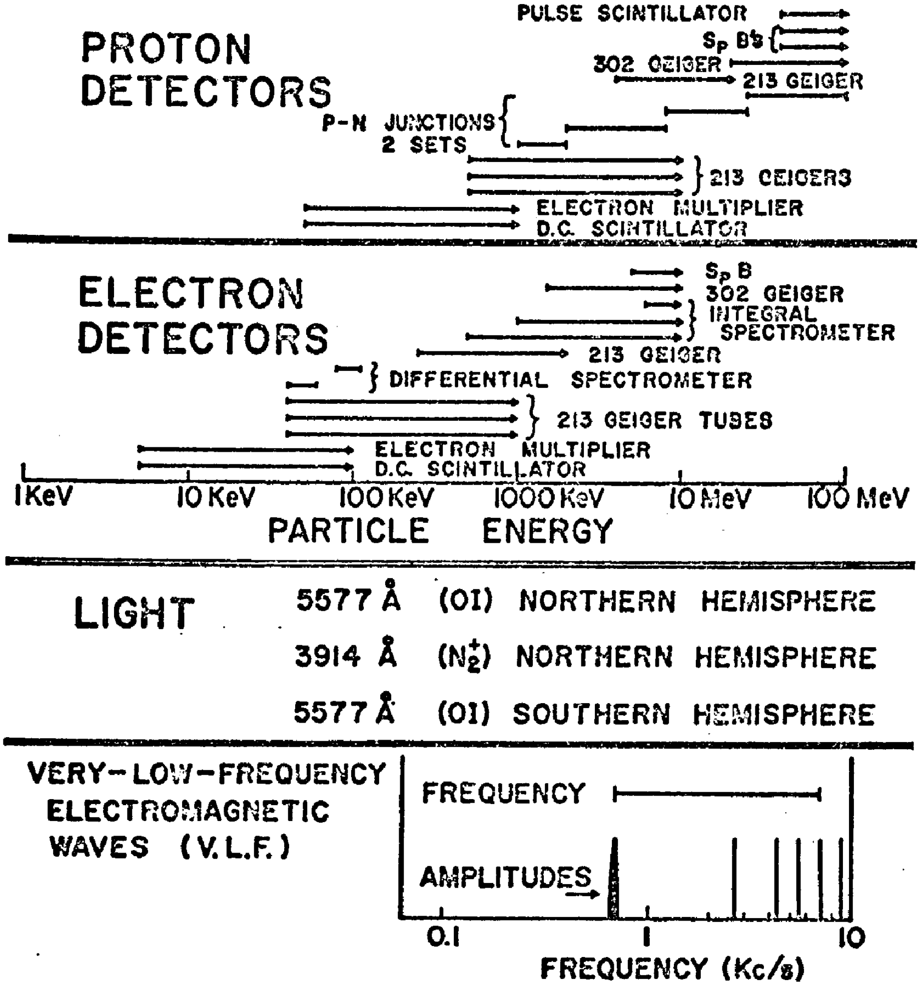

Fig. 5. Summary of the physical parameters measured with Injun 3. For explanation of symbols, see text.

TABLE 1. Injun 3 Detector Complement

Number	Detector	Orientation*	System	Detectable Radiation: Proton Energies	Detectable Radiation: Electron Energies
1	213 Geiger counter	$\theta = 90°$	AB	$E \gtrsim 0.5$ Mev	$E \gtrsim 40$ kev
2	Pulse scintillator	Omnidirectional	AB	$E \gtrsim 40$ Mev	...
3	213 Geiger counter	$\theta = 90°$	A	$E \gtrsim 4$ Mev	$E \gtrsim 250$ kev
4	213 Geiger counter	$\theta = 130°$	AB	$E \gtrsim 0.5$ Mev	$E \gtrsim 40$ kev
5	213 Geiger counter	$\theta = 180°$	A	$E \gtrsim 0.5$ Mev	$E \gtrsim 40$ kev
6	302 Geiger counter	Omnidirectional	AB	$E \gtrsim 20$ Mev	$E \gtrsim 1.5$ Mev
7	Magnetic (a)		AB	...	$42 < E < 53$ kev
8	Electron (b)	$\theta = 90°$	A	...	$83 < E < 98$ kev
9	Spectrometer (c)		A	$E > 40$ Mev	$E > 5$ Mev
10	DC scintillator	$\theta = 130°$	AB	$E \gtrsim 50$ kev	$E \gtrsim 5$ kev
11	Electron multiplier	$\theta = 130°$	A	$E \gtrsim 50$ kev	$E \gtrsim 5$ kev
12	*p-n* junction (a)	$\theta = 90°$	A	$1 < E < 2$ Mev	...
13	*p-n* junction (b)	$\theta = 90°$	A	$2 < E < 8$ Mev	...
14	*p-n* junction (c)	$\theta = 180°$	A	$8 < E < 24$ Mev	...
15	*p-n* junction (d)	$\theta = 180°$	A	$24 < E < 100$ Mev	...
				and two backgrounds for each pair	
16	Photometer (a)	$\theta = 0°$	AB	Light of 5577 A	
17	Photometer (b)	$\theta = 0°$	A	Light of 3914 A	
18	Photometer (c)	$\theta = 180°$	AB	Light of 5577 A	
19	VLF detector	...	A	VLF 700 cps to 10 kc/s in 6 frequency bands and carrier modulation 0.5 to 7 kc/s	
20	Integral (a)	$\theta = 90°$	A	$E \gtrsim 4$ Mev	$E \gtrsim 1.5$ Mev
21	Magnetic (b)	$\theta = 90°$	A	$E \gtrsim 4$ Mev	$E \gtrsim 3$ Mev
22	Spectrometer (c)	...	A	$E \gtrsim 40$ Mev	$E \gtrsim 5$ Mev

* Orientation is referred to the direction of the magnetic field line such that $\theta = 0°$ corresponds to a detector looking downward toward the earth in the northern hemisphere.

We will not attempt to discuss here the reasons for choosing the various detectors or assigning their orientations, nor will we discuss how the array of electron and proton detectors can be used to analyze definitively the type, energy, and flux of the particles encountered around the satellite orbit. Such discussion will accompany any such analysis. The function of this paper is to gather the most important relevant information about all detectors into a conveniently available publication.

Geiger tubes. The two Geiger tubes detectors 1 and 4 are thin-windowed directional detectors, essentially the same as that in Injun 1, with angular fields of view of about 26° in diameter and a window thickness of 1.2 mg cm^{-2} of mica. The transmission of electrons by such a window is shown in Figure 7. The geometric factors are, respectively, about (0.6×10^{-2}) and (1.1×10^{-2}) cm^2 ster. Detector 5 is similar in window thickness but has a field of view of about 86° in diameter and a geometric factor of about (5×10^{-2}) cm^2 ster. Detector 3 is similar to detector 1 and 4 but has an additional window thickness of 45 mg cm^{-2} of aluminum. All these detectors are shielded by about 3 g cm^{-2} of lead and stainless steel except over their apertures.

The type 302 Geiger tube (detector 6) is an omnidirectional detector with uniform shielding of about 0.465 g cm^{-2} of stainless steel and 0.265 g cm^{-2} of magnesium. The omnidirectional geometric factor of this detector is ~ 0.75 cm^2.

All Geiger counters are prescaled by 2^3, or a factor of 8. Detectors 1, 3, and 4 are similar to detectors on Explorer 14, having the same field of view but a geometric factor about 10 times those on 14. The 302 Geiger counter is also similar to that on Explorer 7, 12, and 14, Pioneers 3 and 4, and Traac.

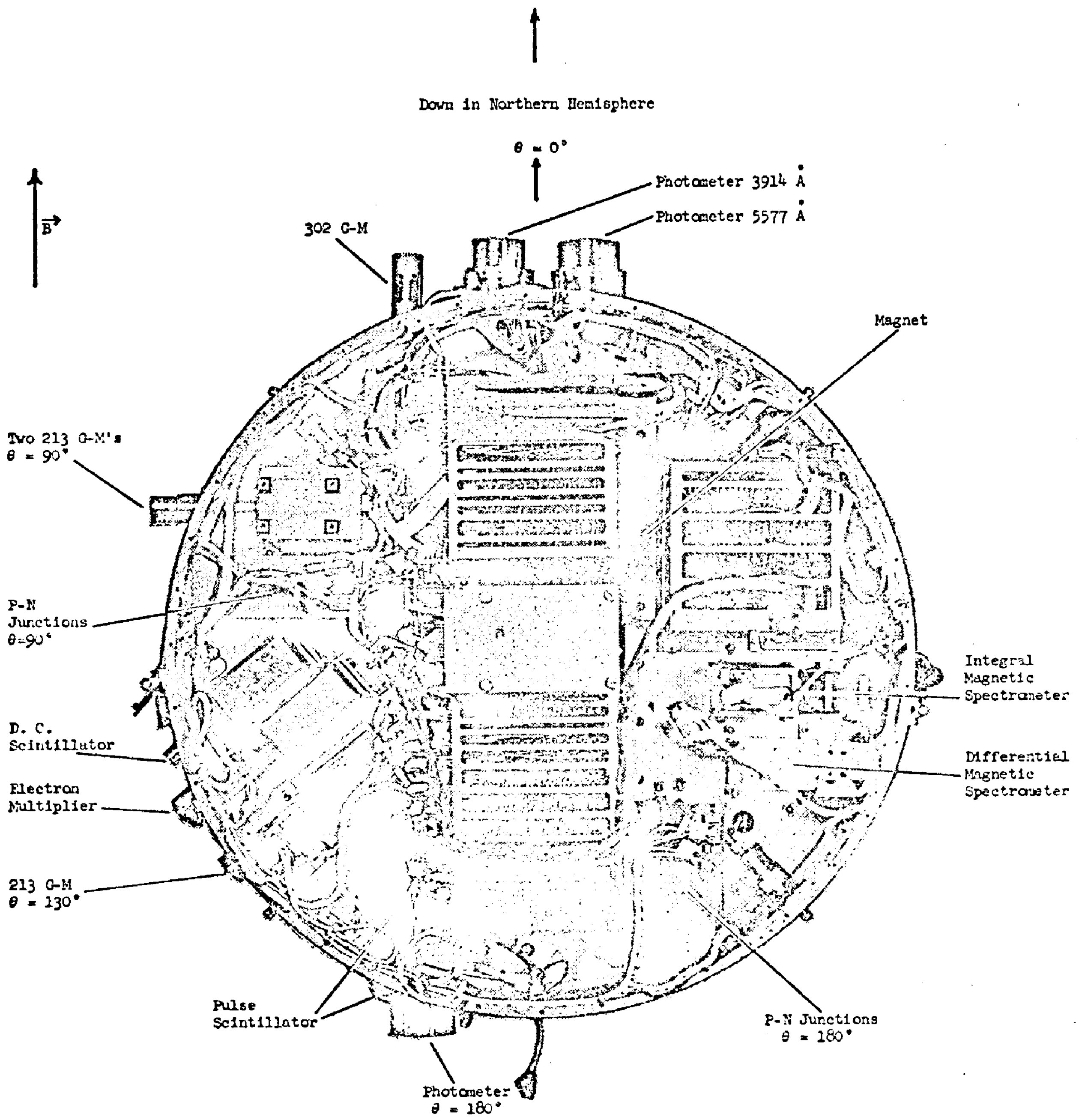

Fig. 6. Plan view of the satellite and detectors.

Pulse scintillator. This has a spherical plastic scintillator of diameter about 0.4 cm on a light pipe to a ruggedized 6199 photomultiplier. The scintillator is inside a shielding of ~1 g cm^{-2} of aluminum, and the electronic discrimination level is set at 3.5 Mev.

The pulse length prior to discrimination is restricted by a delay-line clipper to about 0.25 μ sec, and so pile-up due to many small pulses should be negligible.

The combination of the shielding, pulse-height discrimination, and short pulse length should effectively restrict the response to protons with initial energy above 40 Mev, and the fission electrons now in the inner zone should not be detected efficiently. A similar detector has been flown by McIlwain in Explorer 15.

The detector protrudes beyond the shell (see Figure 6) and has clean geometry over 2π ster. Its omnidirectional geometric factor is about 0.1 cm^2. The detector is prescaled by 2^2, or 4.

Magnetic differential electron spectrometer. This contains three 213-type Geiger tubes encased in a lead cylinder 3.5 g cm^{-2} thick. Two magnets

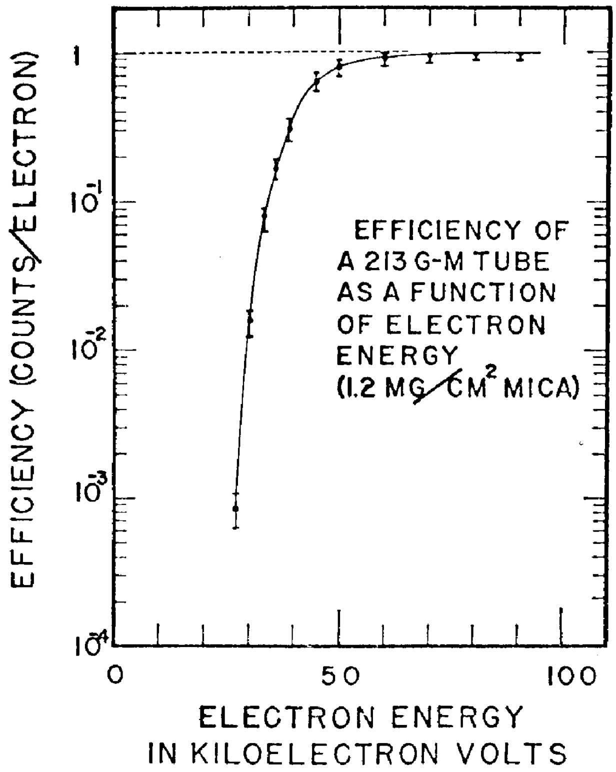

Fig. 7. Relative transmission of electrons through the thin-windowed Geiger tubes, detectors 1, 4, and 5 (courtesy L. Frank).

focus electrons with energy E_e such that $42 \lesssim E_e \lesssim 53$ kev and $83 \leq E_e \leq 98$ kev into two of the Geiger tubes which have thin (1.2 mg cm^{-2}) windows similar to detector 1. The third Geiger tube (SpB) measures omnidirectional intensity of penetrating radiation and bremsstrahlung.

This unit is similar to that flown on Injun 1 and Explorer 12, except that the directional geometric factors of the low- and high-energy channels (SpL and SpH, respectively) have been increased to (2.3×10^{-4}) and (3.0×10^{-4}) cm^2 ster, respectively. The omnidirectional geometric factor of the background tube SpB determined in flight from cosmic radiation is roughly 0.2 cm^2.

The angular field of view of SpL and SpH is about 6° in diameter, and the detector is cross-eyed by about 9°, with the fields of view converging in a plane containing both axes. The spectrometer is oriented in the payload so that this plane is the $\alpha = 90°$ plane, and the difference in azimuthal viewing angle does not matter.

The spectral discrimination of this detector is shown in Figure 8.

Integral magnetic spectrometer. This detector was designed very rapidly to study high-energy fission electrons injected into the geomagnetic field by the Starfish high-altitude nuclear explosion. Consequently, use was made of an electronics package and housing from the differential spectrometer.

There are three type 213 thin-window (1.2 mg cm^{-2}) Geiger tubes in a lead cylinder with 3.5 g cm^{-2} lead shielding. Two of them have 45 mg cm^{-2} of aluminum end windows (same as detector 3, so as to have similar proton contributions), with apertures between the poles of two magnets. These magnets act as brooms to sweep away electrons with energy less than ~1.5 Mev (detector 20), and less than ~3 Mev (detector 21). Directional geometric factors are $(1.1 \pm 0.4) \times 10^{-3}$ cm^2 ster. The third Geiger is a thin-windowed tube similar to the other two and serves the same function as SpB in monitoring background radiation and bremsstrahlung.

The dc scintillator. This was designed primarily for outflux and auroral studies, so as to detect very-low-energy electrons and protons.

The scintillator is a thin disk ~20 mg cm^{-2} thick of cesium iodide, under a nickel foil 1000 A (~100 μg cm^{-2}) thick which shields it from light. The foil attenuates light by ~10^5. The photomultiplier is an Ascop-type 541A, as in the photometers, and it is run from a 2500-volt power supply, with an analog-to-digital neon flasher circuit taking the output to the accumulators, as with the Injun 1 photometer.

The detector responds linearly to energy loss in the crystal up to about 400 cps, and then the curve of apparent counting rate versus energy

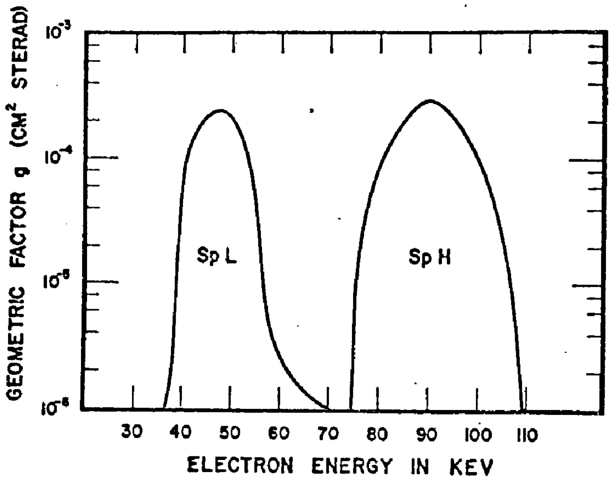

Fig. 8. Spectral passbands of the Injun 3 differential magnetic spectrometer.

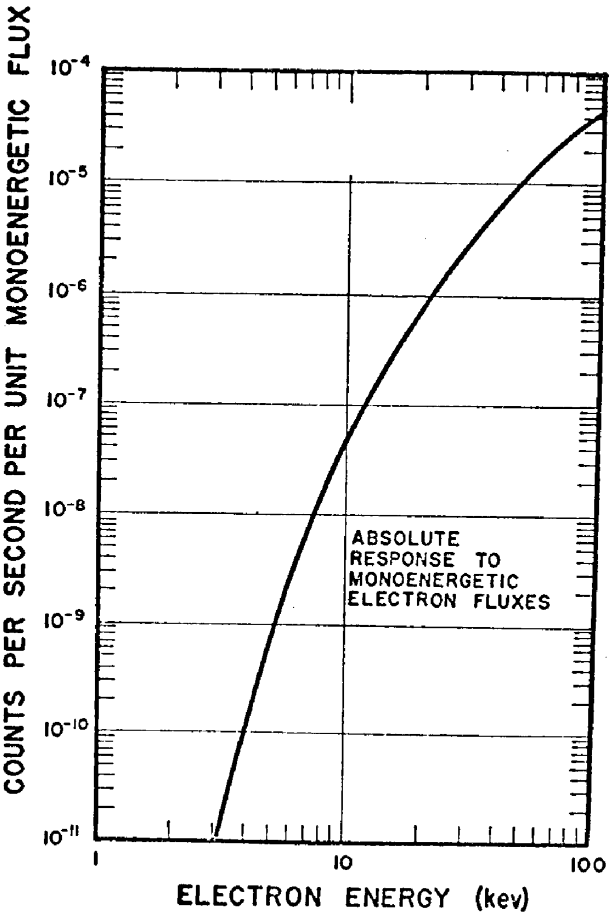

Fig. 9. Response of the Injun 3 dc scintillator to monoenergetic electrons. The reciprocal of the ordinate is the flux of electrons (of energy E) in particles cm^{-2} sec^{-1} $ster^{-1}$ required to give 1 cps from the detector.

loss breaks rapidly. The effective dynamic range is from $\sim 10^{-2}$ to 10^3 ergs cm^{-2} sec^{-1} ster of electrons with energy $E_e \gtrsim 5$ kev and protons with energy $E_p \gtrsim 50$ kev. The response to electrons is shown in Figure 9.

The angular field of view has a diameter of ~20°. The response to ~50-kev electrons incident at ~40° to the axis of the field of view is less than 10^{-3} of that parallel to the axis.

The geometric factor is 1.4×10^{-2} cm^2 ster. Omnidirectional shielding, except over the aperture, is ~4 g cm^{-2} of lead or stainless steel.

Electrons with energy as low as ~5 kev are detected with low but finite efficiency (see Figure 9).

Electron multiplier. This detector is similar to the Ascop 541A photomultiplier except that it lacks a photocathode, and instead is open-ended. A charged particle striking the first dynode produces secondary emission, and the cascade in the subsequent dynodes under 2500 volts accelerating potential causes an over-all gain of about 2×10^5. The anode current is converted to digital pulses as in the dc scintillator and the photometers [*Stilwell*, 1963].

Although this detector can respond to particles with energies of only ~100 ev, we decided to place before it a nickel foil 1000 A thick as in the dc scintillator. The field of view and geometric factor (~20° diameter and $\sim 10^{-2}$ cm^2 ster) are also roughly similar to those of the dc scintillator. The detector responds with efficiency constant to ~50 per cent to electrons with energy $E_e \gtrsim 10$ kev, and the efficiency drops by 10^4 for $E_e \sim 3$ kev. Its response to electrons is shown in Figure 10.

This detector is intended to give total number flux. With the dc scintillator giving total energy flux, an average energy can be calculated. The foils ensure that only electrons or protons with sufficient energy to penetrate through the atmosphere to an auroral altitude of ~100 km are detected.

The p-n junction detectors. There are four detectors in all, being in two pairs pointing at right angles to one another. Each has its own

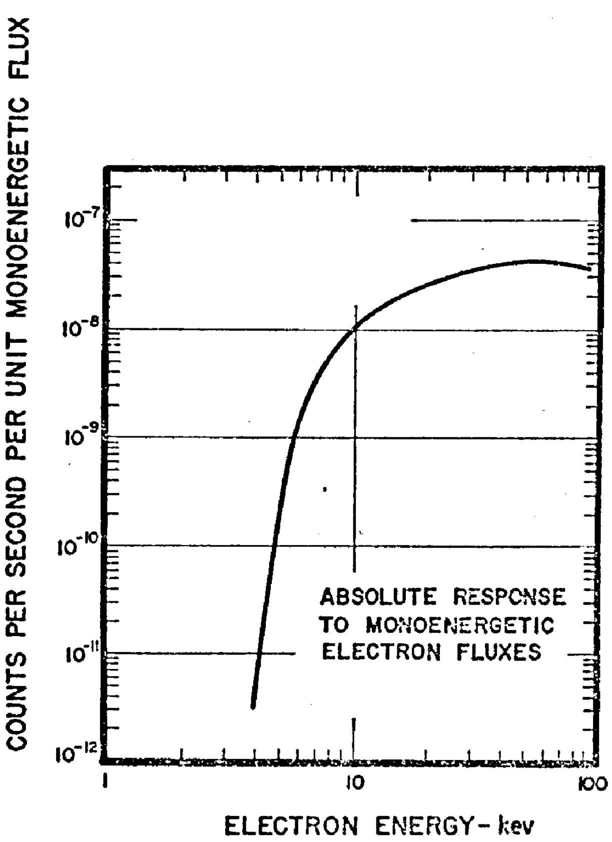

Fig. 10. Similar to Figure 9, being response of the Injun 3 electron multiplier to monoenergetic electrons.

amplifier, but since only one pair is sampled at a time, a common power supply and logic box are used.

Consider one pair. Each of the two detectors is about 0.8 cm in diameter having 500 microns thick fully depleted active regions. The two are in a coincidence array, with pulse length of 2 μsec prior to discrimination. Two electronic biases are set at 700 kev and 2 Mev, and the front aperture is covered by 2.6 mg cm^{-2} of aluminized mylar.

Six signal leads come from each pair. These correspond to the conditions A_1B, A_2B, $A_1\bar{B}$, $A_2\bar{B}$, $\bar{A}_1B$, and $\bar{A}_2B$, where the subscript 1 or 2 refers to a pulse triggering the 700-kev discrimination level or the 2-Mev one, respectively, and where the bar indicates no satisfactory (i.e., triggering) signal in the detector. For detector B, only the 700-kev discrimination level is set.

The signals correspond to:

$A_1\bar{B}$	Proton 1.2 to 2.2 Mev
$A_2\bar{B}$	Protons 2.2 Mev $\leq E_p \leq$ 8 Mev
A_1B	8 to 24 Mev
A_2B	24 to 100 Mev
$\bar{A}_1B$	Background
$\bar{A}_2B$	Background

Magnets before the apertures have a 2400-gauss field over a gap 1/4 inch by 1/4 inch wide and 3/8 inch deep, sweeping away electrons with energy below ~200 kev.

The front aperture is about 0.5 cm by 0.5 cm, and the directional geometric factor for $A_1\bar{B}$ and $A_2\bar{B}$ is about 0.016 cm^2 ster, whereas that for A_1B and A_2B is about 0.0045 cm^2 ster.

Shielding elsewhere is at least 3.5 g cm^{-2} of copper, being increased to ~5 g cm^{-2} on the sides of the detectors themselves and to ~12 g cm^{-2} at the back of detector B.

Each channel is given its own accumulator of twelve bits, and all six of a pair are gated on for 1 sec at the start of 16 frames simultaneously and read out over a subcommutation interval of 16 frames in system A. Then the next pair is sampled, and so on. The detectors are not sampled in system B.

The photometers. The three photometers are similar in design to that on Injun 1, frustrated by the nonseparation of Greb, and on Injun 2, frustrated by the launch malfunction.

Each consists of an Ascop-type 541A photomultiplier operated at 2500 volts, a single ~3-inch focal length lens and an interference filter 2 inches in diameter. The anode signal is converted to a digital pulse by a neon flasher circuit as in Injun 1 et seq.

The two photometers to survey the northern hemisphere have filters with peak transmission at 5577 A (detector 16) and 3914 A (detector 17). The one for the southern hemisphere (detector 18) has a 5577 A filter. All filters are wide, about 50 A wide to half-peak transmission, so as to minimize any temperature characteristics. All count at some 100 cps for 1 kR of the relevant emission, and, with the satellite temperature as cool as planned, this is generally 2 orders of magnitude above the thermal dark current.

The fields of view are about 10° in diameter.

VLF experiment. Two properties of very-low-frequency electromagnetic emissions are measured with two VLF receivers fed by the same loop antenna.

The antenna consists of 50 turns of #16 copper wire in a 12-inch diameter loop parallel to the equatorial plane of the satellite (~horizontal at launch).

One receiver amplifies the signal and feeds it through an attenuation of 0, 20, or 40 db into a set of six magnetostrictive filters. Each is 50 cps wide with attenuation of 12 db per octave of filter bandwidth and with peak transmission at 700 cps, 2.7 kc/s, 4.3 kc/s, 5.5 kc/s, 7.0 kc/s, and 8.8 kc/s. From each output the signal is taken to an analog-to-digital converter with four bits output. Each VLF channel thus produces counts of 0 to 15, the larger number corresponding to the smaller signal. A given attenuator is operative for 32 sec at a time, or it can be eliminated on command from Iowa City. The dynamic range with a given attenuator in place is about 40 db. The output signal is proportional to the *minimum* signal seen in each channel since the previous sample was taken.

The second amplifier is used to modulate the transmitter (in system A only) so as to obtain frequency information. A low-pass filter restricts the passband to below ~7 kc/s. The modulation is kept constant with an automatic gain control (AGC) whose output is monitored as a measure of the total power between ~500 cps and ~7 kc/s.

Magnetometers. The two Schonstedt flux-gate magnetometers are mounted with axes parallel to $\theta = 90°$ and $\theta = 130°$.

Calibration was made in the controlled magnetic field at the Naval Ordnance Laboratory. The stray magnetic field from the payload was minimized in each sensor with an adjustable trimming magnet. The sensors give linear response for fields ranging over 0.4 gauss, with good resolution over twice this range. The midpoint of each detector characteristic was chosen so as to be the midpoint of the operating range when the satellite oriented.

Optical aspect sensors. There are five of these sensors, each of which is a simple photodiode with a transistor amplifier to give a yes-no (1 or 0) output, depending on whether the sun is in the field of view or not.

Two pairs of sensors are set with optical axes parallel to detectors 1 and 4 so as to monitor for solar X-ray contamination of the open-ended Geiger tubes. One of each pair has a field of view of $\sim 30°$ diameter, the other $\sim 5°$ diameter for occasional calibration in flight of the magnetometers. The fifth detector has a field of view $\sim 80°$ in diameter and looks in the same direction as detector 5.

These sensors do not respond to moonlight and earthlight.

Housekeeping parameters. The two payload voltages are monitored in system *A*. The temperatures of the photometer detector 16 and the dc scintillator are monitored in system *A*. No housekeeping parameters are monitored in system *B*.

CALIBRATION CHECKS IN FLIGHT

The large array of particle detectors on Injun 3 was chosen so as to provide cross checks in flight of analysis of particle fluxes. For example, the electron fluxes can be found uniquely with the electron spectrometers, and the proton fluxes with the *p-n* junction proton spectrometers, and the results cross checked with the Geiger counters which measure the sum of electron and proton fluxes. Consequently, the in-flight performance of the detectors can be checked against preflight calibrations to an extent relatively unusual in satellite studies.

During the first few weeks after launch when the satellite spun rapidly, the relative geometric factors of the detectors 1, 4, and 5 could be ascertained in flight on many occasions when they viewed identical particle fluxes. Such examples occurred, for instance, when they all were pointed at right angles to **B**. The relative geometric factors in flight agreed to within about 20 per cent of the preflight calibrations.

Some differences were noted in Geiger counters 1, 4, and 5 between preflight peak counting rates and in-flight peak rates. Accordingly, new curves of true versus apparent counting rates were devised for these Geiger tubes from flight data by comparing their high counting rates with the rates of other detectors operating over the linear part of their characteristics. This work is still proceeding, and it is likely that the calibrations will be refined further in the future. The following treatment uses preliminary calibrations, and we therefore list below the nominal accuracy of these calibrations.

At present there is an uncertainty of a factor of about 2 for true counting rates above about 10,000 cps corresponding to particle fluxes above about 1.6×10^6, 10^6, and 2×10^5 particles cm^{-2} sec^{-1} ster^{-1} for detectors 1, 4, and 5, respectively. For true counting rates less than about 6000 cps, corresponding to particle fluxes of 10^6, 5×10^5, and 10^5 particles cm^{-2} sec^{-1} ster^{-1}, the absolute uncertainty in correction of apparent to true rates is about 20 per cent or less. The absolute geometric factors of the Geiger tubes are uncertain to about 20 per cent for detectors 1 and 4, and about 30 per cent for detector 5 (L. Frank and J. Craven, private communication). In general, a factor of 2 uncertainty in the absolute fluxes reported in the following papers will be the maximum likely error. Since particle fluxes being measured by any one detector such as a thin-windowed Geiger tube may vary over a range of one hundred million or so, we regard a factor of 2 uncertainty in absolute fluxes as being quite adequate for these preliminary studies.

Intercomparison of other detectors in flight will be made as necessary in the analyses in the following papers.

CONCLUSION

From the satellite Injun 3 there are received every day about one million measurements of some thirty parameters characterizing part of the geophysical environment at various locations in space. It will be our endeavor in this series to present preliminary analysis of selected parts of these data so as to justify the enormous human effort and the not-inconsiderable economic investment in Injun 3.

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