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CHARACTERISTICS OF THE THERMAL PLASMA MONITOR (SSIES) FOR THE DEFENSE METEOROLOGICAL SATELLITE PROGRAM (DMSP) SPACECRAFT S8 THROUGH S10

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This report provides an overview of the capabilities of the Special Sensor for Ions, Electrons, and Scintillation (SSIES), its operating modes, the data the instrument produces, and the programs used to process the data. This information is necessary to users of SSIES data, including scientists and the Air Force Geophysics Laboratory (AFGL), Regis College, the University of Texas at Dallas (UTD), and others.

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1. INTRODUCTION

This report provides an overview of the capabilities of the Special Sensor for Ions, Electrons, and Scintillation (SSIES), its operating modes, and the data it produces. This information is necessary to users of SSIES data, including scientists at the Air Force Geophysics Laboratory (AFGL), Regis College, the University of Texas at Dallas (UTD), and others.

The SSIES instrument consists of four sensors and associated electronics. The sensors are a planar ion retarding potential analyzer (RPA), a planar ion drift meter (DM), a planar total ion density trap (SM), and a spherical electron Langmuir probe (LP). The instrument measures in situ ion and electron temperatures or scale heights, the bulk flow velocity of the thermal plasma, the plasma density and its fluctuations, the ratio of light ions (H^+ and He^+) to O^+, and the differences between the drift velocities of the light ions and the drift velocity of O^+. SSIES will be flown on the Block 5D-2 Defense Meteorological Satellite Program (DMSP) spacecraft S8 through S10. These spacecraft travel in sun-synchronous, circular polar orbits at altitudes near 832 km in the topside ionosphere.

The purpose of the SSIES is to monitor the ionospheric thermal plasma, which affects Air Force communications and operations. The total ionospheric electron content (TEC) determines the phase delay of radio signals. The in situ plasma density and scale height measured by SSIES, together with other data sources which describe the lower ionosphere, are used to determine TEC on an operational basis. Density fluctuations near the peak density regions of the E and F layers cause scintillation of radio signals. SSIES measurements of density fluctuations at 832 km altitude can be related to these fluctuations at lower altitudes. The volume rate of joule heating is a function of the electric field and ionospheric conductivity. The electric field is proportional to the ion drift velocity. Electrostatic analyzer (SSJ/4) measurements of precipitating particle fluxes will be used as inputs to conductivity models. Thus, the SSIES and SSJ/4 measurements can be combined to calculate the rate of Joule heating of the lower ionosphere by currents driven by forces from the magnetosphere.

SSIES incorporates several new features which make it an improvement over its predecessor, the Special Sensor for Ions and Electrons (SSIE). Unlike SSIE, SSIES can sense differences between the spacecraft potential and the plasma potential and can keep the reference potential for the Langmuir probe and the ion detector apertures close to the plasma potential. This allows the measurement of ion and electron temperatures under a wide range of spacecraft conditions. Two of the sensors of the SSIES instrument, the drift meter and the total ion density trap or scintillation meter, are new to the DMSP satellites. The drift meter makes measurement of the plasma's bulk velocity and, hence, the convection electric field. The scintillation monitor measures the power spectrum of in-situ plasma density fluctuations. SSIES, unlike SSIE, is microprocessor controlled. The microprocessor performs on-board data reduction including calculation of the plasma potential. Because the instrument is microprocessor controlled, it has a wide selection of operating modes appropriate to different ionospheric and spacecraft conditions.

The environment in which the SSIES operates has three major ion species, O^+, H^+, and He^+. O^+ predominates. At mid-latitudes, nighttime ion temperatures usually are of order 1000° (.086 eV) and daytime ion temperatures of order 3000° (0.26 eV). Nighttime electron temperatures are of order 1200° (0.10 eV) and daytime electron temperatures of order 3500° (0.30 eV). Both ion and electron temperatures depend on local time, latitude, and magnetospheric activity. For an ion temperature of 2000°, O^+ has a thermal velocity of 1.4 km/s, He^+ 2.9 km/s, and H^+ 5.7 km/s. At 2000°, the electron thermal velocity is 240 km/s. Plasma densities usually are between 10^3 and 10^6 cm^{-3}.

The instrument is designed to operate well when densities and temperatures are within these ranges. A density of 10^3 cm^{-3} is necessary to provide ion currents large enough to be measured by the three ion sensors, and to provide Debye shielding of the ion apertures and the Langmuir probe from spacecraft potentials at normal plasma temperatures. Plasma densities greater than 10^6 cause saturation of the instrument electronics. Intense fluxes of electrons with energies large enough to pass through the ion collectors' suppressor grids may occasionally contaminate the ion measurements. For an electron temperature of 25 eV, a density > 100 electrons cm^{-3} or flux > 10^{10} cm^{-2} s^{-1} is required to cause problems.

The design, development, construction and testing of the SSIES instruments is a joint project of the Air Force Geophysics Laboratory, the University of Texas at Dallas, Regis College and Analytyx Electronics Inc. After completion of the hardware, the SSIES instruments are delivered to RCA AstroElectronics, the DMSP spacecraft contractor. The prime sensor on the DMSP spacecraft is the Operational Line Scanner (OLS), constructed by Westinghouse Electric Corp., Defense Electronics Division.

2. THE DMSP SPACECRAFT

The DMSP spacecraft are a series of vehicles built and launched since the 1960's under the direction of the Air Force Space Division for the Air Force Air Weather Service (AWS). They are operated by AWS from Global Weather Central, Offutt AFB, NE as a service to the DoD community. The prime sensor for the spacecraft is the Operational Line Scan (OLS) system which makes high-resolution white-light and infra-red images of the earth's cloud systems. Other instruments which measure the tropospheric and space environment are included as payload capacity and operational needs allow.

The DMSP spacecraft are launched into a 832 km, 98.7° inclination circular orbit. The non-spherical terms of the earth's gravity field cause the orbit plane to precess so that the orbit plane always has the same orientation with respect to the earth-sun line; i.e. the orbit is sun-synchronous. The DMSP spacecraft have a planned lifetime on orbit of 3 years. Two functioning DMSP spacecraft are supposed to be on orbit at all times: one in the 6 a.m. - 6 p. , meridian plane and one in the 10:30 a.m. - 10:30 p.m. meridian plane. (The orbit in the 10:30 a.m - 10:30 pm plane often is referred to as a noon-midnight orbit.) Before launch, the spacecraft are referred to as "spacecraft number" 7 or S7 and after launch, they are referred to as "flight number" 7 or F7. Since the beginning of the current Block 5D series, the S number

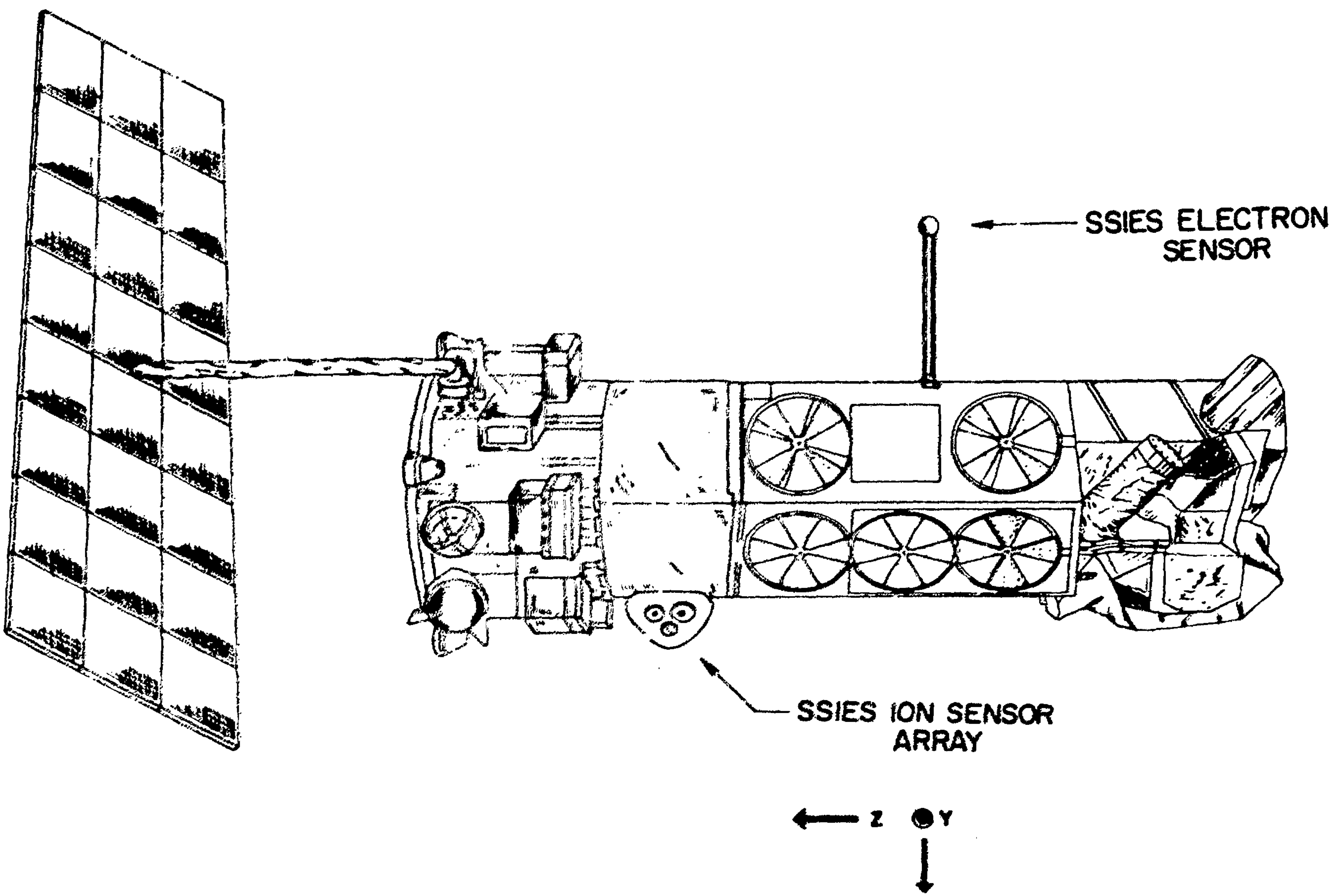


Figure 1: The DMSP S8 satellite.

and F numbers have been the same, but they may be different in the future. At this writing, F6 (launched in December, 1982) and F7 (launched in November, 1983) are functioning and S8, S9 and S10 are waiting for launch.

Figure 1 shows both the S8 spacecraft as it will appear in orbit and the spacecraft coordinate system. The solar panel is attached to a boom which points in the +Z direction, and the OLS is attached to the precision mounting platform at the -Z end of the spacecraft. Successful OLS operation requires that the spacecraft be three-axes stabilized. The X-axis points along the nadir and the Y-axis is parallel or anti-parallel to the spacecraft velocity vector. The Z-axis is normal to and on the sunward side of the orbit plane. In the primary operating mode, this orientation is maintained to within 36 arc-seconds. In an allowed secondary mode, the attitude tolerance is 140 arc-seconds.

The SSIES ion sensors must face the ram direction. Figure 1 shows the ion sensors mounted on the +Y surface. This is the standard placement, used when the ascending node of the orbit is in the morning or noon sector. If a DMSP spacecraft is launched with the ascending node in the evening or midnight sectors, the SSIES ion sensor array will be mounted on the -Y surface. The ion sensors are on a spacecraft surface which may bend and flex slightly, but due to the tight spacecraft attitude requirements, they are always within 0.5° of their preferred orientation.

The solar array must face the sun. The solar array boom is parallel to the +Z axis; the array's long axis is perpendicular to the boom; and the short axis make a 60° angle with the boom. The solar array rotates 360° on its boom about the Z axis. For a noon-midnight orbit, the solar array is always perpendicular to the earth-sun ecliptic plane, and thus it rotates 360° per orbit in spacecraft coordinates. For a dawn-dusk orbit, the solar array angle with respect to the ecliptic changes with season. As a result of the changing aspect of the solar array in spacecraft coordinate, the tip of the solar panel is forward of the SSIES ion sensor array twice per orbit.

The glare obstructor (GLOB) is not shown in Figure 1. This is a pair of panels which hang down (in the +X direction) from the +X surface. The panels are attached to the middle of the spacecraft and make approximately a 45° angle with the X-Z plane. Thus the tip on one panel is slightly forward of the SSIES ion sensor array. The purpose of the GLOB is to prevent sunlight from reaching the optical instruments on the +X surface of the precision mounting platform. The GLOB is used only for dawn-dusk orbits; not for noon-midnight orbits.

The data from all space environmental monitors including SSIES are acquired by the OLS system and merged with the OLS data. The OLS system stores the data on tape recorders which are played back upon command from ground tracking stations. The playbacks occur at intervals of one to three orbits (100 to 300 minutes). The DMSP data system uses a 36 bit word. The SSIES sends data to the telemetry system in 9 bit words.

3. THE SSIES INSTRUMENT

Figure 2 is a block diagram of the SSIES sensors, electronics packages and electrical system. The instrument has four sensors, labeled on the diagram as drift meter (DM), ion SM (scintillation monitor), RPA (ion retarding potential analyzer), and electron sensor (Langmuir probe, or LP). The first three of these measure ions and are mounted in a common ground plane (shown in Figure 1) which is electrically connected to the ion sensors' aperture grids. The ion sensors with the ground plane are shown in Figure 3.

The planar ion sensors are designed so that all ions falling on the aperture will be collected on a plate behind the aperture unless blocked by a grid wire or by an electrostatic potential and all thermal electrons falling on the aperture will be electrostatically blocked from reaching the collector plate. The scintillation monitor and the RPA have circular apertures and collecting plates. The drift meter has a square aperture and a circular collector divided into four quadrants. In all the ion sensors, the wires of various grids physically block a few ions. In the case of the SM, all ions which do not strike a grid wire reach the collector. When the drift meter is in normal mode, internal grid biases may be set so that all ions which do not strike a grid wire reach a segment of the collector, or so that a fixed retarding voltage excludes light ions. The threshold energies required to

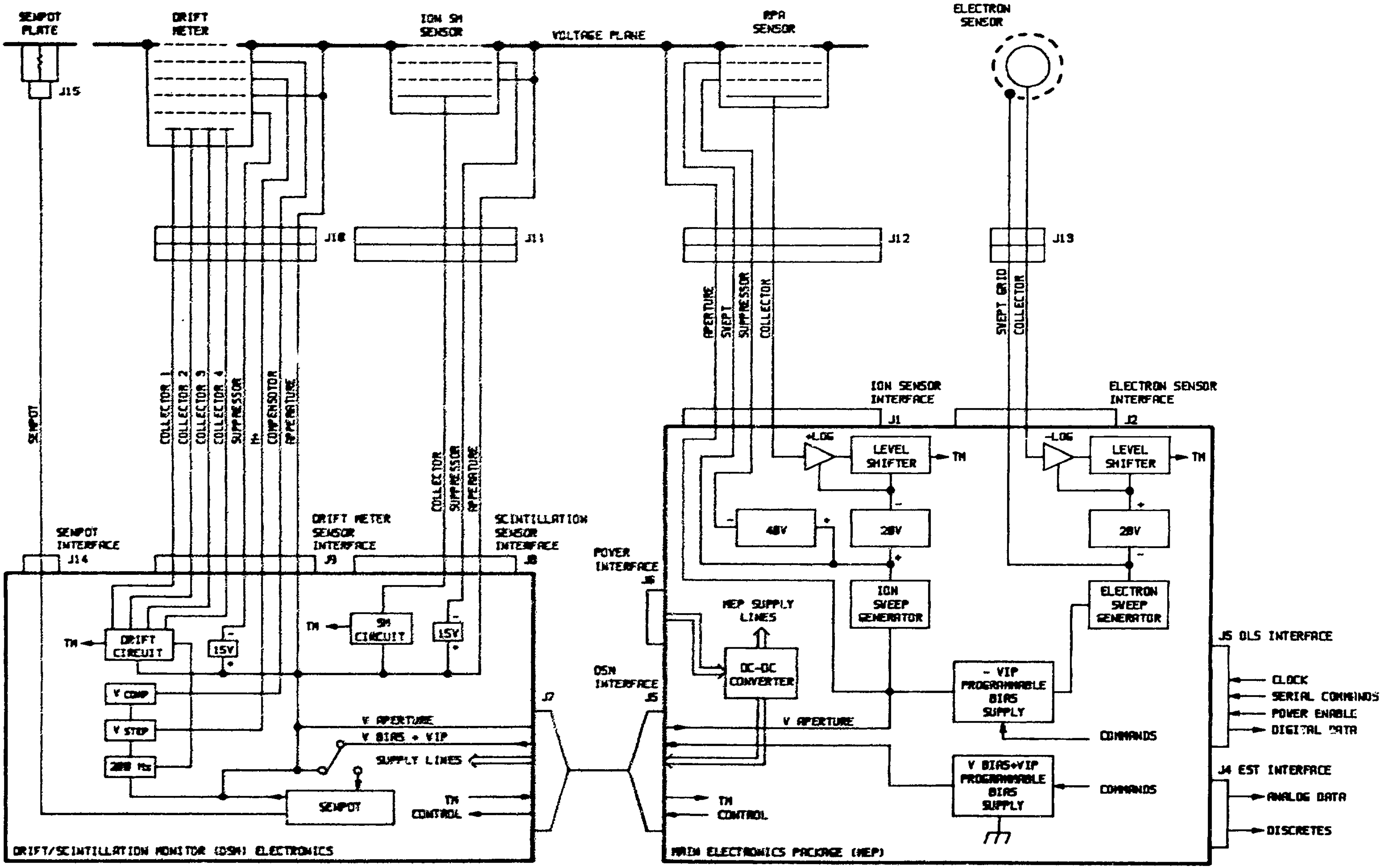


Figure 2:

SSIES/S9 AND S10
FUNCTIONAL / ELECTRICAL
SYSTEM BLOCK DIAGRAM

reach the collector of the RPA or that of the drift meter in H^+ mode are systematically varied by changing the retarding voltages applied to the sensors' internal grids.

The Langmuir probe is a spherical collector surrounded by a spherical grid. A Langmuir probe unit for the SSIES-2 instrument is shown in Figure 4. The SSIES Langmuir probe is nearly identical. The Langmuir probe is mounted on a boom on the -X surface of the DMSP spacecraft. The spherical grid physically blocks a few ambient electrons and is a source of photoelectrons which can reach the collector. The potential of the grid is swept from positive to negative with respect to the plasma. At positive voltages, the Langmuir probe draws current from the plasma, while at negative voltages, some electrons are electrostatically excluded from the collector. The potential of the spherical collector is maintained high enough to collect all thermal electrons which pass through the grid and to exclude thermal ions.

The drift meter determines the components of the plasma flow velocity along two axes perpendicular to the spacecraft's velocity vector. The scintillation monitor measures total ion density and the power spectrum of density fluctuations with scale sizes from 1 m to 100 km. The ion RPA data are used to determine the temperatures, masses and densities of the different ion species present, their velocities parallel to the spacecraft's direction of motion, and the spacecraft potential. Data from the Langmuir

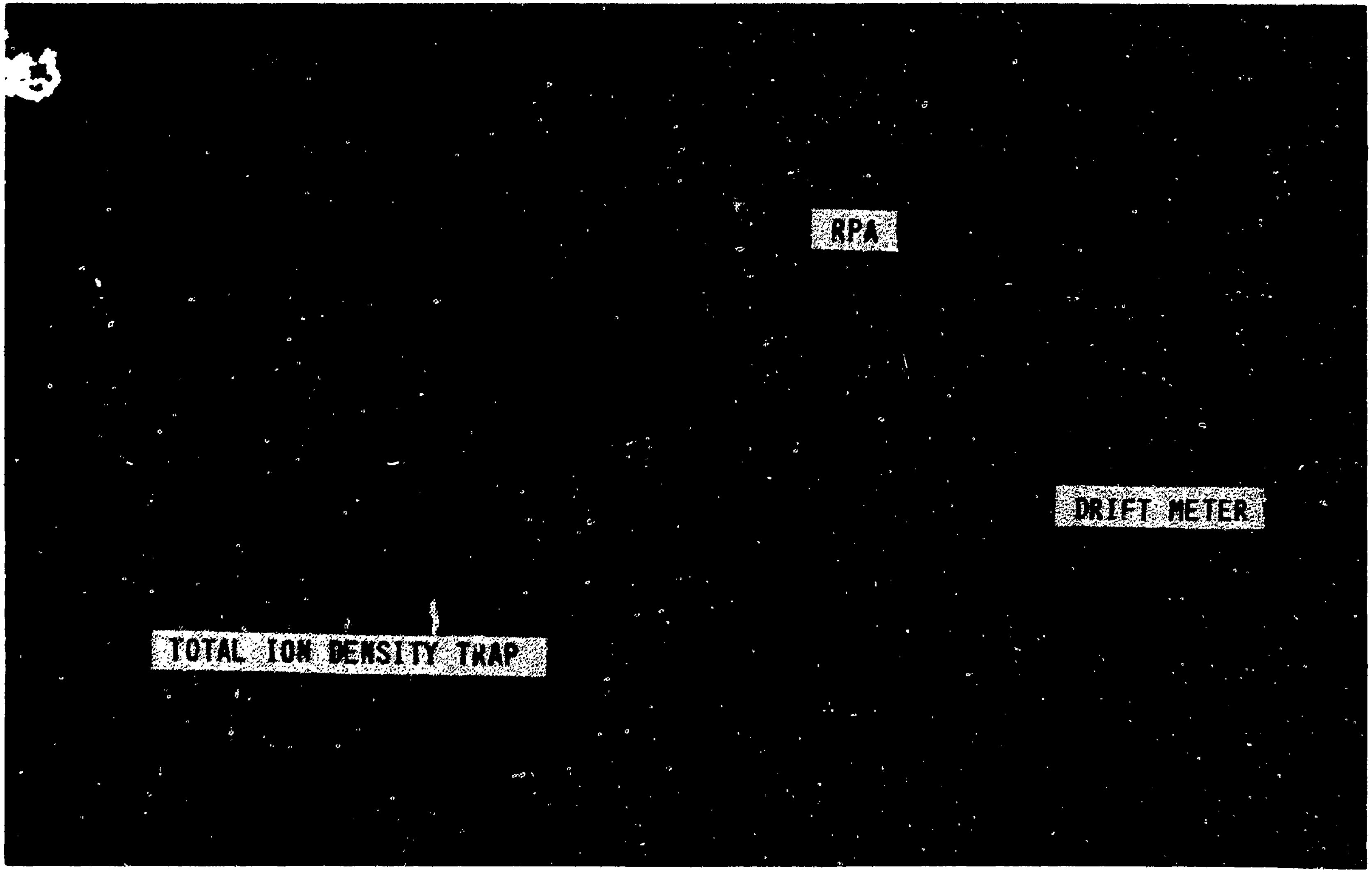


Figure 3: Ion sensor array

probe are used to determine the electron temperature and density and the spacecraft potential. The data handling and control systems are not shown in Figure 2. These sensors are controlled and the data collected by a Texas Instruments SBP9900A microprocessor which also analyzes data from the ion RPA and electron Langmuir probe.

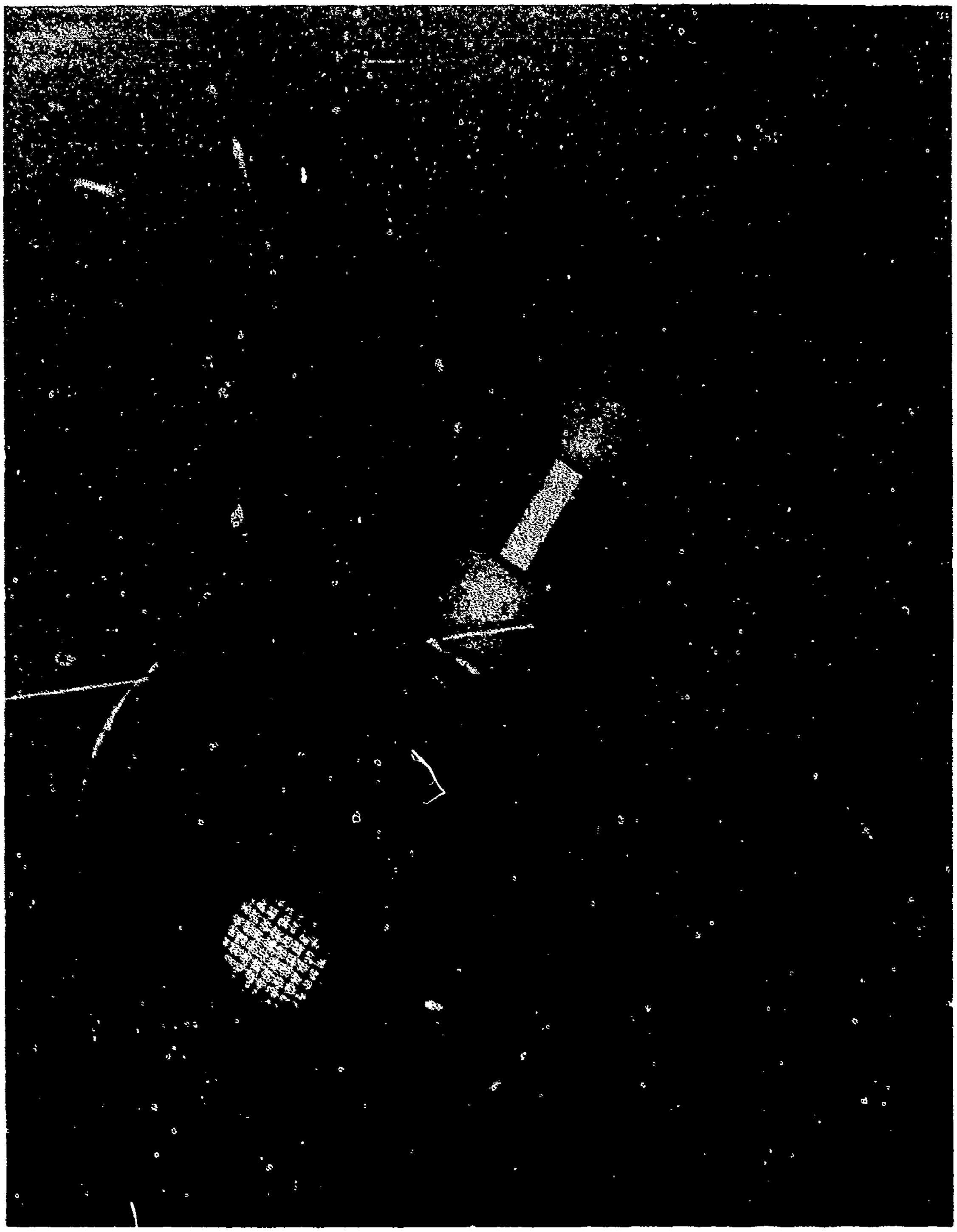


Figure 4: Langmuir probe

3.1. ION DETECTOR THEORY

Although the designs of the three SSIES ion sensors have been optimized for the determination of different ionospheric parameters, all three measure the current from the ambient plasma to planar surfaces. The same concept is involved in calculating the geophysical parameters from the current measured by the three sensors. This concept is that the current collected depends in a known manner on the distribution functions of the different ion species present, on the spacecraft velocity, and on the maximum electrostatic potential barrier between the ambient plasma and the collector plates. Information about these quantities is extracted from the current measurements.

The three detectors have gridded apertures electrically connected to the common aperture plane shown in Figure 3. The sensors and aperture plane are designed to make the apertures behave as if they are part of an infinite equipotential plane. The electric field of an infinite conducting plane affects only the component of ion motion normal to the plane. When the infinite plane approximation is valid the electrostatic potentials of the SSIES ion aperture plane and the ion sensors' grids affect only the motion of ions parallel to the spacecraft Y axis, which is perpendicular to the aperture plane. Ions with trajectories normal to the aperture plane are not deflected toward or away from the sensor apertures. As long as the potential of the aperture plane remains ≤ 0 with respect to the plasma, changes in the aperture potential do not change the total current to the apertures. In flight, the aperture potential should be between 0 V and approximately -2 V with respect to the plasma. Under these conditions, the infinite plane approximation is valid. A strong (tens of volts) negative potential would focus ions toward the aperture plane and increase the current to the sensors.

When there is a retarding potential with maximum value $\phi > 0$ between the aperture plane and an ion sensor's collector, the ion current to the collector plate is a function of ϕ:

$$I(\phi) = A\, a \sum_i q_i \int_{-(2q_i\phi/m_i)^{1/2}}^{\infty} dv_y\, v_y \int_{-\infty}^{\infty} dv_x \int_{-\infty}^{\infty} dv_z\, f_i(v_x, v_y, v_z) \qquad (1)$$

where

A = Area of collector accessible to ions

a = grid transparency

f_i = phase space distribution function for ion species "i" expressed as a function of velocities in the ambient plasma

m_i = mass of ion species "i"

N_i = number density of ion species "i"

q_i = charge of ion species "i"

v_r = bulk plasma ram velocity

= spacecraft speed plus component of ion drift normal to sensor aperture

(v_x, v_y, v_z) = ion velocity at aperture plate in spacecraft frame of reference

ϕ = maximum retarding potential which exists between the ambient plasma and the collector

The velocities in Equation 1 are in the spacecraft frame of reference. In Equation 1 the limits on the integral over v_y run from $-(2q_i\phi/m_i)^{1/2}$ to $-\infty$ because the y component of the velocity of an ion must be negative in the spacecraft coordinate system (shown in Figure 1) for the ion to enter an ion sensor aperture. An ion with velocity v_y in the spacecraft frame has velocity $v_y + v_r$ in the reference frame drifting with the plasma, so that $f_i(v_x, v_y, v_z)$, the phase space density expressed as a function of ion velocities in the spacecraft frame, is $f_i(v_x, v_y + v_r, v_z)$ expressed as a function of velocities in the drifting plasma frame.

When there is no retarding potential between the plasma and the collector plate the integral over v_y runs from 0 to $-\infty$. When the mean ion thermal speed is much less than the ram velocity,

$$I = A\, a\, v_r \sum_i q_i N_i \qquad (2)$$

This current is the current onto the scintillation meter collector plate at all times, onto the drift meter collector plates in the normal mode and on the RPA collector plate at zero retarding voltage.

If we replace the arbitrary distribution function in equation (1) with the Maxwellian distribution, we will obtain the same formula for $I(\phi)$ and for $dI/d\phi$ as given by Rich and Heelis (1983). Figure 5a shows the theoretical ion current collected I as a function of retarding voltage ϕ in a Maxwellian plasma with two ion species, O^+ and H^+, with the same temperature. Figure 5b shows the theoretical $dI/d\phi$ as a function of ϕ. In Figure 5a, $I(\phi)$ is plotted as a solid line. The dashed line shows the O^+ contribution to the total current in the voltage range where the H^+ current is significant. In Figure 5b, $dI/d\phi$ is plotted as a solid line, and the H^+ and O^+ Maxwellian distribution functions for speed $v = v_r - (2q_i\phi/m_i)^{1/2}$ are plotted as dashed lines. Note from Equation 1 that for Maxwellian distribution functions $dI/d\phi$ is proportional to $-\Sigma\ (q_i{}^2/m_i)\ f_i[v= v_r-(2q_i\phi/m_i)^{1/2}]$ where v is the ion speed in the plasma. Assuming the sensor potential is 0 V with respect to the ambient plasma and $v_r = v_{s/c} = 7.44$ km/sec (no bulk plasma motion), the minima in the derivative curve in Figure 5 are at 0.29 V due to the peak of the H^+ distribution function and at 4.6 V due to the peak of the O^+ distribution function. A negative (accelerating) aperture potential would increase the

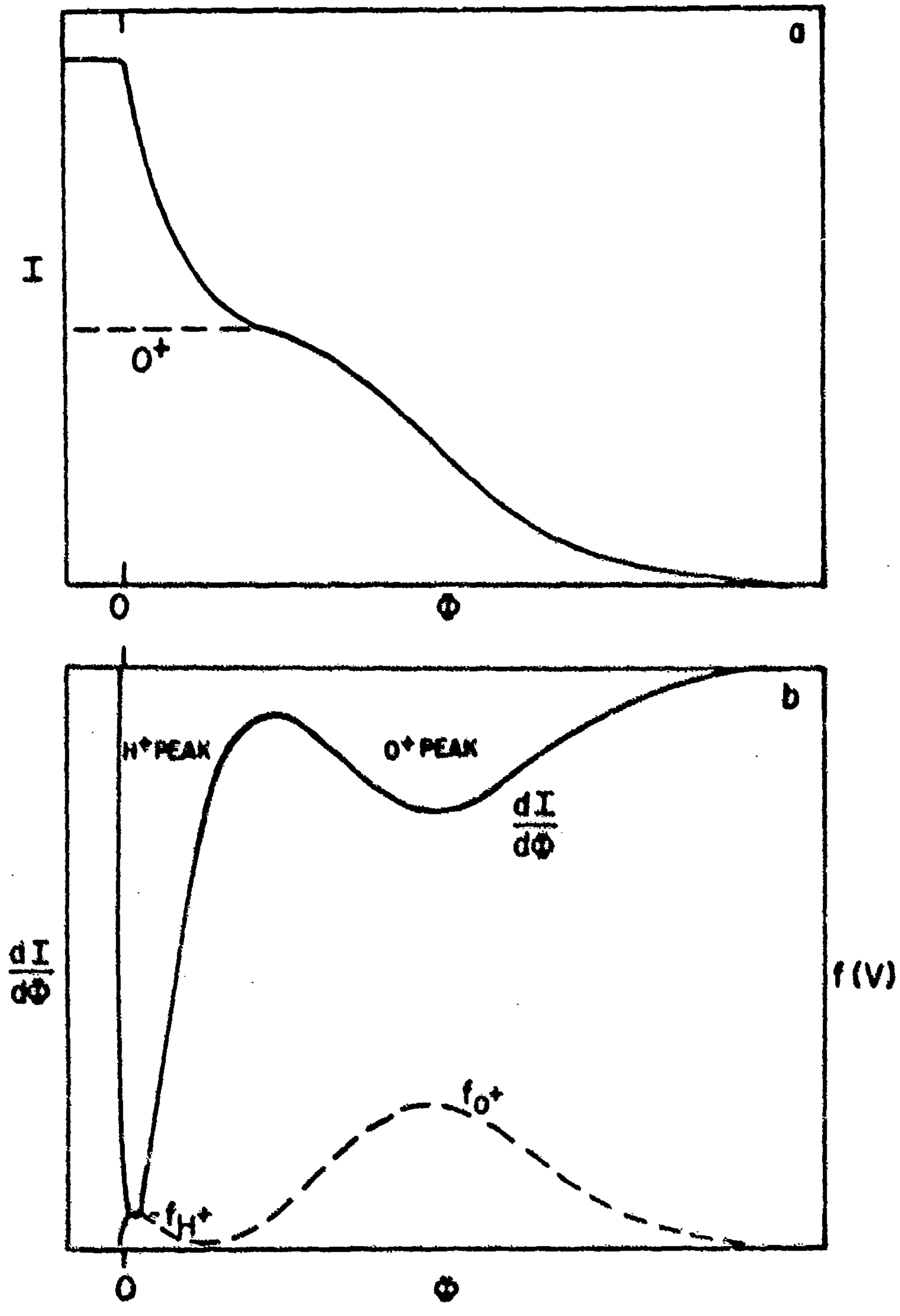


Figure 5: a. Theoretical current I versus retarding voltage Φ for an RPA in a Maxwellian plasma. b. Solid Line: Theoretical $dI/d\Phi$ curve for an RPA in the Maxwellian plasma of Figure 5a. Dashed Line: Maxwellian H^+ and O^+ distribution functions $f_i(v)$ where $v = v_r - (2q_i\Phi/m_i)^{1/2}$.

voltage of the two minima equally. A bulk motion of the plasma along the Y-axis would change the difference in voltage between the two minima.

Both the ion RPA and the DM in H^+ mode measure ion current as a function of variable retarding voltages. The RPA sweeps a retarding voltage upward over a 4 second interval and measures the ion current collected versus retarding voltage. The result is a set of current versus retarding voltage curves similar to the one shown in Figure 5a. These curves are analyzed to determine ion density N_i, ion temperature T_i, ion mass m_i, the Y component of the bulk plasma motion, and the potential of the sensor aperture with respect to the ambient plasma. In H+ mode, the ion drift meter operates by rapidly oscillating the retarding voltage around a base level which is slowly stepped upward. The quantity measured depends on the magnitude of the oscillation and the electronic processing of the current collected. The fluctuating currents resulting from small oscillations in the retarding voltage are processed to give an analog measurement of $dI/d\phi$ versus ϕ at several points which lie on a curve similar to the derivative curve of Figure 5b. The current fluctuations produced by large oscillations in the retarding voltage are used to measure the perpendicular drift of the light ion component of the plasma which produces the sharp peak in the derivative curve of Figure 5b.

Equations 1 and 2 are excellent approximations when the infinite aperture plane approximation holds and when v_r is much greater than the thermal velocities and perpendicular drift velocities of the ion species. This is true for the RPA, the scintillation meter, and the drift meter in normal mode, but not for the drift meter in H^+ mode. In reality, the range of perpendicular ion velocities which have access to a point on a sensor's collector does not run from $-\infty$ to $+\infty$. This range depends on v_y and on location on the collector plate. Ions with grazing trajectories (large ratios of perpendicular to parallel velocity) do not have access to all points on a collector. However, because the spacecraft velocity is much greater than the drift velocity or the mean ion thermal velocity, most ion trajectories are nearly perpendicular to the aperture plane.

The RPA and scintillation meter have been designed to minimize position dependence and maximize the range of arrival angles with which ions reach their collector. The drift meter uses the variation in ion access to its collectors with v_x/v_y and v_z/v_y to measure perpendicular velocities. However, as long as the spacecraft velocity is much greater than the thermal velocity, Equations 1 and 2 are valid if A is set equal to the area of the collector accessible to ions with $v_y = -v_r$ and perpendicular velocity equal to the perpendicular drift velocity. For H^+ and He^+, thermal velocities are comparable to the spacecraft velocity. Therefore, Equation 1 is not accurate for the drift meter in H^+

mode. Either a complex calculation or a cross calibration of the light ion drift signal with the O^+ drift measurement is necessary to obtain light ion drift measurements.

3.2. THE DRIFT METER

The SSIES drift meter (DM) was designed at the University of Texas, Dallas. In physical design, it is identical with the drift meter flown on the HILAT satellite (Rich and Heelis, 1983) and very similar to the drift meters flown on Dynamics Explorer B (Hanson et al., 1981) and on the Atmospheric Explorer satellites (Hanson et al., 1973). The measurement techniques used in the SSIES drift meter have been described in detail by Holt (1984). The DM measures the two components of the plasma drift velocity perpendicular to the instrument's direction of motion. The drift meter is designed to operate in a plasma containing O^+, He^+, and H^+. At 2000°, their thermal velocities are 1.4 km/s, 2.9 km/s, and 5.7 km/s respectively, all less than the DMSP spacecraft velocity of 7.44 km/s and greater than the typical plasma drift velocity (zero to 2 km/sec).

The drift meter has two operating modes, normal mode and H^+ mode. Normal mode is intended to measure the average drift velocity of all ion species. The H^+ mode is intended to separate the measurement of the drift velocities of lighter ions, H^+ and He^+, from the total ion drift velocity which is dominated by O^+.

3.2.1. Normal Mode

In normal mode, the drift meter determines the components of the plasma drift velocity perpendicular to the aperture normal. It does this by measuring the difference in the currents to the top and bottom or left and right halves of its collector plate. The drift meter collector actually is divided into four quadrants which are aligned with the aperture so that the four plates meet directly below the center of the aperture. The connections between the four plates are switched electronically to form either a horizontal or a vertical pair of collector plates.

The telemetered normal mode data is proportional to the difference between the logarithms of the currents to the halves of the collector plate. To find this difference, the currents are measured with logarithmic amplifiers, and their outputs are input to a difference amplifier. The rezero and offset technique is used to cancel the effects of biases in the log amp outputs when those outputs are input to the difference amplifier. The telemetered data is the difference amplifier's output shifted to a range of 0.0 V to 5.10 V.

Under normal ionospheric conditions, the logarithm of the difference in the currents to the halves of the collector plate is proportional to v_x/v_y or to v_z/v_y. Here, (v_x,v_y,v_z) is the plasma drift velocity in the spacecraft frame. The plasma velocity parallel to the spacecraft velocity (or anti-parallel to the spacecraft velocity if the ascending node of the satellite orbit is in the dusk-evening sector) is v_y. The two perpendicular velocity components are v_x and v_z. If v_y is known, v_x and v_z can be determined. (See Rich and Heelis [1983] for the procedure.) In the spacecraft frame, $-v_y$ is the sum of the ion drift into the sensor and the spacecraft velocity. However, the ion drift is generally very small compared to the spacecraft velocity, and can be neglected in calculating perpendicular drifts during routine processing. The relationship between the currents to the collector plates and v_x/v_y or v_z/v_y is derived by assuming that the ions follow parallel trajectories within 25° of the aperture normal. This approximation is valid when the O^+ is the dominate ion species, as is normally the case along a DMSP satellite orbit.

At times, the plasma may have a substantial H^+ or He^+ component with thermal velocity comparable to the spacecraft velocity. To exclude such light ions, the drift meter has a repeller grid (the H^+ grid in Figure 2) which can be biased to a d.c. voltage of 1 V, 1.5 V, 2 V, 2.5 V, or 3 V above the aperture potential V_{AP}. O^+, which has a mean energy near 4.6 eV in the spacecraft frame of reference, will pass through the repeller grid, while H^+ and He^+, with mean energies near 0.29 eV and 1.2 eV, are excluded. The repeller grid is preceded by a compensation grid which is biased to keep the location and angle of incidence of ions which reach the collector as close as possible to their values in the absence of both grids. A shield grid precedes the collector, and returns ion velocities to their value at the sensor aperture. The suppressor gird electrostatically blocks ambient electrons from reaching the collector and drives photoelectrons from the collector plate back into the the plate.

3.2.2. H^+ mode

The goal of H^+ mode is to reject the large drift signal from O^+ ions and detect the much smaller drift signal due to the light ions. At DMSP's altitude, where collision frequencies are low, the ionospheric electric field causes thermal ions and electrons to convect perpendicular to the geomagnetic field with a drift velocity independent of mass or charge. However, in the polar regions, ions may flow upward along the magnetic field lines with mass-dependent velocities. The H^+ mode is designed to measure field-aligned flow velocities of light ions at high latitudes. This measurement is difficult to make because the light ions, H^+ and He^+, make up only a small fraction of the ion population in the high latitude regions and because the thermal velocities of these ions may be a large fraction of the spacecraft velocity. For these reasons, the light ion current collected by the drift meter is much smaller than the O^+ current.

The subtraction of O^+ current from total ion current is accomplished by modulating the light ion signal and synchronously detecting it. The drift meter repeller grid voltage is slowly stepped through a series of retarding voltages. The current to the collector is modulated by a small 200 Hz (100 Hz for DMSP S8) square wave voltage (referred to as a "wiggle") to the retarding grid voltage. The current from each half of the collector plate is input to a synchronous detector. The output of each synchronous detector is proportional to the amplitude of the part of the input signal which shows a 200 Hz modulation.

The result is that only the portion of the ion current I for which $dI/d\phi \neq 0$ is detected (see Figure 5). When the d.c. step voltage on the repeller grid is close to the mean energy of the light ions, a large portion of the light ions alternately will be allowed to pass and will be blocked from reaching the collector by the wiggle potential. Since the sum of the step voltages and the a.c. "wiggle" voltages are too small to affect the O^+ ions, the O^+ current will not be modulated, and will not be detected. The size of the current detected will depend on the value of the d.c. voltage and the wiggle voltage. When the d.c. potential is approximately equal to the mean energy of the light ions, $dI/d\phi$ will be maximum and the detected current will be maximum. When the wiggle voltage is small compared to kT_{H^+}/e, only a small portion of the light ion current will be detected. When the wiggle voltage is large compared to kT_{H^+}/e, most of the light ion current will be detected.

Because the light ion species, plasma potential, and the downrange drift velocity are unknown, the light ion mean energy in the spacecraft frame of reference cannot be determined in advance. To insure setting the repeller grid voltage close to the light ion mean energy, the H^+ mode employs a 4 second cycle during which both the repeller grid d.c. voltage and the wiggle voltage are varied. During the first and second seconds, data is collected for determination of the vertical light ion drift. During the third and fourth second, data is collected for determination of the horizontal light ion drift. As in normal mode, twelve measurements are made each second. A initial DC voltage of 0, 1, 2, or 3 V for the repeller grid is selected by command. For the first two measurements of each second, no wiggle voltage is applied and two normal drift measurements are made, one horizontal and one vertical. For the third through twelfth measurements, the 200 Hz (100 Hz for S8) modulating voltage is added. The repeller grid d.c. voltage is increased by 0.2 V after each measurement from the third to the twelfth sample. At the end of a second, the modulating voltage is removed, the repeller grid voltage is returned to its original value, and the grid voltage cycle is repeated.

The goal during the first and third seconds of a four second H^+ mode cycle is to identify the light ion mean energy. During these seconds, a small amplitude is selected for the modulating square wave applied to the repeller grid, so the synchronously detected signal from each half of the collector is proportional to the derivative, $dI/d\phi$. The signal from one half of the collector is output to the telemeter. The voltage at which the signal has its maximum identifies the minimum of $dI/d\phi$ and the light ion mean energy. The first and third seconds of a 4 second H+ mode cycle are referred to as the H+DERIV mode.

During the second and fourth seconds of the H^+ mode cycle, the aim is to measure the light ion drift velocity. A larger modulating voltage is applied to the repeller grid, so that when the grid d.c. voltage equals the mean light ion energy, the signal from each synchronous detector is proportional to the light ion current to half of the collector plate. During the ten light ion measurements, the telemetry is proportional to the difference in the logarithms of the modulated signals from the two halves of the collector plate. The exact relationship between the telemetry and the light ion drift velocity cannot be determined before launch. The relationship will be found from flight data by using the fact that the horizontal drift velocity of the light ions is the same as that of O^+. The second and forth seconds of the 4 second H+ cycle are referred to as the H+DS mode.

Table I shows the H^+ mode four second cycle with the twelve measurements made each second. The beginning of this cycle is indicated by inserting the value 511 (all 1's in a binary 9 bit word) in word 60 of the SSIES data format (see section 4). In the table, horizontal measurements are marked with an "H" and vertical measurements with a "V". During the first two measurements of each second, the horizontal and vertical drift velocities of the total plasma are measured as in normal mode. During the final 10 measurements of a second, the repeller voltage is modulated with a 200 Hz (100 Hz for DMSP S8) square wave. There are two choices for modulation amplitudes, WIGLO, and WIGHI. If WIGLO is selected, the modulation is 50 mV for H^+DERIV measurements, and 400 mV for H^+DS measurements. If WIGHI is chosen, the modulation is 100 mV for H^+DERIV measurements, and 800 mV for H^+DS measurements. To avoid changes in H^+DERIV or H^+DS due to changes in the O^+ arrival angle as the repeller grid voltage changes, the drift meter compensation grid is biased in the opposite sense from the repeller grid, and its bias is modulated 180° out of phase with the repeller grid modulation.

TABLE I: H^+ MODE 4 SECOND MEASUREMENT CYCLE

Sample #	Cycle A	Cycle B	Cycle C	Cycle D
1	H	H	V	V
2	V	V	H	H
3	H^+DERIV (V)	H^+DS (V)	H^+DERIV (H)	H^+DS (H)
4	"	"	"	"
5	"	"	"	"
6	"	"	"	"
7	"	"	"	"
8	"	"	"	"
9	"	"	"	"
10	"	"	"	"
11	"	"	"	"
12	"	"	"	"

3.2.3. Drift Meter Data Reduction

Twelve drift meter measurements are made every second. Because H^+ mode is experimental and requires in-flight calibration, there is no routine procedure for converting raw H^+ mode data into velocities. In normal mode, the connections to the collector quadrants are switched immediately after each sample from the difference amplifier is obtained. The timing of the samples is related to the sample location in the SSIES data format (see Section 4). To a reasonable approximation, the samples are uniformly spaced in time and a Fourier analysis of the flight measurement can be done. The switching of the connections to the quadrants results in 6 horizontal and 6 vertical measurements of the ion drift per second.

The data analysis software at AFGL (see Section 5) gathers one minute of drift meter data into an array called DRIFT(12,60). The formula used to obtain a velocity in km/s from normal mode telemetered data is:

```
V = (SCVEL + VDR) * (.01*DRIFT(I,J) - VDO) * CD
```

where

V = computed drift velocity (km/s)

SCVEL = spacecraft velocity (km/sec)

VDR = downrange (y component) of the plasma drift velocity

DRIFT(I,J) = telemetered drift meter output for "I"th sample in the "J"th second of a minute (range 0 to 511)

VDO = rezero voltage (V)

CD = calibration constant (unitless)

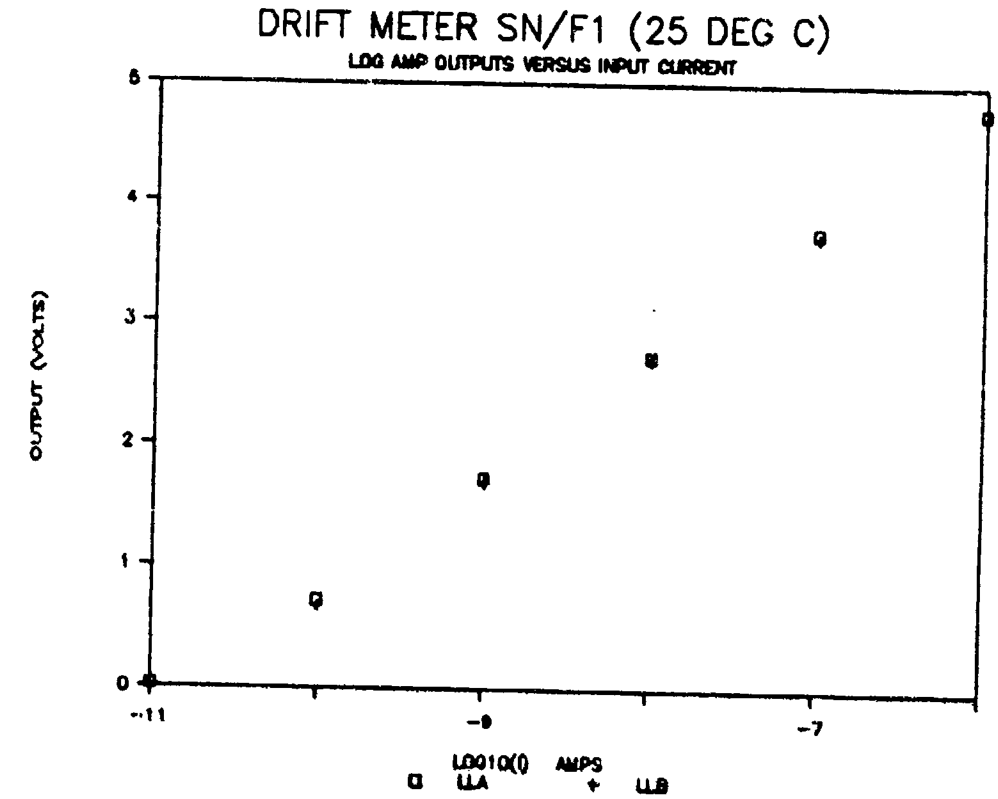
Initially, we will use 7.44 km/s for the spacecraft velocity, set VDR = 0, VDO = 2.53, and CD = .1413 for routine processing (for S/N 01 on S8). If the spacecraft does not reach its nominal orbit, SCVEL will be adjusted. Instrument performance may indicate a need to adjust VDO and CD after launch. VDR is much smaller than SCVEL, the spacecraft velocity. Setting VDR = 0 will cause an uncertainty < 10% in the perpendicular velocities calculated from the drift meter output. For special purposes, VDR sometimes can be determined from the RPA data.

The output of each of the two log amplifiers is included in the telemetry data every other second. These data could be used to obtain the ion density, but are only intended to be used to verify the operation of the drift meter.

3.2.4. Drift Meter Calibration Data

The SSIES drift meter units F1, F2, and F3 were calibrated at 0° C, 25° C, and 50° C. The calibration changes very little as a function of temperature. Past experience indicates that the drift meter electronics units, which are located in the Equipment/Service Module (ESM), will always be at 25 °C +/- 5 °C. Numerical values for the calibration data at any temperature may be obtained from AFGL or the University of Texas, Dallas if necessary.

The drift signal zero values for SSIES drift meter units F1, F2, and F3 at 25° C are 2.53 V, 2.56 V, and 2.54 V respectively. In Figures 6, 7, and 8, the logarithmic amplifier outputs for these units are shown as functions of input current and the drift signal outputs are shown as functions of the ratio of the currents to the halves of the drift meter collector at 25° C. LLA and LLB are the two logarithmic amplifiers used to amplify the signals to the halves of the collector. C2/C1 is the ratio of the currents to the halves of the collector. The number to the left of each point on the plot of drift signal versus Log(C2/C1) is the value of C2/C1 at that point.



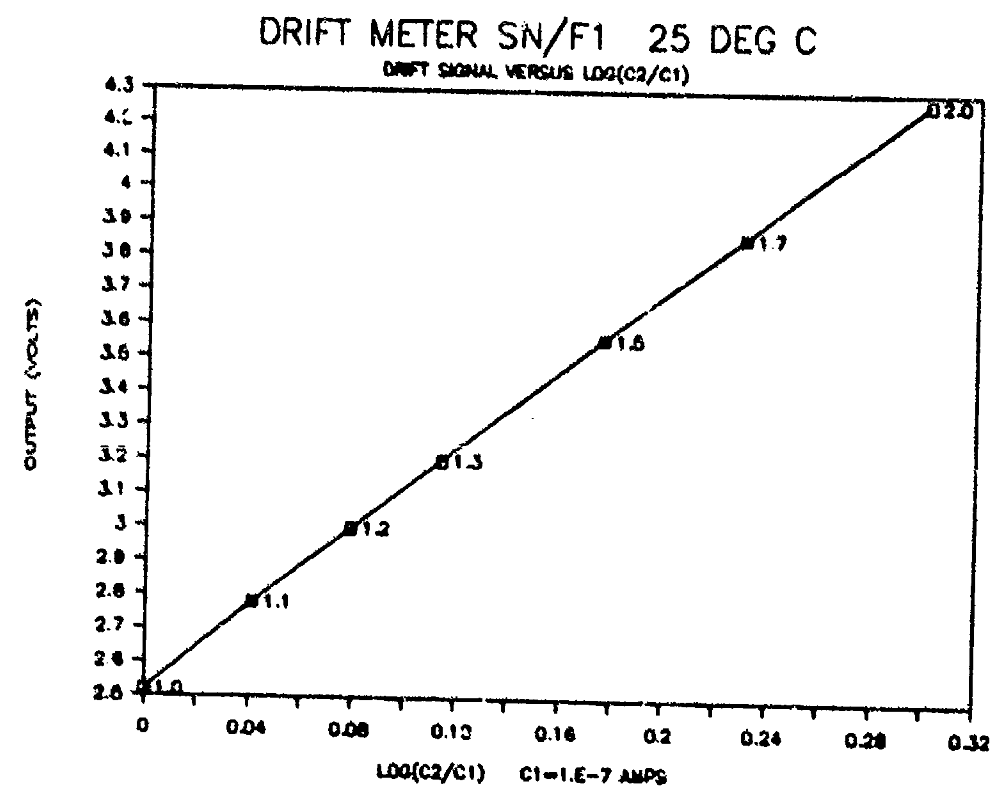
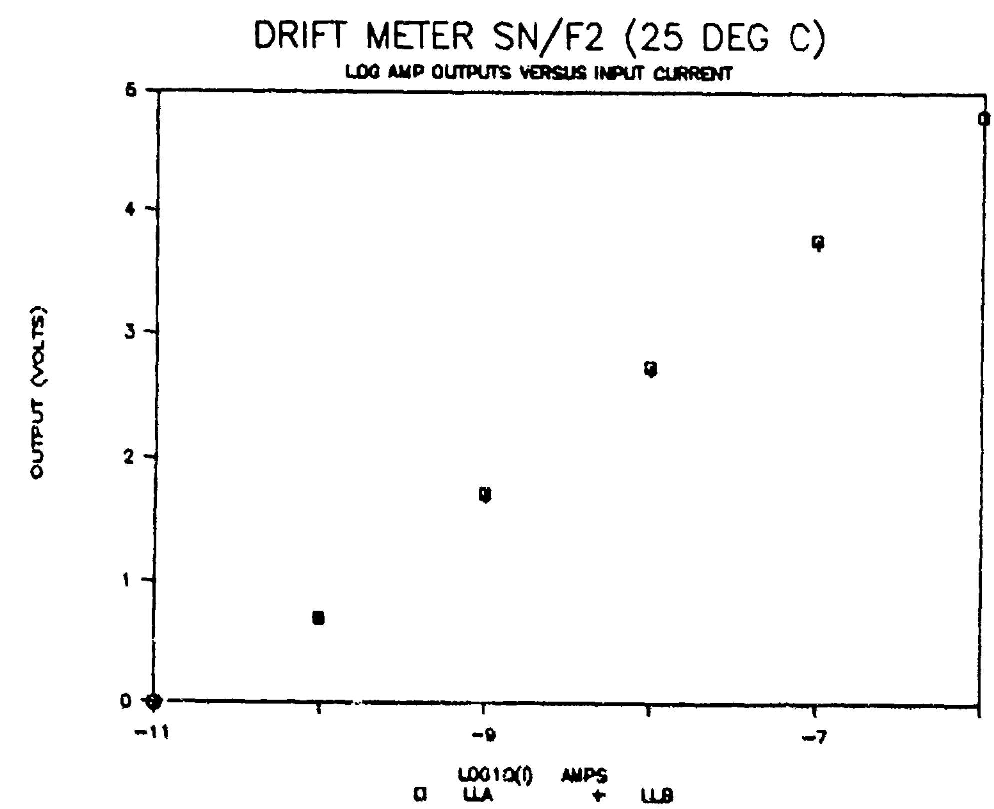


Figure 6: Calibration data for drift meter unit F1.



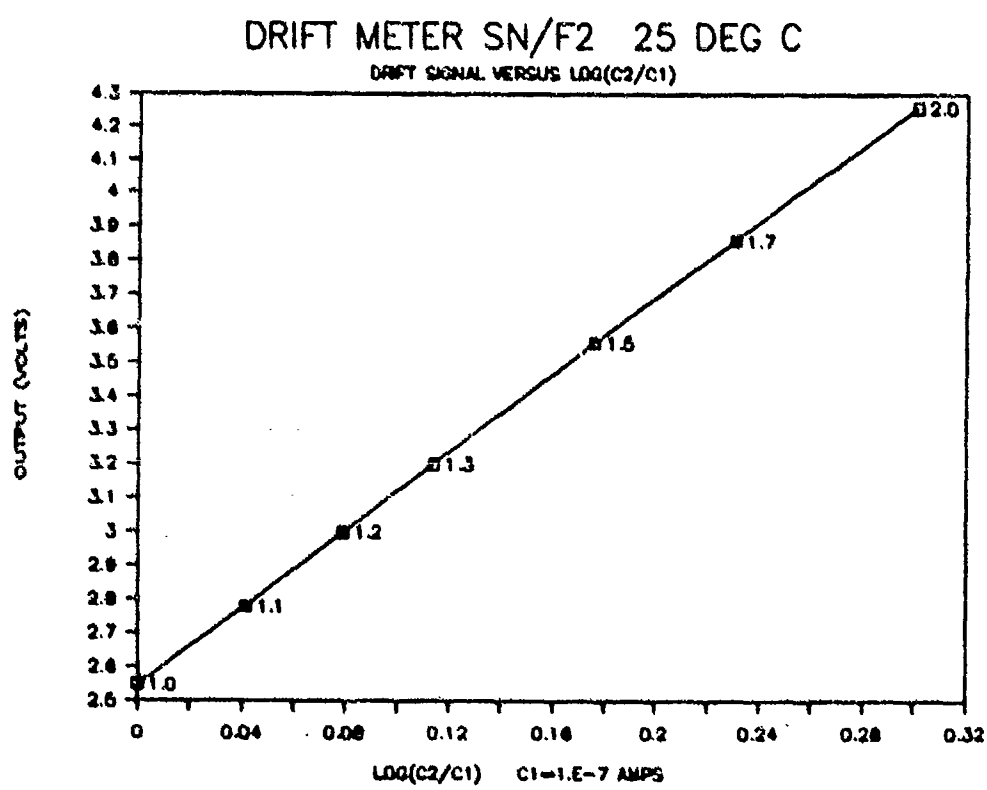
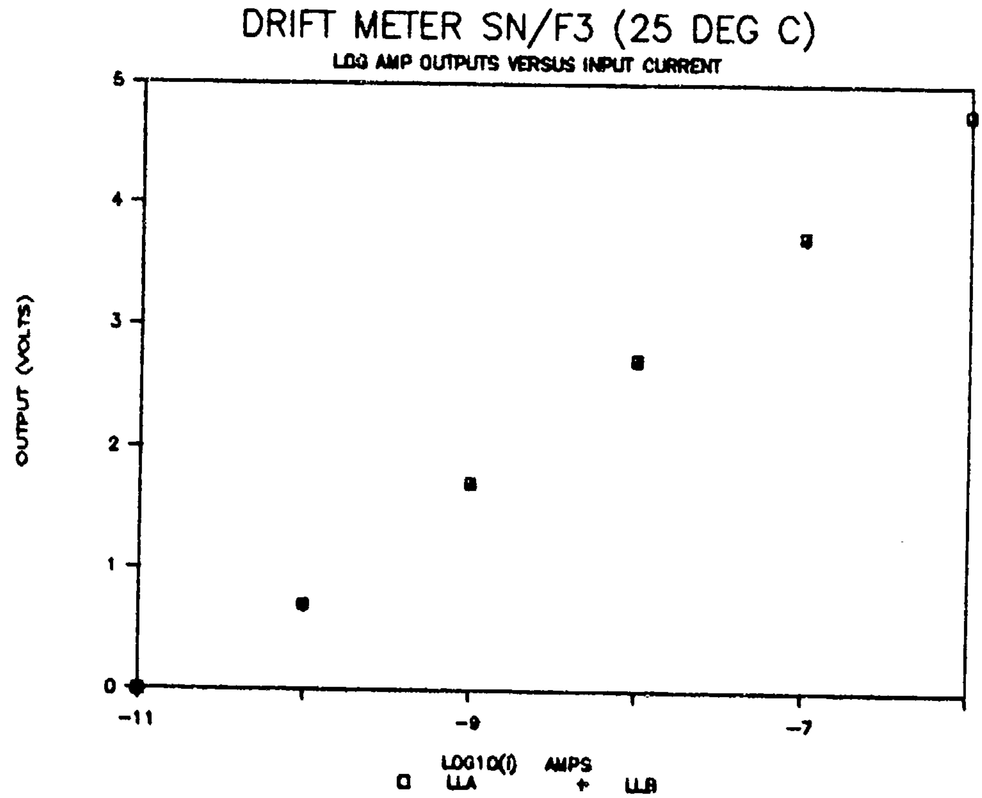


Figure 7: Calibration data for drift meter unit F2.



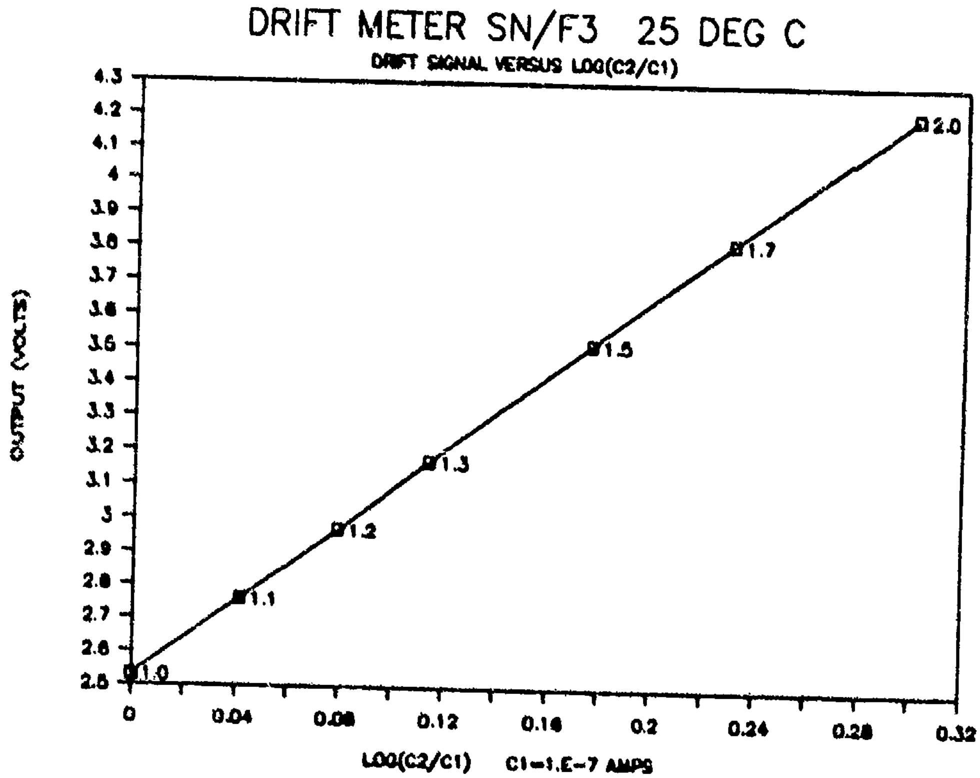


Figure 8: Calibration data for drift meter unit F3.

3.3. THE SCINTILLATION METER

The scintillation meter (SM) was designed at the University of Texas at Dallas, to measure variations in the plasma density over scale lengths from kilometers to 1 meter. This ion sensor is a simple ion trap (Faraday cup) with no retarding voltage. The voltage on the SM aperture will be maintained at an electrostatic potential close to the plasma potential. An internal suppressor grid is employed to block ambient electrons from reaching the collector plate and to avoid any photoelectron current from the plate. Thus, the current collected will be proportional to the product of ion density and ion ram velocity as in Equation (2) above.

The scintillation meter processes the collected current in two different ways. First, the magnitude of the ion current to the collector plate is sampled 24 times per second from the output of an electrometer or a difference amplifier. Since the nominal satellite velocity is 7.44 km/s, the 12 Hz Nyquist frequency of the electrometer-amplifier measurements means that the smallest irregularity scale length which can be measured with the individual samples of the ion current is 620 m. Second, to detect the presence of smaller scale irregularities, nine bandpass filters with center frequencies from 17.7 Hz to 8.2 kHz are attached to the output of the electrometer or difference amplifier and are sampled once per second. The size of a time-stationary density variation which will produce a signal at 8.2 kHz is about 1 m.

3.3.1. Electrometer-Amplifier Measurements

The electrometer-amplifier system for measuring the magnitude of the collected current has been designed to give accurate readings for a wide range of density values. The electrometer has 5 linear sensitivity ranges. The range is adjusted automatically to maintain maximum sensitivity while staying within the telemetry band. Sensitivity decreases by a factor of $10^{1/2}$ for each range change from 6.32×10^{-9} amps/volt to 6.32×10^{-7} amps/volt.

To achieve higher sensitivity to small density changes when large fluctuations are absent, the electrometer output is stored periodically at one terminal of a x10 difference amplifier. The live electrometer output is connected to the other terminal. The zero output of the difference amplifier is set to the middle of the telemetry band so that either positive or negative density changes can be detected. Either the electrometer or the difference amplifier output may be telemetered, depending on the magnitude of the density variations. If the output of the difference amplifier falls outside preset upper or lower limits which are near the edge of the telemetry hand, the electrometer is connected to the telemeter. At the next "T_0 Cycle 1" pulse, the amplifier is reconnected to the telemeter. ("T_0 Cycle 1" pulses indicate the beginning of an odd second in the SSIES operations cycle.) If the amplifier output falls outside the preset limits again within one second, the electrometer is connected to the telemeter until 8 "T_0 Cycle 1" pulses have occurred (15 to 16 seconds). At the end of this period the telemetry output switches back to the amplifier. If over-range occurs again within 1 second, the electrometer output is telemetered for another 15 to 16 seconds. If over-range does not occur, the amplifier output is telemetered until one of the following events occurs:

1. An amplifier over-range switches the telemetry back to the electrometer. The next "T_0 Cycle 1" pulse begins a new cycle
2. After 16 seconds, the electrometer output is telemetered for two samples.

The electrometer and amplifier readings appear in words 2, 7, 12, ..., 117 of the SSIES data format (Section 4), and in the array SCIN in the SSIES Phase II data processing at AFGL (Section 5). Control flags replace regular data in the scintillation meter telemetry to indicate when switching between the electrometer and difference amplifier occurs. Table II shows the possible events, and the nominal telemetry readings which mark them. The actual flags may differ from the nominal values by one or two. A number indicating the ranges of the electrometer and the wideband amplifier for the filters is also telemetered once each second in Word 51 of the SSIES data format, which becomes SMFILT(10,J) in the SSIES Phase II processing program.

TABLE II: SCINTILLATION METER CONTROL FLAGS

Event		Flag	Duration
Amplifier to electrometer switch with no electrometer range change		0	Either 1 or 2 samples
Electrometer range change (always causes an amplifier to electrometer switch)			Either 1 or 2 samples
Range	Sensitivity		
1	6.32×10^{-9} A/V	28	
2	2×10^{-8} A/V	24	
3	6.32×10^{-8} A/V	20	
4	2×10^{-7} A/V	16	
5	6.32×10^{-7} A/V	12	
Electrometer to amplifier switch (occurs only at T_0 Cycle 1)		511	1 sample

The upper and lower bounds at which the electrometer ranges have been set so that the flag values are outside the normal data range. If the instrument encounters densities less than 700 cm^{-3}, the electrometer will be in Range 1 and telemetered data will have values less than 34, which may be confused with control flags. Densities much above 10^6 will cause the scintillation meter amplifier to saturate in range 5. In this case, the telemetry will show a steady stream of 511's, since this is the highest number possible to telemeter. Since the 511 control flag can appear only in the first telemetry reading of an odd cycle, saturation should be easy to distinguish.

The first step required to convert electrometer-amplifier raw data from the SCIN array to densities is to determine whether an element of SCIN represents an ion current measurement or a control flag. To process a current measurement, control flags received earlier must be examined to determine the source of the data (electrometer or difference amplifier) and the electrometer range. The formula for converting an electrometer reading to a density in units of cm^{-3} is:

$$\text{DENSITY} = 20.77 \times 10^{(MTR-1)/2} \times \text{SCIN}(J,K)$$

Here, MTR is the electrometer range, and SCIN(J,K) is raw telemetered data in the range 0 to 511. For a difference amplifier reading, the formula is:

$$\text{DENSITY} = 20.77 \times 10^{(MTR-1)/2} \times \{\text{OLDSCIN} + [\text{SCIN}(J,K)-273]/10.06\}$$

OLDSCIN is the last available element of the SCIN array which came from the electrometer.

3.3.2. The Filters

Nine bandpass filters are used to detect the presence of higher frequency variations in the ion current than can be resolved in the 24 samples per second of electrometer and/or amplifier data in the telemetry. If the ambient plasma is time-stationary during the one second sampling period, these higher frequency components represent small scale variations in the ambient plasma density over the distance covered by the satellite in one second.

To measure these higher frequency density fluctuations, the output of the electrometer is a.c. coupled to a wide band ranging amplifier (WIBAN), and then to the bandpass filters. Each bandpass filter is followed by an AD536 RMS-to-DC converter, which provides an output V_{out} proportional to log $(\langle V_{in}^2 \rangle^{1/2})$, where $\langle V_{in}^2 \rangle$ is the average of the square of the input voltage. The RMS-to-DC converters use RC filters with a time constant of 25 ms to average the input signals. Because the time constant is comparable to the bandpass frequencies of the first three filters, the signals from these filters are somewhat attenuated. The output from each RMS converter is sampled once each second. The filter numbers, their bandpass frequencies, the locations of their RMS outputs in the SSIES data format, and the variable names used for them in the Phase II processing are shown in Table III.

TABLE III: SCINTILLATION METER FILTERS

Filter #	Bandpass Frequencies	Data Format (See Sec. 4)	Variable Name (See Sec. 5)
1	12-26 Hz	word 21	SMFILT(4,N)
2	26-56 Hz	word 41	SMFILT(8,N)
3	56-120 Hz	word 20	SMFILT(3,N)
4	120-260 Hz	word 40	SMFILT(7,N)
5	260-560 Hz	word 11	SMFILT(2,N)
6	560-1200 Hz	word 31	SMFILT(6,N)
7	1.2-2.6 kHz	word 10	SMFILT(1,N)
8	2.6-5.6 kHz	word 30	SMFILT(5,N)
9	5.6-12 kHz	word 50	SMFILT(9,N)

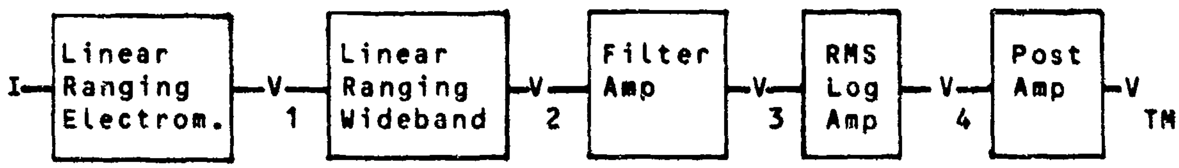
The wideband amplifier has 5 linear sensitivity ranges, with sensitivity changing by $10^{1/2}$ with each range change. This amplifier has two automatic ranging modes. Its range also can be set by ground command. During automatic ranging, the sensitivity range is determined by the filter channel with the largest output voltage. In the free ranging automatic mode (RNGFR), the wideband amplifier will range any time any filter output exceeds the upper comparator limit (nominally 4.5 V) or any time the highest filter output goes below the lower comparator limit (nominally 3.0 volts). In the restricted automatic ranging mode (RNGRE), the wideband amplifier can range only during a 1/3 seconds window beginning immediately after the period (about 1/3 seconds long) during which all the filter outputs are sampled and the range is telemetered. Thus, in RNGRE mode, all channels are fixed for at least 1/3 seconds prior to the next set of samples being taken. Data taken in RNGFR mode may be difficult to interpret, because, although the wideband amplifier can range at any time, its range is telemetered only once a second in Word 51 of the SSIES data format. Thus, the telemetered range may not be the wideband range at which all the filters were sampled.

Table IV shows the nominal values which should appear in Word 51 for each possible combination of electrometer and wideband amplifier ranges. Range 1 is the most sensitive range and Range 5 the least sensitive for both the electrometer and wideband amplifier.

TABLE IV: ELECTROMETER AND WIDEBAND AMPLIFIER RANGE FLAGS

Electrometer Range / Wideband Amp Range	1	2	3	4	5
5	398	388	376	366	356
4	316	306	296	284	274
3	234	306	296	284	274
2	152	142	132	120	110
1	70	58	50	38	28

To derive the formula for converting the raw data in SMFILT to rms density variations, the gain of each stage of the filter network must be included. A block diagram of these stages is shown below.



I is the current to the collector of the scintillation meter, and V_1, V_2, V_3, and V_4 the output voltages of the various stages. V_{TM} is the final output voltage which is multiplied by 100 and telemetered. The relationships between input and output for the various stages are:

$$V_{TM} = G_P V_4$$

$$V_4 = G_{RMS} \log\langle V_3\rangle + O_{RMS}(k) \qquad \langle\ \rangle \text{ indicates RMS average}$$

$$\langle V_3\rangle = G_F(k) \langle V_2\rangle$$

$$\langle V_2\rangle = G_W \ 10^{0.5 (1 - R_W)} \ \langle V_1\rangle$$

$$\langle \text{DELTA I}\rangle = G_E \ 10^{0.5 (R_E - 1)} \ \langle V1\rangle$$

The quantity <DELTA I> is the rms amplitude of the current fluctuation in the frequency range passed by filter k. The post amplifier gain G_P, the RMS log amplifier gain G_{RMS}, the wideband amplifier gain G_W, and the electrometer gain G_E all have the same constant values for each filter. R_W is the wideband amplifier range, and R_E is the electrometer range. The RMS log amplifier offsets, $O_{RMS}(k)$ and the filter gains, $G_F(k)$, are different for each filter k. The values of these constants are determined from calibrations and are given in Table V below.

Combining the above formulas for the gain of each stage gives

$$\log\langle DELTA\ I\rangle = V_{TM}/(G_P G_{RMS}) - \log[G_F(k) G_W/G_E] - O_{RMS}(k)/G_{RMS}$$
$$-0.5(2 - R_W - R_E)$$

This can be transformed into an equation relating the telemetered values to density fluctuations by using Equation 2 in Section 3.4.2 above. For the scintillation meter, the effective aperature area Aa = 25.53 cm^2. It is assumed that all ions are singly charged with q = 1.6 x 10^{-19} Coulomb. Inserting the correct values for the constants,

$$DELTA\ N \text{ in } cm^{-3} = DELTA\ I\ (amps) \times 10^{11.517}$$

Thus, the equation which relates density variations to telemetry is:

$$\log\langle DELTA\ N\rangle = .00653 \times SMFILT(FILT(k)) - C_F(k)$$
$$-0.5(2 - R_W - R_E) + 11.517$$

where <DELTA N> = amplitude of density fluctuations (in cm^{-3}) in the frequency band passed by filter k.

SMFILT(FILT(k)) = 100 V_{TM}. SMFILT(FILT(k)) is the telemetered signal which indicates the output of filter k. (The filters are numbered, but not sampled, in order of increasing frequency, and the ordering of elements in the array SMFILT corresponds to the order of sampling.

.00653 = $(100\ G_P\ G_{RMS})^{-1}$

$C_F(k)$ = $\log[G_F(k) G_W / G_E] + O_{RMS}(k)/G_{RMS}$, determined by calibration for each filter k.

3.3.3. Scintillation Meter Calibration Data

TABLE V: SCINTILLATION METER CALIBRATION DATA

$G_E = 6.32 \times 10^{-9}$ $G_P = -25.53$ $G_{RMS} = -0.06$ $G_W = 44.8$

Filter #	O_{RMS}	G_F	$C_F = O_{RMS}/G_{RMS}$
1	-0.1537	21.568	13.746
2	-0.1582	21.091	13.811
3	-0.1594	23.763	13.883
4	-0.1610	23.036	13.896
5	-0.1633	27.928	14.018
6	-0.1666	30.506	14.112
7	-0.1676	28.063	14.092
8	-0.1700	18.666	13.955
9	-0.1805	4.4220	13.504

TABLE V: SCINTILLATION METER CALIBRATION DATA continued

	SN/F1	SN/F2	SN/F3
Difference Amp Drift @ 25° C	.7 mV/sec	0 V/sec	.5 mV/sec
Electrometer Range Limits @ 25° C			
Upper	4.98 V	4.98 V	4.98 V
Lower	1.15 V	1.15 V	1.14 V
Dif Amp/Electrom Switch Limits @ 25° C			
Upper	5.01 V	5.00 V	5.01 V
Lower	0.365 V	0.36 V	0.37 V
Wideband Amp Range Limits @ 25° C			
Upper	4.481 V	4.50 V	4.49 V
Lower	2.98 V	3.00 V	2.99 V

3.4. THE RETARDING POTENTIAL ANALYZER

3.4.1. The Sensor

The SSIES retarding potential analyzer (RPA) is used to determine the densities of O^+, H^+, and He^+, as well as the ion temperature. The SSIES RPA is very similar to the RPA's flown on the HILAT satellite [Rich and Heelis, 1983] and on the DMSP satellites F2, F4, F6, and F7 [Smiddy et al., 1978; Rich et al., 1980]. The major difference between the SSIES RPA and those flown on previous DMSP satellites is the method of setting the sensor's reference potential, which equals the aperture potential and is the base level of the RPA sweep. The reference potential of the SSIE RPA was strongly affected by the operation of the solar panels. As a result, the SSIE reference potential was often far removed from the plasma potential. The SSIES has two automated methods (SENPOT and the on-board microprocessor) to keep the sensor's reference potential close to the plasma potential. The reference potential may also be set by ground command.

In general, the SSIES RPA resembles many previous RPA's, including those flown on DMSP F2 through F4 and Atmospheric Explorer. Ions H^+, He^+, and O^+ with thermal velocities much less then the DMSP spacecraft's 7.44 km/s velocity will enter the RPA aperture. Their average energies are close to $(.29 - e\emptyset)$ eV, $(1.2 - e\emptyset)$ eV, and $(4.6 - e\emptyset)$ eV, respectively, where $e\emptyset$ = the aperture potential with respect to the ambient plasma ($\emptyset$ should be ≤ 0 V). The retarding grid voltage with respect to the aperture is swept up or down, from -3 V to +12 V or from +12 V to -3 V, every 4 seconds. The RPA sweep cycle and its relation to the sweep cycles of the Langmuir probe are shown in Figure 13. As the retarding voltage increases, first H^+, then He^+, and finally O^+ will be prevented from reaching the collector. A suppressor grid lies between the retarding grid and the collector. Its purpose is to block ambient electrons and to suppress any photoelectron current from the collector plate.

3.4.2. Data Reduction

The RPA data is processed to find the ion densities, temperature, and downrange velocity, and the spacecraft potential. These plasma parameters are obtained by fitting the measured current versus voltage points to the theoretical current-voltage curve for a multi-species, one temperature Maxwellian plasma illustrated in Figure 5a and given in Rich and Heelis [1983]. This curve is the result of evaluating Equation 1 of section 3.1 for Maxwellian f_i. The collected current is a non-linear function of the temperature, downrange plasma velocity, and spacecraft potential, and a linear function of the densities of the different ion species.

If both O^+ and light ions are present, both the component of the plasma drift velocity along the spacecraft track and the spacecraft potential can be determined. If only one ion species is present, one of these quantities must be assumed so that it is possible to solve for the other one. In such cases, we assume that the downrange component of the drift velocity is 0 at latitudes below 55°. At higher latitudes, we assume that the spacecraft potential remains unchanged from its last low-latitude value. (The RPA is not the only source of information about the spacecraft potential. The spacecraft potential can be determined more accurately from Langmuir probe data, and also can be found from the value of the ion aperture potential V_{AP} in SENPOT mode.)

In the Phase II data processing at AFGL one of two subprograms, RPATEX or RPAEWA, can be selected to process RPA data. These subprograms use different methods to find the plasma parameters which produce the best agreement between the theoretical current-voltage curve and the RPA data. RPATEX is slow and accurate; RPAEWA is faster and less accurate. Either RPATEX or RPAEWA will be selected for routine processing after evaluation of their performance with actual SSIES data. The SSIES microprocessor also calculates ion densities and temperatures, and, if two ion species are present, downrange drift velocity and spacecraft potential. It uses an algorithm similar to RPAEWA. These calculations are described in section 3.6.

Several assumptions are made in the processing of RPA data. In RPATEX, RPAEWA, and the microprocessor analysis, it is assumed that the ion distribution functions are Maxwellian, that all ion species have the same temperature, and that the plasma parameters do not change over the four seconds or 30 km required to obtain a measured current-voltage curve. If these conditions are not good approximations, the results will be questionable. The approximation that the retarding voltage felt by the ions is identical to the voltage applied to the retarding grids is used in all processing of RPA data. Although theoretical calculations of the potential experienced by an ion passing through a grid with known potential exist, they do not agree well with observations. For the double retarding grid in the SSIES RPA, the difference between grid voltage and voltage felt by an ion should be small [Smiddy et al., 1978].

3.4.2.1. RPATEX

RPATEX is a non-linear, least-squares fitting algorithm. It is a slightly modified version of a program developed at the University of Texas at Dallas for Atmospheric Explorer. The program must receive initial guesses for the non-linear parameters in Equation 1, temperature, downrange plasma velocity, and spacecraft potential. Using these initial guesses, it performs a linear least squares fit to obtain a first guess at the ion densities. These densities and the initial guesses or assumed values for the non-linear parameters are used as inputs for a non-linear least squares fitting routine which uses the method of Powell (1965). Then, using the new values for the non-linear parameters, new densities are found by linear least squares fitting. This procedure is iterated until the solutions converge, or until the number of iterations exceeds a preset maximum. The convergence requirements for the vehicle potential, drift velocity, and ion temperature, and the maximum number of iterations are set in the subroutine LSTKR. The convergence conditions are stored in the array E(3), and the maximum number of iterations in the variable MAXFUN. At present, the vehicle potential must converge to within .01 eV, the drift velocity to 1000cm/s, and the temperature to 1° K. The maximum number of iterations is 100.

3.4.2.2. RPAEWA

RPAEWA is an algorithm which uses the locations of the minima in the slope of the current-voltage curve, $dI/d\phi$, to determine the plasma parameters. It was developed at Regis College for AFGL use in processing RPA data from the HILAT satellite. The subprogram is described in an unpublished report by Basinska and Rich (1984), but the method used to determine ion densities has been altered since the report was written. As shown in Figure 5b, minima in $dI/d\phi$ indicate peaks in the distribution functions of the different ion species. The retarding voltages at which these minima occur depends on the spacecraft potential and on the down-range drift velocity. If only one species is present, producing only one minimum in $dI/d\phi$, either the drift velocity or the spacecraft potential must be assumed. If two species and thus two peaks are present, both drift velocity and spacecraft potential can be found from the data. If $dI/d\phi$ has only one minimum, the ion species present is assumed to be O^+. If two ion species are present, the light ion initially is assumed to be H^+. If this assumption gives an unreasonable value for the spacecraft potential, RPAEWA repeats the calculation assuming that the light ion is He^+. If the result is still un-physical, the calculation is aborted, and the data are flagged as bad.

RPAEWA uses the magnitude of the ion current at the minima of $dI/d\Phi$ to calculate densities. At a minimum of $dI/d\Phi$, half the ions of the ion species which produced the minimum are retarded and half are collected. Thus, the current I equals one half the product of density of the species which produced the minimum, the spacecraft velocity, and the effective RPA aperture area. Temperatures are calculated from the ratio of I to $dI/d\Phi$ at the O^+ minimum in $dI/d\Phi$. The values of $dI/d\Phi$ are estimated by fitting straight lines through several measurements of $I(\Phi)$.

When the minima of $dI/d\Phi$ cannot be located, the current at low voltage is used to find the total ion density. At low voltages, all ions are collected. The current I equals the product of total density, spacecraft velocity, and effective RPA aperture area. This current is used to calculate total ion density.

3.4.3. Telemetry

Twenty-four samples of the RPA log electrometer output are telemetered each second; i.e., 96 samples are telemetered during each four second voltage sweep. The formula used to find currents from raw data is:

$$\log_{10}(\text{ I (Amps)}) = (0.06/5) \times \text{RAW DATA} - 11.30103.$$

The RPA sweep voltages are sampled and stored in the telemetry 6 times each second. Telemetered values of the RPA retarding grid voltages are used only for instrument status checks. The nominal values of the voltages are used for data processing. The nominal voltage V is given as a function of t, the time in seconds since the start of a sweep, by the formula,

$$V(t) = -3. + 3.75t \text{ for upward voltages sweeps}$$

$$V(t) = 12. - 3.75t \text{ for downward sweeps.}$$

The PHASE II program checks four of the telemetered voltages per sweep (the first value of each second) against their nominal values. If the difference exceeds 0.8 V, an error message is printed and processing for that sweep is terminated.

3.4.4. Calibration Data

Figures 9, 10, and 11 show the results of the calibration of the SSIES RPA electrometers at 20° C. The electrometers also were calibrated at 6° C and 36° C, although the electronics temperature should be close to 20° C on orbit. Additional calibration data are available from AFGL.

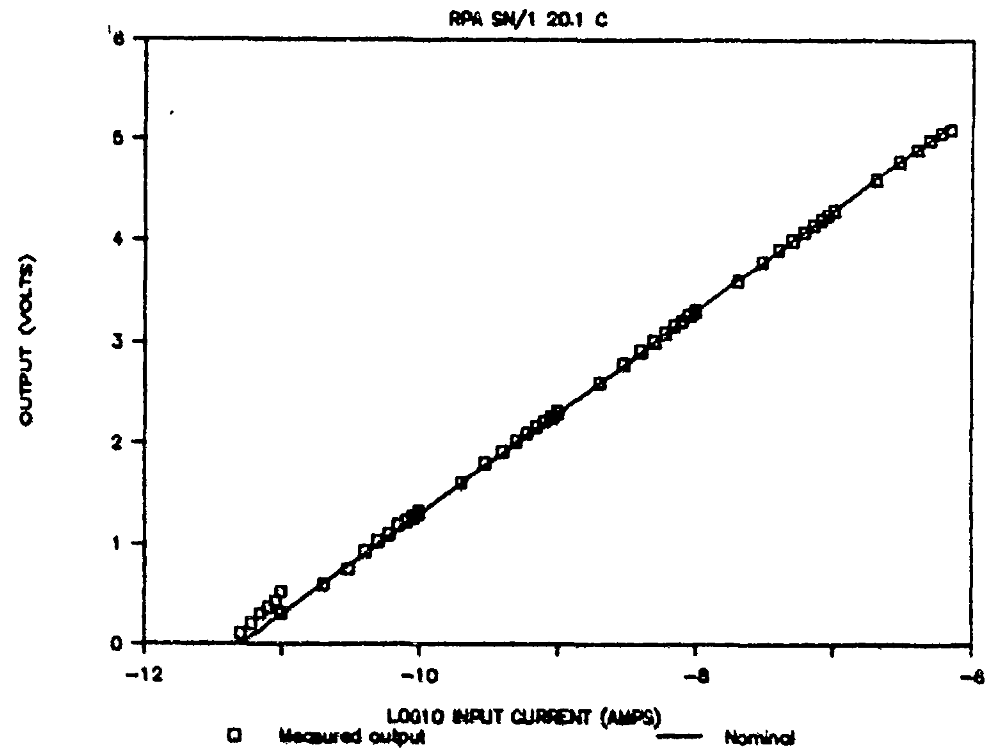


Figure 9: SSIES RPA SN/1 Calibration

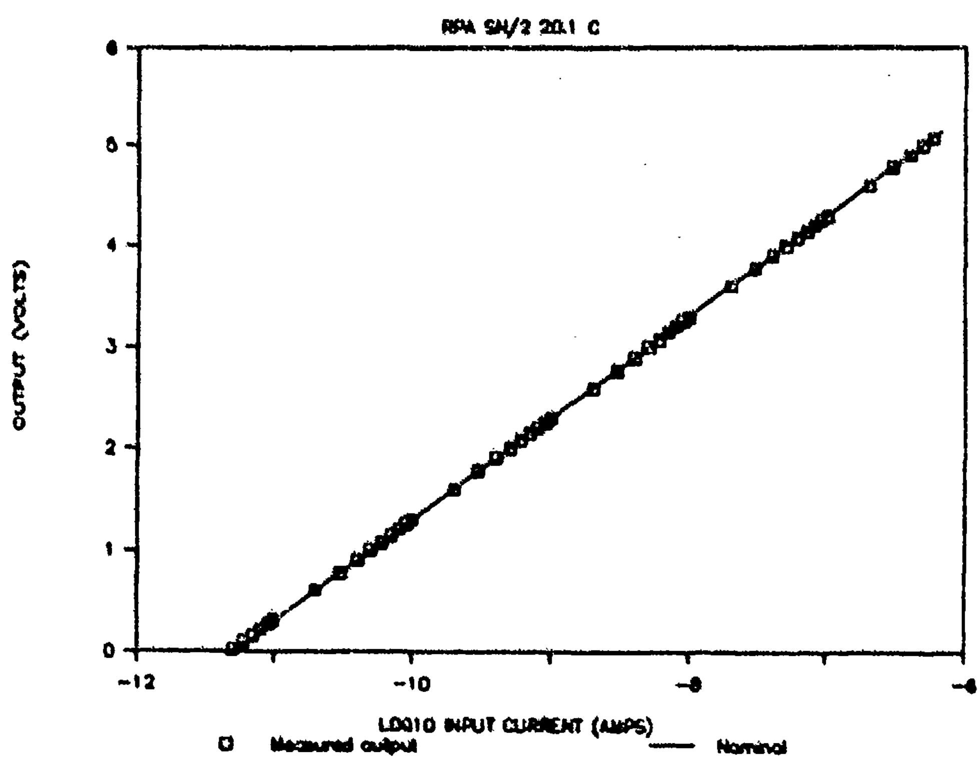


Figure 10: SSIES RPA SN/2 Calibration

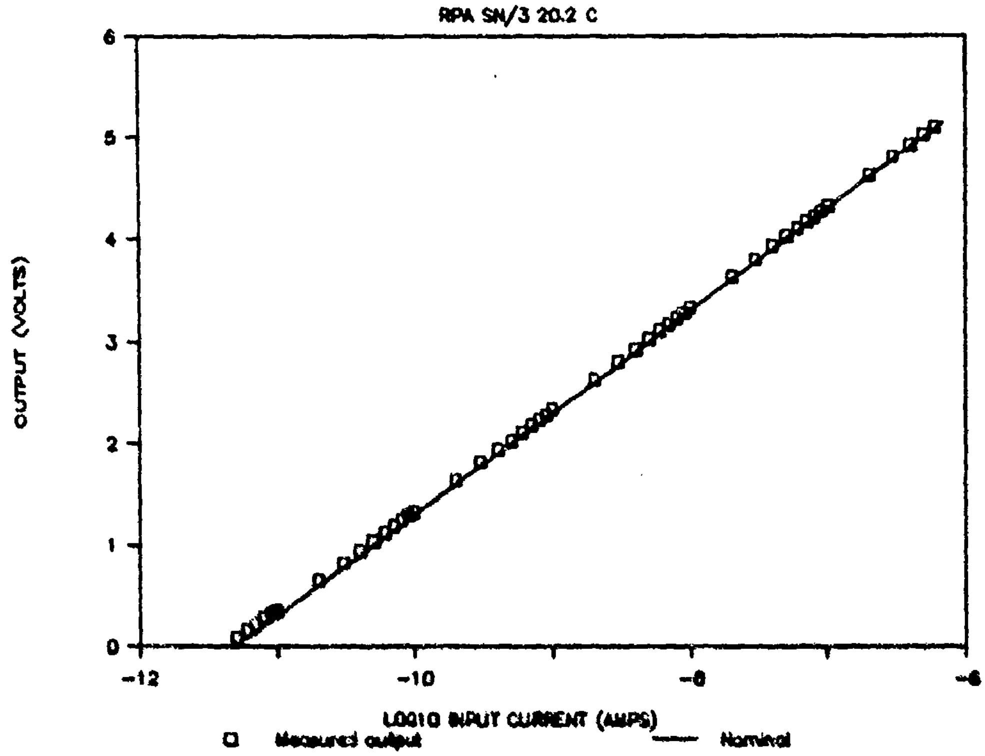


Figure 11: SSIES RPA SN/3 Calibration

3.5. THE LANGMUIR PROBE

3.5.1. The Sensor

The Langmuir probe is a conducting sphere surrounded by a spherical grid. As the voltage applied to the grid changes, the sphere collects the resulting current. The Langmuir probe is seen at the end of the 30 inch insulating boom which separates it from the spacecraft in Figure 1. Figure 4 is a close-up of an SSIES-2 Langmuir probe, which is extremely similar to the SSIES Langmuir probe.

The dimensions of the Langmuir probe have been chosen to permit good measurements of electron temperature and density in the topside ionosphere. The instrument is a gold plated 1.75 inch (4.45 cm) diameter sphere, surrounded by a gold plated 2.25 inch (5.72 cm) diameter spherical grid. The grid has a transparency factor of 0.8. The sphere is kept at a constant +20 V with respect to the grid so that any electron which penetrates the grid is collected and ambient ions are repelled. The probe collects ambient electrons, photoelectrons from various spacecraft surfaces, and photoelectrons from the inside of the grid. The 30 inch (76.2 cm) boom which separates the Langmuir probe from the spacecraft is long compared to typical Debye lengths of the plasma, so the Langmuir probe measurements should not be affected by the spacecraft.

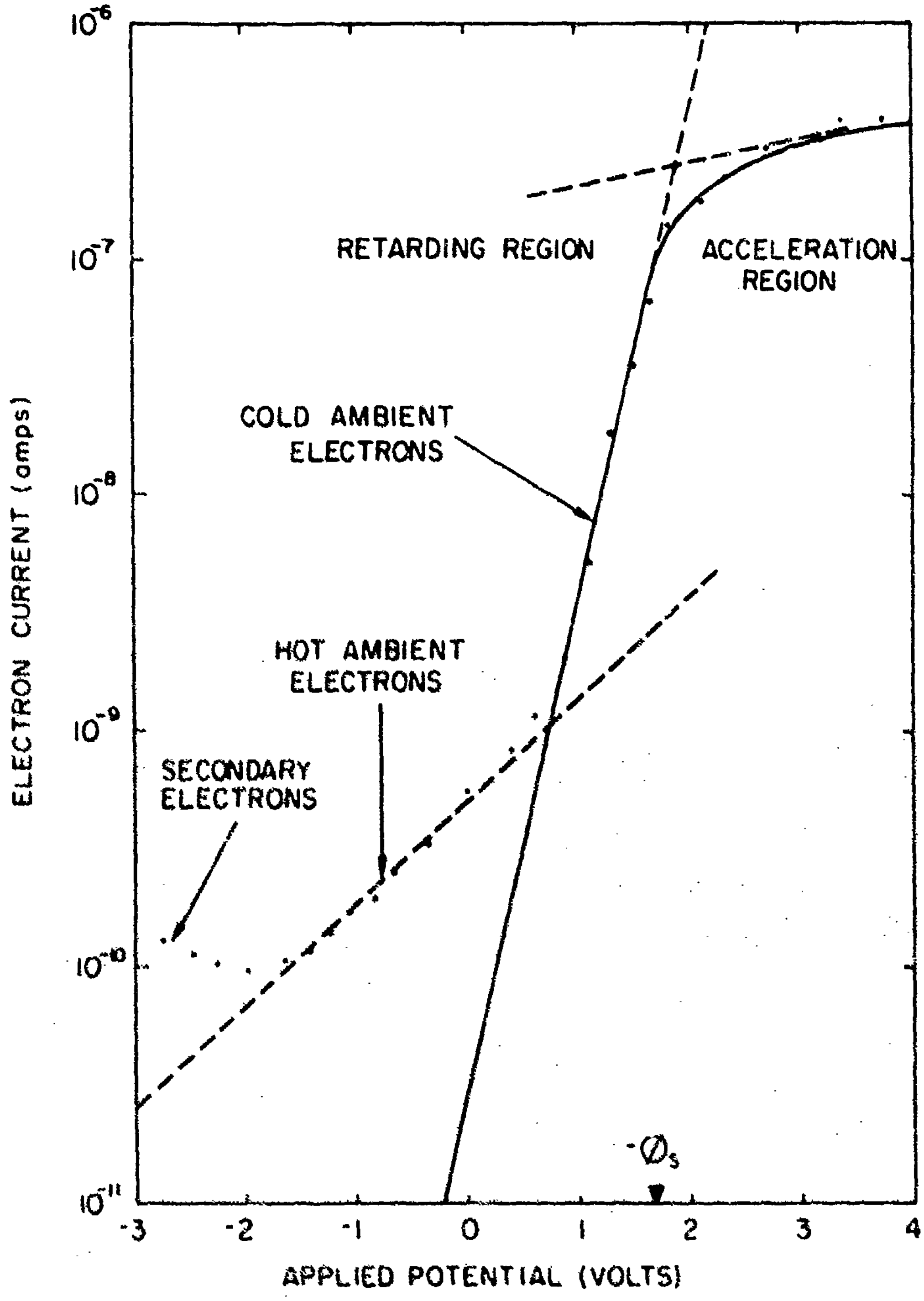


Figure 12: Theoretical and measured current versus applied voltage for a Langmuir probe in a Maxwellian plasma. The data are from the HILAT satellite (Rich and Heelis, 1983). The measured currents indicate the presence of hot ambient electrons and spacecraft-generated photoelectrons as well as the thermal plasma whose characteristics the instrument is intended to determine.

3.5.2. Theory

The theoretical current-voltage relationship for a Langmuir probe in a Maxwellian plasma with density N_e and temperature T_e is given below and shown in Figure 12 (See Langmuir and Mott-Smith, 1926, for a derivation.)

$$I_e = 4\pi r^2 e \alpha N_e v_t \exp(-x^2) \qquad \text{for } \emptyset < 0 \text{ (retarding)} \qquad (3)$$

$$I_e = 4\pi a^2 e \alpha N_e v_t \left[1 - \frac{a^2 - r^2}{a^2} \exp \left[\frac{-r^2 x^2}{a^2 - r^2} \right] \right] \qquad \text{for } \emptyset > 0 \text{ (accelerating)} \qquad (4)$$

where

a = distance from the center of the spherical collector to the boundary of the plasma sheath which shields the ambient plasma from the Langmuir probe potential.

e = electron charge = -1.6×10^{-19} Coulomb

I_e = collected current (amps)

k = Boltzman constant = 1.38054×10^{-23} joule/°K

m_e = electron mass = 9.11×10^{-31} kg

N_e = electron density (m^{-3})

r = radius of spherical grid (m) = .0286 m for SSIES

T_e = electron temperature (°K)

v_t = $[kT_e/(2\pi m_e)]^{1/2}$ electron thermal velocity

x^2 = $|e\emptyset/(kT_e)|$

α = grid transparency factor

ϕ = Langmuir probe potential with respect to the ambient plasma

The collected current I_e does not depend on the sheath radius a when $\phi < 0$ (retarding), but does when $\phi > 0$ (accelerating). This is because only electrons which are within the sheath can be attracted by the probe's positive potential. The sheath thickness, $a - r$, is several Debye lengths. The Debye length, L_D, is proportional to $(T_e/N_e)^{1/2}$. For $T_e = 2500°$ and $N_e = 10^3$ cm^{-3}, L_D = 15.4 cm. For T_e = 2500° and $N_e = 10^6$ cm^{-3}, L_D = .5 cm. When the exponent in Equation 4 is small, the collected current is given by:

$$I_e = 4\pi r^2 e \alpha N_e v_e (1 + x^2)$$

Because of Debye shielding, the current does not go on increasing indefinitely as the attractive potential increases. When the exponent in Equation 4 becomes very large, the collected current saturates at a value $4\pi a^2 N_e v_t$, which is the thermal electron flux into the sheath region.

3.5.3. Data reduction

NEWEL, the subroutine used to process Langmuir probe data, is a slight modification of M2EL, the subroutine used to process data from the HILAT satellite. Equation 3 shows that, for retarding voltages, the logarithm of the thermal electron current collected is a linear function of the potential, with the slope of the line inversely proportional to the electron temperature. However, as Figure 12 indicates, photoelectrons and high energy electrons often are present as well as the thermal electron population which the Langmuir probe is intended to characterize. This means that the collected current at large retarding voltages frequently is larger than Equation 3 predicts. NEWEL is designed to weed out points at which photoelectrons or hot electrons make a major contribution to the current as well as bad points in the accelerating region. After doing this, it fits a straight line in the retarding region to determine the cold electron temperature. Another straight line is fit to the four points at highest accelerating voltage. The voltage at which the two lines intersect ($-\emptyset_s$ in Figure 12) gives a reasonable approximation to the plasma potential. The current which corresponds to this voltage is obtained by linear interpolation from the adjacent values of the measured current. Then the electron density is calculated from this current by setting $x^2 = 0$ in Equation 3 or Equation 4.

As in the case of ions passing through the RPA grids, the potential felt by electrons passing through an opening in the Langmuir probe grid is not identical to the potential applied to the grid. Since the Langmuir probe has a single grid exposed to the plasma, the difference between the potential applied to the grid and the potential experienced by a particle is likely to be greater than the difference in the case of the RPA. The potential experienced by an electron will be slightly shifted toward the plasma potential. Because the voltages applied to the grid are used in the data reduction, the calculated temperatures will be slightly too high.

3.5.4. Telemetry

Twenty-four Langmuir probe current readings are telemetered each second. These data are placed in the array ELEC in the SSIES Phase II data processing program. The formula for converting raw data from the telemetry to currents is

$$\log_{10}(-\text{Amps}) = (0.06/5) \times \text{TM Value} - 10.0.$$

The Langmuir probe grid voltage is monitored six times each second. The telemetry values can be converted into voltages by using the formula

$$\text{Volts} = 0.16 \times (\text{TM Value} - 256).$$

Instead of using the telemetered values in data processing, the Phase II data processing program uses the nominal grid voltage. The first voltage measured each second is tested to see if it departs from its nominal value by more than 0.8 V. If this happens, an error message is printed, and calculation of the plasma parameters is aborted until good data are found.

3.5.5. Operating Modes

The Langmuir probe (LP) has five different operating modes, A through E. Figure 13 shows sweep voltage as a function of time for the different Langmuir probe modes and for the RPA. In modes A, B, and E, the Langmuir probe grid sweeps continuously, but in modes C and D, sweeps are interspersed among long periods during which the Langmuir probe grid dwells at the reference voltage V_B. V_B equals $V_{AP} - V_{IP}$, where V_{AP} is the reference voltage for the ion sensors, and V_{IP} is an offset which is set by command. When reference potentials are set by the on-board microprocessor or by ground command, $V_B = V_{BIAS}$, the sum of the outputs of the $V_{BIAS} + V_{IP}$ supply and the $-V_{IP}$ supply shown in Figure 2.

In all modes, the on-board microprocessor calculates the spacecraft potential, electron temperature, and electron density from each sweep's data, using an algorithm similar to NEWEL. The calculated spacecraft potential is used to set the value of V_{BIAS} in modes A, C and E, but not in modes B and D. (See Section 3.7 for more information about how the reference potentials for the LP and the ion sensors are set.) The time required for a normal sweep and the length of a sweep cycle also vary from mode to mode. In modes A through D, the normal sweep duration is 4 seconds; in Mode E it is 2 seconds. The sweep voltage cycle repeats every 128 seconds in Modes A, B, and E; in modes C and D, the cycle repeats every 1024 seconds.

Figure 13 shows that two 3-second large sweeps, each followed by a 1-second dwell at V_B, begin the sweep program in all modes. In mode A, the microprocessor inserts large sweeps at other times if certain conditions occur. During a large sweep, the Langmuir probe grid voltage goes from -6 V to 14 V with

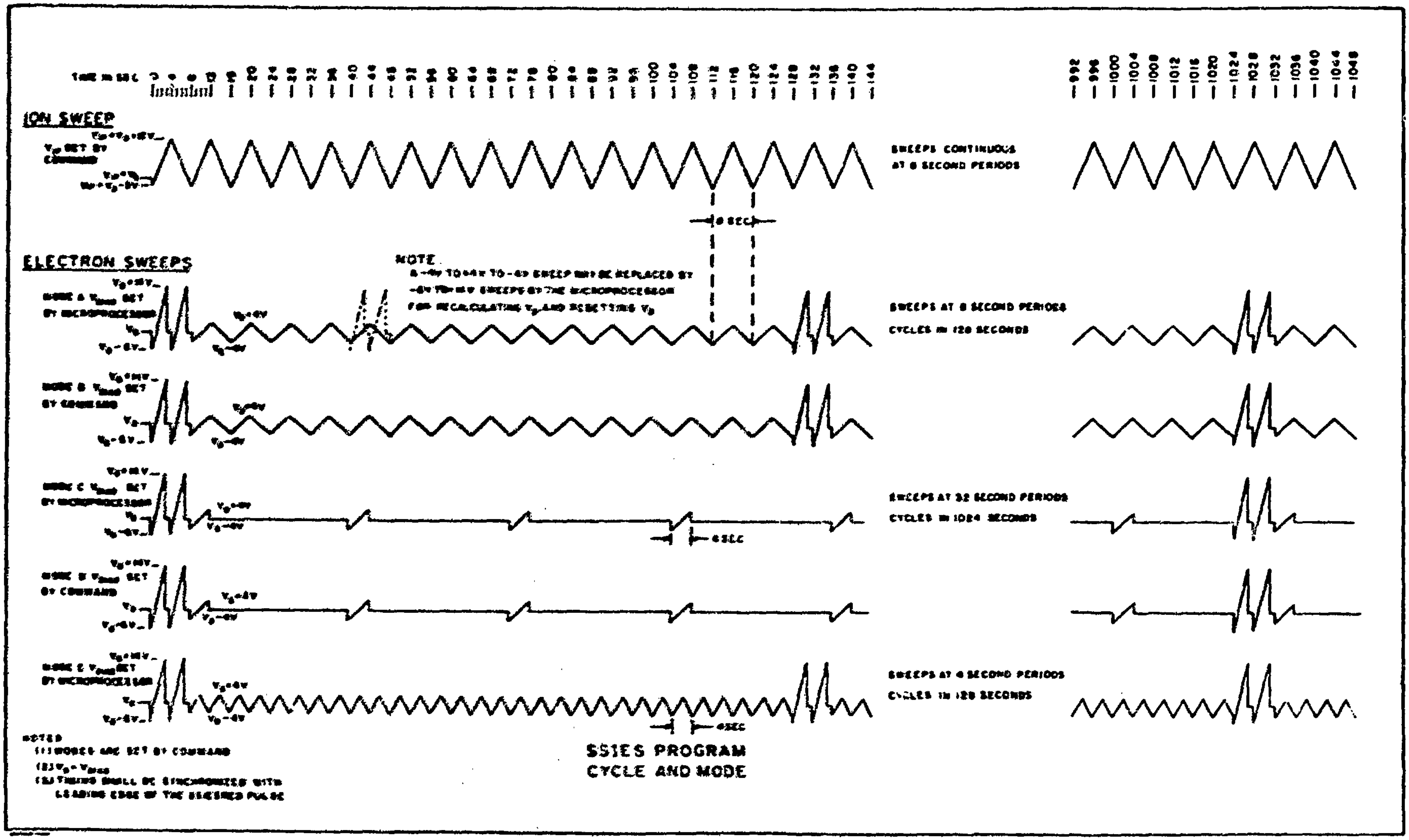


Figure 13: RPA and Langmuir probe sweep voltages during the different Langmuir probe modes.

respect to V_B. During the first large sweep, V_{BIAS} is set to 2 V above spacecraft ground, and during the second large sweep, to 17 V above spacecraft ground. These changes in V_{BIAS} alter the potential of the ion sensor aperture plane, will make ion measurements inaccurate during at least one of the large sweeps. The eight second large sweep sequence can be identified because bit 3 of word 1 in the SSIES data format is set to 1. This bit is 0 at all other times. The variable IBM in the SSIES Phase II data reduction program equals the value of this bit.

The value of V_B is set by the on-board microprocessor in modes A, C, and E; V_B is set by ground command or, for DMSP S9 and S10, by the SENPOT system in modes B and D. When SENPOT is operating in Modes B and D, V_{BIAS} (which no longer equals V_B) defaults to 13 V after the 8-second large sweep sequence. During even telemetry frames, bit 8 of word 70 in the SSIES data format is set to 1 when biases are controlled by SENPOT and reset to 0 when biases are set by ground command. The value of this bit is contained in the variable SENPOT in the SSIES Phase II data processing program.

3.5.5.1. Mode A

Mode A is selected when SSIES is turned on or a reset command is sent. Mode A begins with two large sweeps. During the 1-second dwell which follows each sweep, the on-board microprocessor calculates V_p, the plasma potential with respect to the spacecraft, from the sweep data. Since the two large sweeps cover the range -4 V to 31 V with respect to spacecraft ground, the knee of the current-voltage curve shown in Figure 12 should be found during one of the two sweeps. After the second calculation of V_p, the microprocessor sets V_{BIAS}. V_{BIAS} can take on integer values between -3 V and 28 V. It is set to the integer value closest to the value of V_p found during the first large sweep if the first value is less than 16 or to the value closest to the value of V_p found during the second large sweep if the second value is greater than 17 V. If the value of V_p cannot be established from the data taken during the two large sweeps, V_{BIAS} is not reset and the 8-second large sweep sequence repeats after 8 seconds. Since Mode A is not a SENPOT mode, V_B, the base voltage for the sweeps, equals V_{BIAS}.

After the initial large sweep sequence, in Mode A the Langmuir probe begins a 120-second sequence of 4-second normal sweeps. These sweeps alternate direction, going first from V_{BIAS} - 4 V to V_{BIAS} + 4 V and then from V_{BIAS} + 4 V back to V_{BIAS} - 4 V. After each sweep is completed, the microprocessor calculates the electron density and temperature and the plasma potential V_p from its data. This calculation occurs during the first second of the following sweep. Results calculated from upsweeps (-4 V to 4 V sweeps) are tested to determine if V_{BIAS} should be reset. If $|V_p| < 1.5$ V, V_{BIAS} remains unchanged. If 1.5 V $\leq |V_p| \leq$ 3.0 V, V_{BIAS} will be set to the integer value closest to V_p 4 seconds after the upsweep is completed. If $|V_p| > 3.0$ V, V_{BIAS} is not changed. However, if the downsweep and the next upsweep after the first upsweep with $|V_p| > 3$ V also have $|V_p| > 3$ V, normal sweeps are interrupted at the end of the next 4 V to -4 V downsweep, and an 8-second large sweep sequence identical to that which occurs from 0 seconds to 8 seconds is used to reset V_{BIAS}. If the potential cannot be determined from the data taken during a large sweep sequence, V_{BIAS} resumes its previous value for 8 seconds, and then the 8-second large sweep sequence is repeated.

In Mode A, the sweep cycle repeats every 128 second. Calculations of V_p from the data of the last two normal sweeps of a cycle, ending at 124 seconds and 128 seconds, are ignored because the large sweeps which begin the next cycle take place before the results of the calculations could be used to change V_{BIAS}.

3.5.5.2. <u>Mode B</u>

Figure 13 shows that Mode B has the same 128-second sweep voltage program as Mode A. The major difference between the two modes is that in Mode B the instrument bias is not set by the on-board microprocessor. It can be set by command or, for S9 or S10, by SENPOT. When Mode B is initialized with biases set by ground command, after the 8-second large sweep sequence V_{BIAS} assumes the last value set in the previous mode until changed by command. As in Mode A, the microprocessor calculates the plasma potential as well as electron temperature and density from the sweep data, but in Mode B, this data is not used to reset V_{BIAS}. In Mode B the large sweep sequence occurs only at the beginning of the 128-second cycle.

3.5.5.3. Modes C and D

Modes C and D have long dwells at V_B. These modes were designed to be used if the Langmuir probe draws sufficient current from the plasma to change the spacecraft potential as the LP grid voltage changes. If this happens, Langmuir probe sweeps interfere with ion measurements. Both modes begin with the 8-second large sweep cycle described above. This is followed by a 32-second sequence which begins with one 4-second upsweep from V_B - 4 V to V_B + 4 V followed by 28 seconds of dwell at V_B. This 32-second sequence repeats until 1024 seconds have elapsed, when the voltage program starts over with two large sweeps. Note that the final dwell, from 1004 seconds to 1024 seconds, is 20 seconds long rather than 28.

In Mode C, biases are set by microprocessor. The large sweep data are used to set biases in the same manner as in Mode A. However, large sweeps occur only during the first 8 seconds of the 1024-second cycle. As in mode A, V_p is computed from the -4 V to 4 V upsweep data. If 1.5 V $\leq |V_p| \leq$ 3.0 V during a 4-second upsweep, V_{BIAS} will be reset to the integer value nearest V_p after four seconds of the following dwell. No changes to V_{BIAS} are made if $|V_p| >$ 3.0 V during a 4-second upsweep.

Mode D has a sweep sequence identical to that of Mode C. The plasma potential and the electron temperature and density are still computed from each sweep, but these data are not used to set V_{BIAS}. Biases can be set either by command or, for DMSP S9 and S10, by SENPOT.

3.5.5.4. Mode E

Mode E was designed to allow higher resolution measurements of variations in the electron temperature and density. In this mode, the initial 8-second large sweep sequence is followed by continuous 2-second sweeps. As in modes A and B, these sweeps alternate direction, running up or down between V_{BIAS} - 4 V and V_{BIAS} + 4 V. The sweep program repeats every 128 seconds. In Mode E, V_{BIAS} is set automatically by the microprocessor. Biases are determined from the large sweeps as in Mode A. However, large sweeps occur only at the beginning of the sweep program in Mode E. The microprocessor analyzes each small sweep to determine the plasma potential V_p, the electron temperature, and the electron density. However, only values of V_p determined from upsweeps which begin at 12 seconds, 20 seconds, ..., 12 + 8n seconds, 116 seconds are used to determine if V_{BIAS} should be changed. If 1.5 V $\leq |V_p| \leq$ 3.0 V during these sweeps, V_{BIAS} will be reset to the integer value nearest V_p at the beginning of the next upsweep (at 16 seconds, 24 seconds, ..., 8n seconds, 120 seconds). No changes to V_{BIAS} are made if $|V_p| > 3.0$ V or if $|V_p| < 1.5$ V.

3.5.6. Calibration Data

Figures 14, 15, and 16 show the results of the calibration of the SSIES Langmuir probe electrometers at 20° C. The electrometers also were calibrated at 6° C and 36° C, although the electronics temperature should be close to 20° C on orbit. Additional calibration data are available from AFGL.

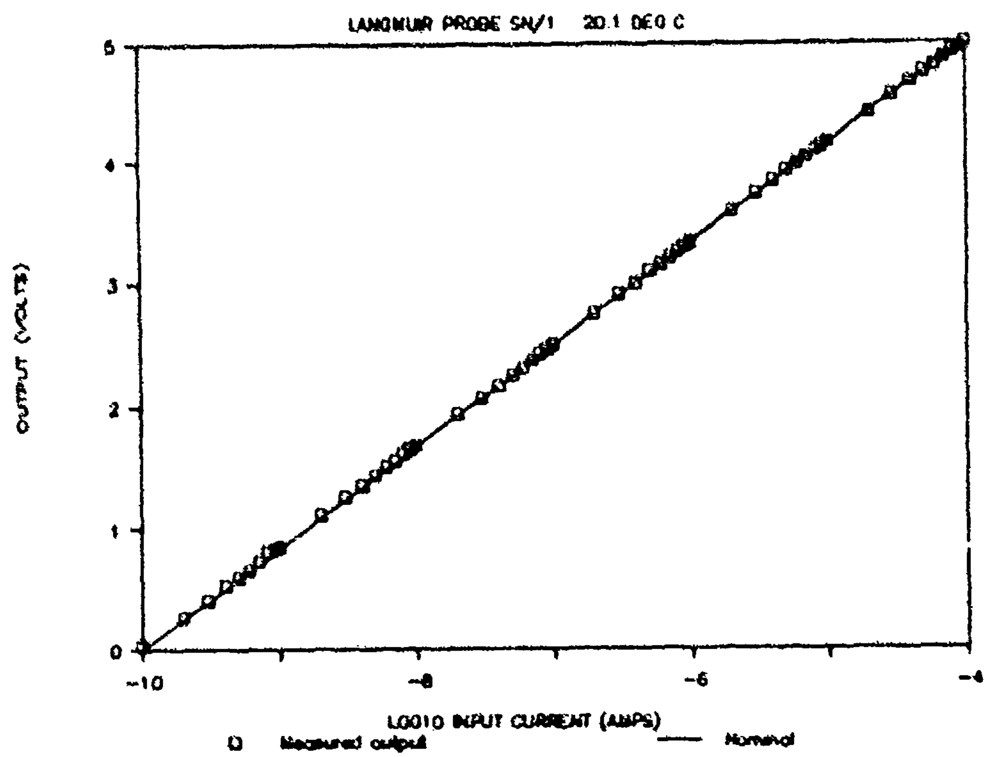


Figure 14: SSIES Langmuir probe SN/1 calibration

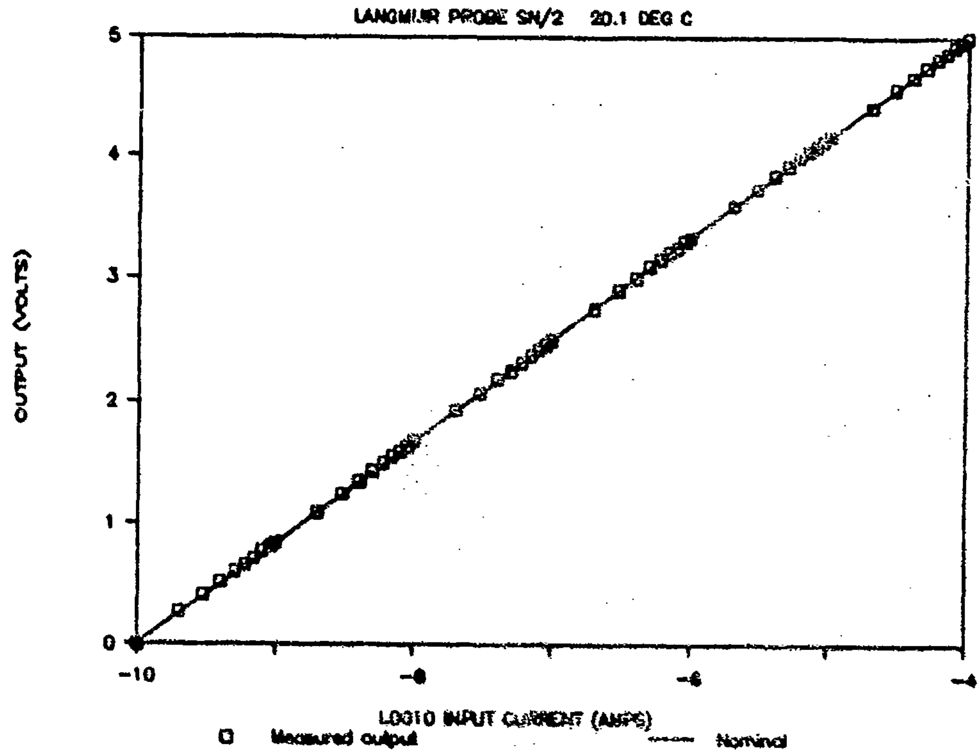


Figure 15: SSIES Langmuir probe SN/2 calibration

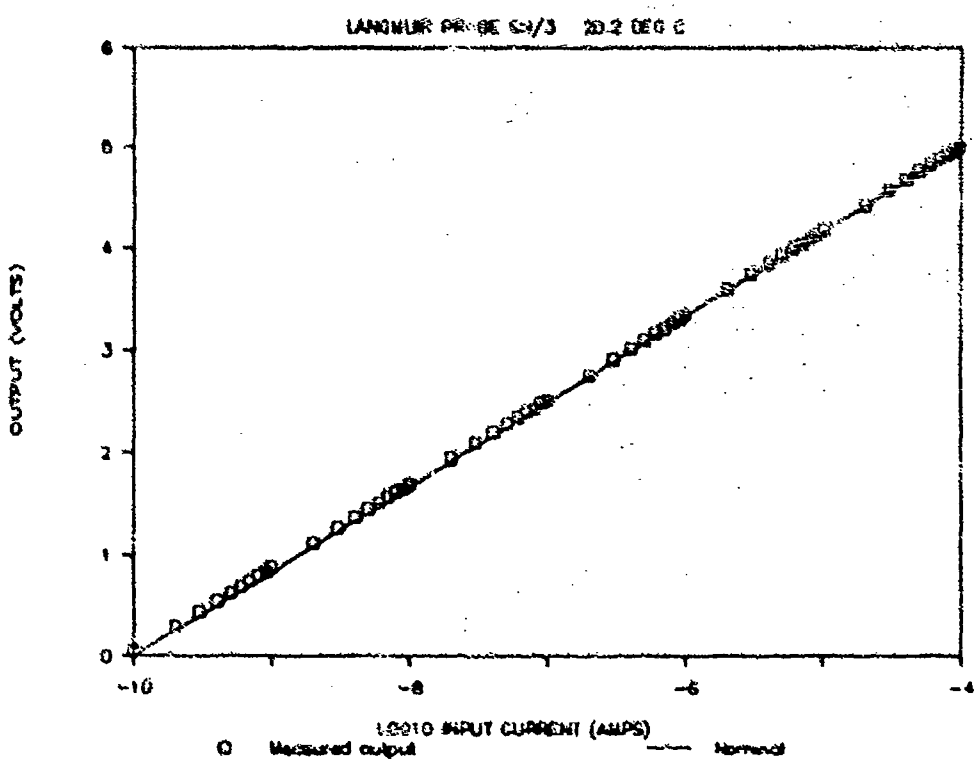


Figure 16: SSIES Langmuir probe SN/3 calibration

3.6. THE MICROPROCESSOR

SSIES is controlled by a Texas Instruments SBP9900A microprocessor. The control program has been placed in read-only memory and cannot be modified in flight. The microprocessor does on-board analysis of RPA and Langmuir probe data. The ion data is reduced by using the locations of minima in the slope of the log(current) versus voltage curve to determine H^+ and O^+ density and temperature, downrange plasma velocity, and spacecraft potential. Electron temperature and density and spacecraft potential are found from the electron data by using an algorithm similar to NEWEL, described in section 3.5.3. There are two reasons for this analysis. First, in Langmuir probe modes A, C, and E, the plasma potential determined from the Langmuir probe data is used to set V_{BIAS}. Second, if the on-board calculations prove to be a reliable method of determining plasma parameters, in the future these parameters can be telemetered instead of the raw RPA and Langmuir probe data. This will decrease both the telemetry and the computer time on the ground required for processing SSIES data.

The microprocessor collects more data from the sensors than can be telemetered to the ground. Analog measurements are converted to 10 bits of digital data, of which at least 9 are significant. Only 9 bits are telemetered. Langmuir probe and RPA measurements are telemetered as 8 bit numbers accompanied by sign bits. Drift and scintillation meter measurement are telemetered as 9 bit positive numbers. The microprocessor receives 25 current measurements from the Langmuir probe and 149 current measurements from the RPA each second. Twenty-four Langmuir probe measurements are telemetered and one is discarded. Of the RPA current measurements, 24 are telemetered, and 125 are averaged in groups of 5 to create 25 samples for the in-flight ion parameter calculations.

The microprocessor must collect data from an entire RPA or Langmuir probe sweep before the ion or electron parameters can be determined. The electron data are analyzed during the first second following the sweep, and the ion data during the second second. The telemetered values for the plasma parameters are updated at different times during the four seconds after the sweep data from which they are calculated appear in the telemetry. Except for electron data from the 3-second large Langmuir probe sweeps, the timing of updates is as follows:

Second 1: Electron temperature, spacecraft potential derived from electron data, and electron computation monitor.

Second 2: Electron, H^+, and O^+ density, downrange drift velocity and spacecraft potential computed from the ion data.

Second 3: H^+ and O^+ temperature. During Mode E only, electron temperature, spacecraft potential derived from electron data, and electron computation monitor from raw data telemetered during seconds 1 and 2.

Second 4: During Mode E only, electron density from raw data telemetered during seconds 1 and 2.

When a large 3-second Langmuir probe sweep occurs, the microprocessor-computed electron density is telemetered in the first second after the sweep data has been telemetered (with data from second 4 or 8 of the large sweep sequence) and electron temperature, spacecraft potential, and electron computation monitor in the second (with data from second 5 of the large sweep sequence or the first second after the sequence.)

3.7. BIASING THE SENSORS

To determine the characteristics of the thermal plasma, it is necessary to hold the instrument potential close to the plasma potential. The DMSP satellites have 28 V, negative ground electrical systems. Because the positive contacts on the solar panels are exposed and can attract electrons, a DMSP spacecraft's ground potential tends to range between 18 V and 28 V negative with respect to the plasma when the spacecraft is in sunlight. This vehicle potential is much greater than the temperature of the thermal plasma, and it is outside the sweep range of the SSIE3

Langmuir probe and retarding potential analyzer. To make measurements of the thermal plasma parameters possible, the SSIES instrument adjusts the reference potential for the Langmuir probe and the ion sensors' ground plane to a potential very close to the plasma potential. Because SSIE could not do this, no temperature measurements were possible in sunlight, although total density measurements were made.

There are three different methods which may be used to control the potential of the SSIES sensors. Two function automatically. The first uses the instrument's microprocessor to compute an appropriate bias potential from an analysis of the Langmuir probe data. The details of microprocessor-controlled bias setting are described in Section 3.5.5. The second method uses an analog circuit called SENPOT to drive the ion sensor ground potential close to the plasma potential. DMSP S9 and S10 have SENPOT systems, but S8 does not. Finally, the reference voltages of the ion sensors and the Langmuir probe may be set by ground command. During Langmuir probe Modes A, C, and E, bias voltages are set by the on-board microprocessor. In Modes B and D, biases may be set by ground command, or, for S9 and S10, by SENPOT. To identify SENPOT modes, during even cycles bit 8 of word 70 in the SSIES data format is set to 1 when biases are controlled by SENPOT and reset to 0 when biases are set by ground command. The value of this bit appears in the variable SENPOT in the SSIES Phase II data processing program. In SENPOT modes, the sensors tracks the plasma potential constantly, while in microprocessor-controlled modes, the sensor bias voltages can change only at the beginning of a 4 second upsweep.

To understand how SSIES works, it is important to know the voltages of different parts of the instrument with respect to spacecraft ground. These voltages are indicated on the block diagram (Figure 2). The $V_{BIAS} + V_{IP}$ programmable bias supply in the Main Electronic Package (MEP) produces a voltage $V_{BIAS} + V_{IP}$ with respect to spacecraft ground. $V_{BIAS} + V_{IP}$ can be set to any integer voltage between -6 V and 28 V with respect to spacecraft ground. This voltage provides the reference or ground potential for the Drift Scintillation Meter (DSM) electronics. The DSM electronics in turn generates a reference potential V_{AP} for the ion sensors. When biases are ground-commanded or microprocessor controlled, the ion sensor aperture plane voltage V_{AP} is set to $V_{BIAS} + V_{IP}$. In SENPOT modes, the SENPOT circuit senses the plasma potential relative to spacecraft ground, and adds the voltage needed to bring the ion sensor reference potential V_{AP} very near the plasma potential. V_{AP} is the reference potential for the ion sweep generator, and is input to the $-V_{IP}$ programmable supply in the MEP. This supply adds a voltage $-V_{IP}$, so that the reference potential for the Langmuir probe sweep generator is $V_B = V_{AP} - V_{IP}$. When the bias voltages are controlled by the micro processor or by command, $V_B = V_{BIAS}$. $-V_{IP}$ may equal 0, 1, 2, or 3 V, so that the electron sensor potential equals or slightly exceeds the ion aperture potential.

SSIES is commanded as if there were a V_{BIAS} supply for the Langmuir probe and a V_{IP} supply to modify this voltage for the ion sensors. (See Table VI in Section 4 for commands.) A command to step V_{BIAS} by -2 V decreases the output of the $V_{BIAS} + V_{IP}$ supply by 2 V, and leaves the $-V_{IP}$ supply output unchanged. In non-SENPOT modes, both the reference voltage for the ion sensors and for the Langmuir probe will decrease by 2 V. In SENPOT modes, the SENPOT circuit will add enough voltage to keep V_{AP} at the plasma potential regardless of the value of $V_{BIAS} + V_{IP}$. Only if the difference between $V_{BIAS} + V_{IP}$ and the plasma potential exceeds the 13 V maximum output voltage of the SENPOT circuit will changing $V_{BIAS} + V_{IP}$ affect the difference between the sensors' reference potentials and the plasma potential. If the command to increase V_{IP} by 1 V is sent, the $V_{BIAS} + V_{IP}$ supply output increases by 1 V, and the $-V_{IP}$ supply output decreases by 1 V. In non-SENPOT modes, the reference voltage for the ion sensors will increase by 1 V, and the reference voltage for the Langmuir probe, V_{BIAS}, will remain the same. In SENPOT modes, the SENPOT circuit will add enough voltage to keep the ion aperture very close to the plasma potential, so that adding 1 V to V_{IP} will decreases the reference potential of the Langmuir probe by 1 V relative to the plasma.

The Langmuir probe makes large sweeps during which V_{BIAS} automatically is reset, first to 2 V for 4 sec and then to 17 V for 4 sec. During these sweeps, ion measurements will be adversely affected. Large sweeps occur during the first 8 sec of all Langmuir probe modes and at other times during Mode A. These sweeps are shown in Figure 13. In SENPOT modes, the SENPOT system will try to keep the ion aperture close to the plasma potential, but it can adjust the voltage by no more than 13 V in either direction. Thus it is likely in microprocessor-controlled modes and possible in SENPOT modes that the difference between the ion sensors' aperture potential and the plasma potential will be large enough to compromise ion measurements.

SENPOT is an analog system which keeps V_{AP}, the reference potential of the ion sensors, close to the plasma potential. A very simplified schematic of the SENPOT system is shown in Figure 17. The circuit was developed at the University of Texas, Dallas (Zuccaro and Holt, 1982; Holt, 1984) and first used on the HILAT satellite. The inverting input of an operational amplifier is connected to an isolated reference surface with potential slightly less than the plasma potential. The non-inverting input is connected to the ion sensor aperture plane and to the amplifier common, which floats to keep the aperture plane potential close to that of the reference surface. (The amplifier +15 V and -15 V power supplies are connected to this floating common.) The amplifier output terminal is connected to the V_{BIAS} + V_{IP} supply, which

SENPOT SYSTEM

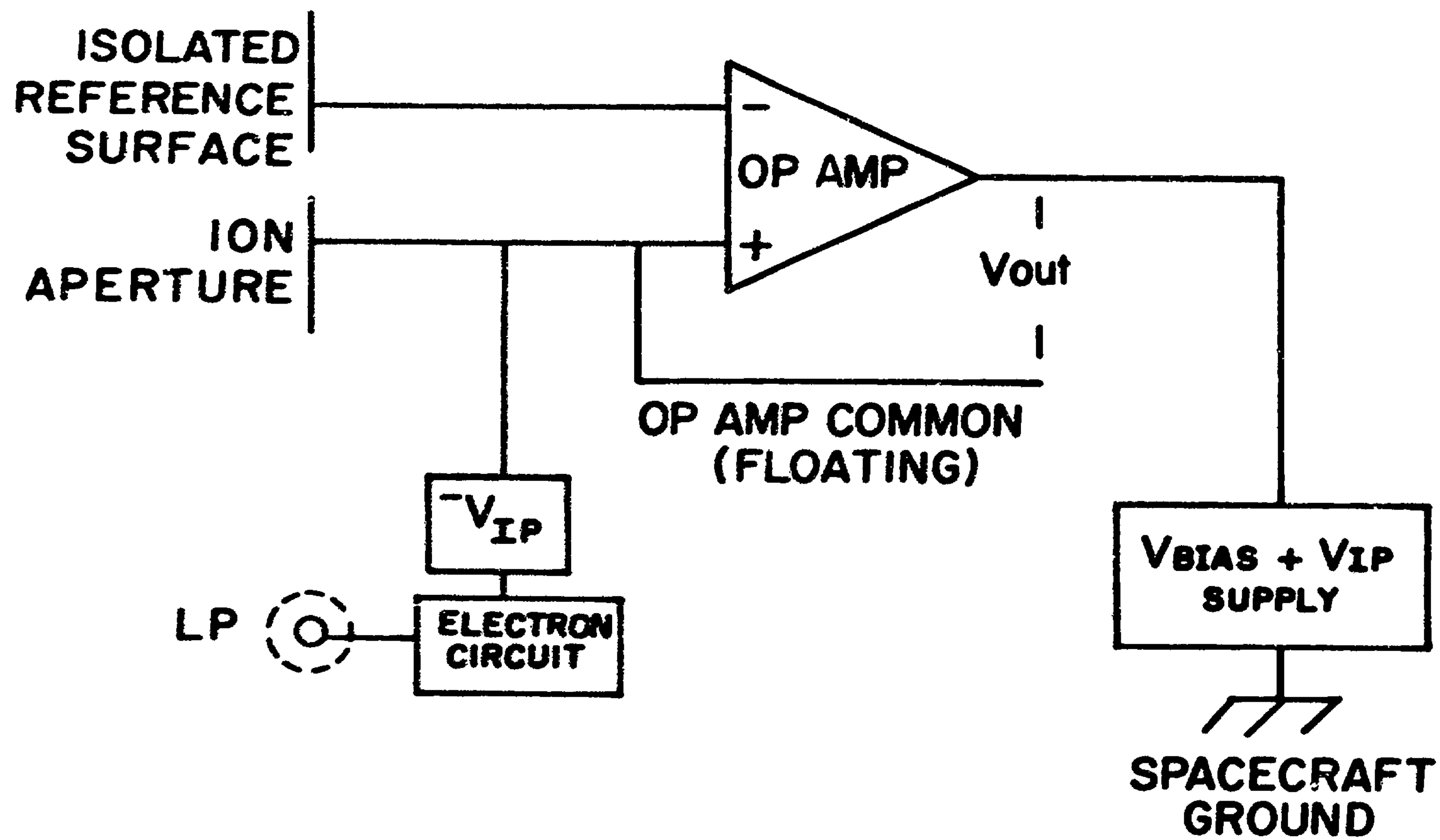


Figure 17

provides a fixed voltage in SENPOT mode. To see how SENPOT works, consider what happens if the ion aperture becomes positive with respect to the reference plane. Then the voltage between the amplifier output and amplifier common becomes large and positive. Since the output terminal voltage is fixed at $V_{BIAS} + V_{IP}$ with respect to spacecraft ground, this means the amplifier common is forced negative. Since the common is connected to the non-inverting input of the amplifier and to the ion sensor aperture, this forces the ion aperture to become more negative until the potential difference between the aperture and the reference surface is very small.

For SENPOT to function properly, three conditions must be met. First, the reference surface must reach an equilibrium potential close to the plasma potential. Second, the op amp must be able to supply a current equal to the net current collected by the biased portion of the sensor aperture plane. Finally, the combined voltage output of SENPOT and the $V_{BIAS} + V_{IP}$ supply must be able to match the difference between the spacecraft potential and the plasma potential.

For SSIES, the reference surface is a corner of the ion sensor aperture plane which is insulated from the rest of the ground plane and the spacecraft. The equilibrium potential of this surface is that at which the net current to it is zero. If the only source of current were the ambient ionospheric plasma, the surface would reach equilibrium at a potential which did not differ from the plasma potential by much more than the typical ionospheric thermal electron energy, which is less than 1 eV. The actual current to the reference surface is the sum of electron and ion currents from the ambient plasma and spacecraft generated photoelectron current, minus the input current to the SENPOT op amp and the leakage current through the insulators to spacecraft ground. For SENPOT to function properly, the other currents must be small compared to those from the ambient plasma. This requires that the plasma density be high enough to screen the reference surface from the spacecraft potential and to provide particle fluxes which exceed the photoelectron flux and leakage currents at typical ionospheric electron temperatures. A plasma density of order 10^3 cm^{-3} is required. If there is sufficient plasma density, the reference surface should reach equilibrium about 1 V below the plasma potential.

The SENPOT op amp has been selected to have low input current and high input impedance, and to be capable of providing more current than needed to drive the sensor aperture planes to the plasma potential. The op amp can drive the apertures 13 V positive or negative with respect to $V_{BIAS} + V_{IP}$. V_{BIAS} is set to 13 V with respect to spacecraft ground at the beginning of SENPOT operations, so, depending on the output of the $-V_{IP}$ supply, $V_{BIAS} + V_{IP}$ may start out at 10, 11, 12, or 13 V above spacecraft ground. V_{BIAS} can be commanded to other levels in the range -3 V to 28 V and V_{IP} can be set to 0, -1, -2, or -3 V. Thus, SENPOT can bias the ion sensor from -19 V to 41 V with respect to spacecraft ground, and the Langmuir probe from -16 V to 41 V with respect to spacecraft ground.

4. TELEMETRY

The communication between the ground and the SSIES is a two way conversation. The instrument receives commands from the ground and sends back digital and analog data. The commands and digital data are routed through the OLS system. The analog and discrete data are routed through the spacecraft housekeeping downlink.

The SSIES instrument is turned on and put into one of its many possible configurations by ground command. These ground commands are sent up to the spacecraft in orbit while it is within sight of a tracking station. The commands either are sent to the OLS for immediate transfer to the SSIES or are sent with a time tag for the OLS for transfer to the instrument within the next few orbits. The on/off command is sent to the spacecraft power system which applies or removes power to the SSIES primary power lines.

The SSIES instrument is allocated 1080 bits per second, or 30 36-bit words per second, of digital telemetry data. All the space environmental data are digitized within the SSIES and are placed into a buffer which is read out to the telemetry stream once per second. The SSIES is allocated 2 analog equipment status signals and 8 discrete equipment status words. The analog signals are converted to 8-bit digital words by the spacecraft telemetry system. These equipment status words are updated once every 2 seconds or once every 10 seconds depending on the spacecraft operating mode.

4.1. COMMANDS

The commands to the SSIES are sent, via the OLS, as a bit pattern which the SSIES must decode and translate into an action. The commands range from 10 (hexadecimal) to 3F (hexadecimal). Table VI gives the commands from 10 to 1F, which are used by the SSIES Main Electronics Package (MEP). Table VII gives the commands from 20 to 3F. Most of these are used by the SSIES DSM Electronics. Commands 21 and 23 affect both the MEP and the DSM. Command 22 affects only the MEP.

TABLE VI: OLS COMMANDS

HEX VALUE	COMMAND	COMMENT
10	Program/Sweep Cycle Reset	
11	MODE A	
12	MODE B	VBIAS and VIP reset to 0 V
13	MODE C	
14	MODE D	VBIAS and VIP reset to 0 V
15	MODE E	
16	STEP VBIAS +1V	
17	STEP VBIAS -1V	
18	STEP VBIAS +2V	
19	STEP VBIAS -2V	
1A	STEP VBIAS +4V	
1B	STEP VBIAS -4V	
1C	STEP VIP +1V	
1D	STEP VIP -1V	
1E	CLOCK ON - CAL ONLY	Sweep clocks on.
1F	CLOCK OFF- CAL ONLY	Sweep clocks are frozen.

Mode changes usually occur within 8 seconds after being commanded. In the worst case, the delay is 16 seconds. When the new mode begins, the program counter is always reset to the beginning of the sweep program.

TABLE VII: DRIFT AND SCINTILLATION METER COMMANDS

HEX VALUE	COMMAND	COMMENT
20	RNGRE	Restricted Ranging for SM Wideband Amp
21	VBIAS[1]	SENPOT off (echoes in TM for 1 sec)
22	TEST[2]	On/Off (does not echo)
23	SENPOT[1]	On, Reset to Mode B (echoes for 1 sec)
24	RNGFR	Free Ranging of SM Wideband Amp
25	SPARE	
26	SPARE	
27	SPARE	
28	RNG01	SM Wideband Amp Range 1
29	RNG02	SM Wideband Amp Range 2
2A	RNG03	SM Wideband Amp Range 3
2B	RNG04	SM Wideband Amp Range 4
2C	RNG05	SM Wideband Amp Range 5
2D	SPARE	
2E	SPARE	
2F	SPARE	
30	DREP00	DM Fixed Repeller Potential, 0.0 V
31	SPARE	
32	DREP01	DM Fixed Repeller Potential, 1.0 V
33	DREP15	DM Fixed Repeller Potential, 1.5 V
34	DREP20	DM Fixed Repeller Potential, 2.0 V
35	DREP25	DM Fixed Repeller Potential, 2.5 V
36	DREP30	DM Fixed Repeller Potential, 3.0 V
37	SPARE	
38	0WIGLO[3]	DM H+ Mode,Start at 0 V, Low Wiggle Potential
39	0WIGHI[3]	DM H+ Mode,Start at 0 V, Hi Wiggle Potential
3A	1WIGLO[3]	DM H+ Mode,Start at 1 V, Low Wiggle Potential
3B	1WIGHI[3]	DM H+ Mode,Start at 1 V, Hi Wiggle Potential
3C	2WIGLO[3]	DM H+ Mode,Start at 2 V, Low Wiggle Potential
3D	2WIGHI[3]	DM H+ Mode,Start at 2 V, Hi Wiggle Potential
3E	3WIGLO[3]	DM H+ Mode,Start at 3 V, Low Wiggle Potential
3F	3WIGHI[3]	DM H+ Mode,Start at 3 V, Hi Wiggle Potential

1 Affects both MEP and DSM

2 Affects MEP only

3 In DM H+ Mode, during each second the DM repeller potential is stepped upward from its starting potential in increments of 0.2 V per sample. In addition, a 200 Hz (100 Hz for S8) square wave is applied to the DM repeller. For WIGLO, the square wave amplitude is 50 mV for H+DERIV and 400 mV for H+DS. For WIGHI, the square wave amplitude is 100 mV for H+DERIV and 800 mV for H+DS.

4.2. SSIES TELEMETERED DATA

The SSIES digital data is converted from analog to digital within the instrument and placed into a buffer for readout to the telemetry system. The format of the data within the 1080 bps allocation is arbitrary as far as the OLS and spacecraft are concerned. For convenience, all SSIES data are truncated to 9-bit word as they are stored in the output buffer. Much of the data are the digitized values of the analog outputs from the sensors. Some of the data are the result of digital output from the microprocessor. Table VIII shows the format for one second of SSIES digital data. Word 1 represent bits 1 through 8; word 120 represents bits 1072 through 1080. Word 1 is a master identification word from the microprocessor. Words 2, 7, 12, 17, etc. are the digitized samples of the scintillation meter. Words 3, 8, 13, 18 etc. are the digitized samples of the ion RPA. Words 4, 9, 14, 19, etc. are the digitized output of the Electron Langmuir Probe. Words 5, 15, etc. are the voltages applied to the outer grid of the Electron Langmuir Probe or the retarding grid of the ion RPA.

The analog data are output to the spacecraft as analog signals which are digitized and telemetered down with other engineering status words. The purpose of the SSIES and all other analog data is to provide the flight controller a health check of the instrument. The discrete data inform the controller of the last command sent. The analog and digital data follow different paths after reaching the 1000th Space Operations Group (SOG) at Offutt AFB, and it is very difficult to correlate the two data sets.

TABLE VIII: SSIES DIGITAL DATA FORMAT

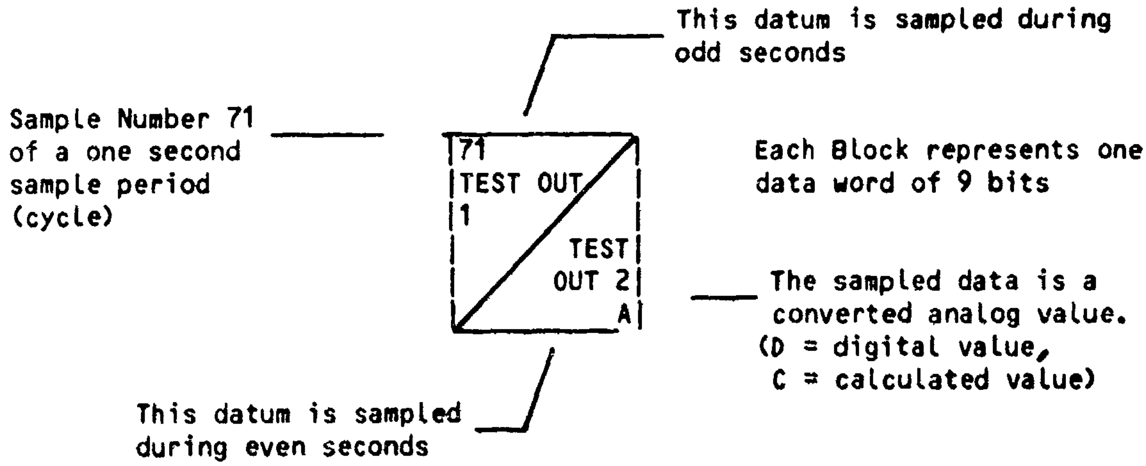
1 CYCLE 1 ID / CYCLE 2 ID	2 SM EL/AMP A	3 ION RPA (NOTE 1) A	4 ELECTRON (NOTE 1) A	5 ELECTRON SWEEP MONITOR A	6 DRIFT METER A	7 SM EL/AMP A	8 ION RPA (NOTE 1) A	9 ELECTRON (NOTE 1) A	10 SM FILTER 7 A
11 SM FILTER 5	12 "	13 "	14 "	15 ION RPA SWEEP MONITOR A	16 "	17 "	18 "	19 "	20 SM FILTER 3 A
21 SM FILTER 1	22 "	23 "	24 "	25 ELECTRON SWEEP MONITOR A	26 "	27 "	28 "	29 "	30 SM FILTER 8 A
31 SM FILTER 6 A	32 "	33 "	34 "	35 ION RPA SWEEP MONITOR A	36 "	37 "	38 "	39 "	40 SM FILTER 4 A
41 SM FILTER 2 A	42 "	43 "	44 "	45 ELECTRON SWEEP MONITOR A	46 "	47 "	48 "	49 "	50 SM FILTER 9 A
51 SM RANGE DATA D	52 "	53 "	54 "	55 ION RPA SWEEP MONITOR A	56 "	57 "	58 "	59 "	60 DM LLA / DM LLB A

TABLE VIII: SSIES DIGITAL DATA FORMAT (continued)

61 DM SIGNAL LEVEL ZERO / DM TEMP	62 "	63 "	64 "	65 ELECTRON SWEEP MONITOR A	66 "	67 "	68 "	69 "	70 CMD MON-OLS / CMD MON-DSM D
71 TEST OUT 1 / TEST OUT 2 A	72 "	73 "	74 "	75 ION RPA SWEEP MONITOR A	76 "	77 "	78 "	79 "	80 EL MON / ION MON D
81 VBIAS + VIP MONITOR A	82 "	83 "	84 "	85 ELECTRON SWEEP MONITOR A	86 "	87 "	88 "	89 "	90 VIP MONITOR D
91 TEMP 1 / TEMP 2 A	92 "	93 "	94 "	95 ION RPA SWEEP MONITOR A	96 "	97 "	98 "	99 "	100 T_e / N_e C
101 T_{H^+} / N_{H^+} C	102 "	103 "	104 "	105 ELECTRON SWEEP MONITOR A	106 "	107 "	108 "	109 "	110 T_{O^+} / N_{O^+} C
111 CURR MONITOR A / VSP C	112 "	113 "	114 "	115 ION RPA SWEEP MONITOR A	116 "	117 "	118 "	119 "	120 VP-EL / VP-ION C

TABLE VIII: SSIES DIGITAL DATA FORMAT (continued)

KEY:



DEFINITIONS:

WORD 1, CYCLE 1

CYCLE 1 ID

MSB								LSB
C	MODE FLAG			TMF	B/M	CLK	PRF	1

C = 1 or 0 , Cycle Counter
Mode Flag = 0, Mode A; = 1, Mode B; = 2, Mode C
= 3, Mode D; = 4, Mode E
TMF = Test Mode Flag = 0 (OFF) or 1 (ON)
B/M = 1 during 8 sec electron sensor bias-setting sweep cycle, 0 otherwise
CLK = 1 if sweep clocks are on
PRF = 1 if program will restart with next cycle beginning

WORD 1, CYCLE 2

CYCLE 2 ID

MSB								LSB
CYCLE COUNTER								0

The cycle counter counts seconds in the mode program. The counter runs from 0 to 1023. The 9 LSB's of the cycle counter are contained in the cycle 2 ID. The MSB of the cycle counter is contained in the MSB of word 1 of the following cycle 1. Each mode program begins at second 1. Modes A, B, and E execute 128 second programs. Modes C and D execute 1024 second programs. For modes C and D, the MSB of the following cycle 1 ID is concatenated with the cycle 2 ID to get the cycle counter value.

WORD 70, CYCLE 1

CMD MON OLS

MSB								LSB
0	Last OLS Command							

See OLS Command Table (Table VI) for explanations of commands.

WORD 70, CYCLE 2

CMD MON DSM

MSB								LSB
S	Last DSM Command							

S = 0, VBIAS ON; S = 1, SENPOT ON (S9 and S10 only)

BIT 8 (MSB) = VBIAS/SENPOT FLAG
0= VBIAS MODE, 1=SENPOT MODE
BIT 7-4 = FBR (ECHOES 4 LSB'S OF DSM CMDS 20(HEX) -3F(HEX))
BIT 3-0 = DREP (ECHOES 4 LSB'S OF DSM CMDS 30(HEX) - 3F(HEX))

The two four bit fields independently update. Command 22(HEX) is used as the Test Mode enable and will not echo in this word. All other commands 20 (HEX) to 3F(HEX) echo. (Command 21(HEX) and Command 23 (HEX) echo only for 1 second and Word 70 then returns to its previous state.)

See DSM command table (Table VII) for explanation of commands.

TABLE VIII: SSIES DIGITAL DATA FORMAT (continued)

WORD	CYCLE	DESCRIPTION
2,7,etc	all	SM Electrometer/Amplifier Output Volts = 0.01 * TM Value
3,8,etc	"	Ion RPA Log Amplifier Output $\log_{10}$(Amps) = 0.01*TM Value-11.30103
4,9,etc	"	Electron Log Amplifier Output $\log_{10}$(-Amps) = (0.06/5) * TM Value - 10.0
5,25, etc	"	Electron Sweep Voltage Volts = 0.16 * (TM Value - 256)
15,35,etc	"	Ion RPA Sweep Voltage Volts = 0.16 * (TM Value - 256)
6,16,etc	"	Drift Meter Offset Output Volts = 0.01 * TM Value
10,11,etc	"	DSM Multiplex Output Volts = 0.01 * TM Value
71	1	Test Output 1 Volts = 0.01 * TM Value = 1.00 V (nominal)
71	2	Test Output 2 Volts = 0.01 * TM Value = 2.00 V (nominal)
80	1	Electron Processing Flags Bit 8 (MSB) = Vp outside sweep range Bit 7 = Io out of range Bit 6 = Vp outside -10 to +41 V Bit 5 = TE > 10,220 °K Bit 4 = Insuff. data range (<1.5 V) Bit 3 = I(V) curve shifted right Bit 2 = I(V) curve shifted left Bit 1 = Slope high (TE < 800) Bit 0 (LSB) = Slope low (TE > 10,000)
80	2	Ion Processing Flags Bit 8 (MSB) = Bad Min/Max current ratio Bit 7 = Bad Temperature ratio Bit 6-5 = Specie flags (0=both,1=H+,2=0+,3=unused) Bit 4 = Vp Ion calculation overflow Bit 3 = TO+ calculation overflow Bit 2 = NO+ calculation overflow Bit 1 = TH+ calculation overflow Bit 0 (LSB) = NH+ calculation overflow
81	all	V_{AP} Monitor Measured Volts = 0.16 * (TM Value - 256)
90	all	V_{BIAS} + V_{IP} Monitor Bits 7-6 = V_{IP} setting Volts = -(TM Value) Bits 4-0 = V_{BIAS} setting Volts = TM Value - 3
91	1	Temperature 1 (@ Electrometer) Deg. C = (TM Value/4) - 35

91	2	Temperature 2 (@ ADC) Deg. C = (TM Value/4) - 35
100	1	Calc. Electron Temperature TE (^{o}K) = 20 * TM Value
100	2	Calc. Electron Density NE (cm^{-3}) = (4.90E+11/SQRT(TE)) * 10.**[(0.06*TM Value)/5-10]
101	1	Calc. H+ Temperature Deg (^{o}K) = 20 * TM Value
101	2	Calc. H+ Density Log10(N_{H}+) (cm^{-3}) = (0.01 * TM Value) + 1
110	1	Calc. O+ Temperature Deg (^{o}K) = 20 * TM Value
110	2	Calc. O+ Density Log10(NH+) (cm-3) = (0.01 * TM Value) + 1
111	1	Input Current (+28 V) mA = 1.33 * TM Value
111	2	Calc. Down-range Relative Plasma Velocity m/sec = (40 * TM Value) - 10000
120	1	Vehicle Potential from Electron Calc. Volts = 0.1 * TM Value - 10
120	2	Vehicle Potential from Ion RPA Calc. Volts = 0.02 * TM Value - 6

NOTE 1:

Ion Sensor values replaced with dummy data during Test 1 Mode
Electron Sensor values replaced with dummy data during Test 2 Mode

The SSIES produces two analog equipment status telemetry (EST) signals which indicate the instrument temperature and the current drawn by the instrument. The range of acceptable values for these signals is shown in Table IX.

TABLE IX: SSIES ANALOG DATA

NAME	EST NO.	NOMINAL VALUE	MAX	MIN
Temp.	A 099	2.40V (35° C)	3.20V (45° C)	1.60V (5° C)
Current	A 100			
S/N 1 & 2		2.87V (382mA)	3.73V (496mA)	2.01V (267mA)
S/N 3		1.93V (257mA)	3.33V (443mA)	1.61V (214mA)

In addition to the analog telemetry, SSIES produces 8 discrete equipment status telemetry signals, D191 through D198. These signals also are used by the controllers to monitor the instrument's status. Signals D191 through D196 echo the last serial command sent to the instrument. D197 is 0 when a reset is in progress and 1 at other times. D198 is 0 during test mode and 1 during normal operations.

4.3. TIMING

SSIES data collected during one second are sent to the Optical Line Scanner (OLS) for recording during the SSIES readgate in the next second. Bits are transmitted from the various special sensors to the OLS at 9990.24 bits/s. The OLS ETC at which the SSIES readgate begins is transmitted in the mission sensor header preceding the mission sensor data. The +/- 2 ms of jitter in the readgate is included in the OLS ETC. Table X shows the times within a second when the OLS begins receiving data from the special sensors.

TABLE X: SPECIAL SENSOR READ GATES

READOUT ORDER	SENSOR	NO. OF 36-BIT WORDS	START TIME	
1	SSIES	30	0.0s	ther al plasma instrument
2	SSM/T	4	0.1081s	microwave radiometer
3	SSJ/4	10	0.1225s	electrostatic analyzer
4	SSB/X	5	0.1586s	x-ray detector
5	SSM/I	91	0.1766s	microwave imager

5. DATA ANALYSIS PROGRAMS AT AFGL

The SSIES data are received at Air Force Global Weather Central (AFGWC), Offutt AFB, NE, within minutes of being received by remote tracking sites. The digital data goes to AFGWC and the analog data goes to the 1000th Space Operations Group. The raw digital data is stored on a disk file in a "first-in, first-out" or "circular file" format. The raw data are processed and used at AFGWC for operational usage. Once a day the raw data are dumped to a magnetic tape for shipment to AFGL for climatological and scientific studies. The magnetic tapes are received at AFGL by U. S. Mail. The raw data are read, edited and copied onto local magnetic tapes (Phase I processing). The raw data are then read and converted into a scientific database (Phase II processing). An overview of the data processing is given in Figure 18.

The SSIES Phase I and II processing will create a database of ionospheric plasma parameters stored on magnetic tapes. Fifteen days of raw data tapes received from AFGWC are input to Phase I. Each input tape contains data from all currently operating DMSP spacecraft. In Phase I, the raw data are sorted by satellite and time ordered. The output from Phase I is one file of raw SSIES data per DMSP satellite per 15 day. The raw SSIES data are packed in 20 x 60 arrays which include 60 sec of SSIES telemetry. There are twenty 60 bit CDC words of data each second. The first 60 bit word contains time in seconds since January 1 of the current year.

SSIES DATA ANALYSIS PLAN

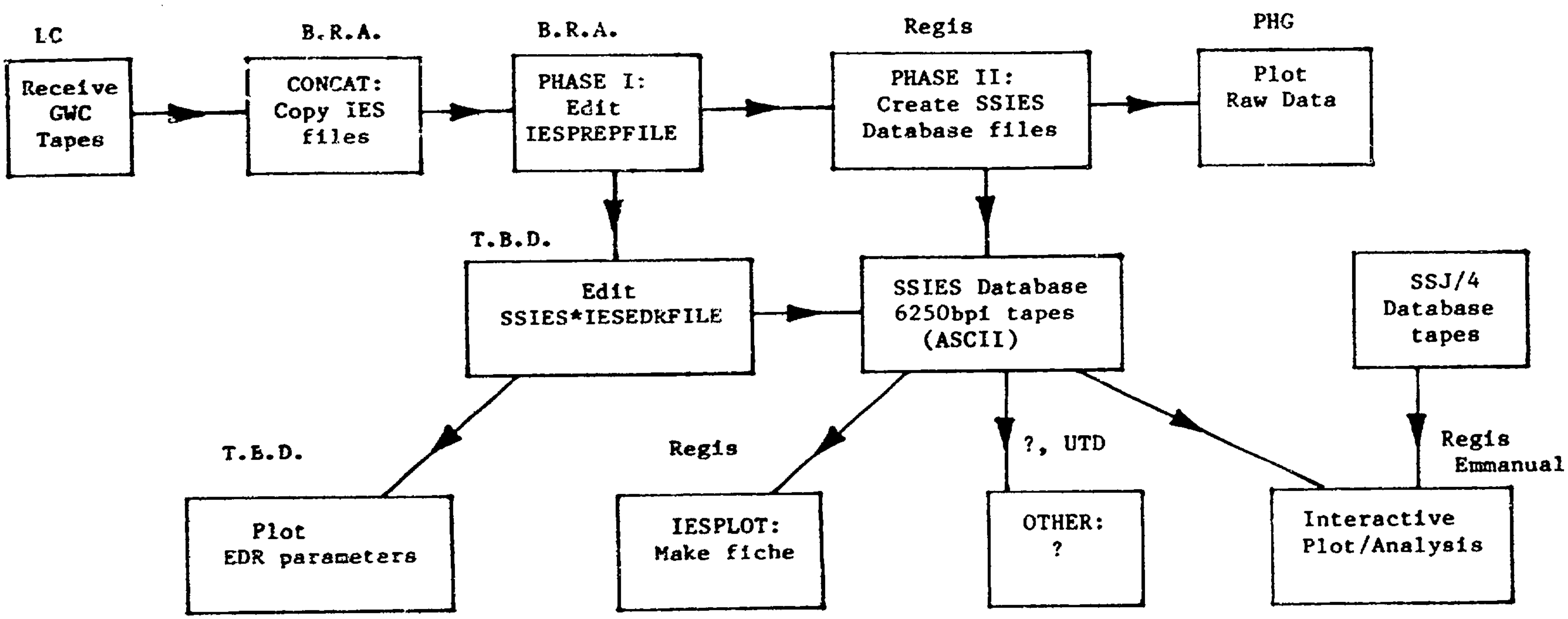


Figure 18

The second is the "SYNC" word, which contains 24 zeros and a fixed 36 bit pattern. Words 3 through 20 contain the 1080 bits of SSIES data transmited every second in the format shown in Table VIII. Each minute, these 1200 words of SSIES data are preceded by six 60 bit CDC words containing ephemeris information and a mapping word. The ephemeris data on the Phase I output tape are listed in Figure 29 of Campbell and Rich (1986). Phase I processing is described in more detail in "The SSIES Database Package" by Campbell and Rich.

In Phase II, the large array containing SSIES telemetry is broken into arrays containing one minute of housekeeping data and one minute of data for each of the four SSIES sensors. The correspondence between these arrays and the 120 word SSIES data format is shown in Table XI. The raw data are then processed into geophysically meaningful parameters including ion and electron temperatures and densities, drift velocities, and spacecraft potential. These parameters along with ephemeris data are written to tape once each minute.

An output tape from Phase II begins with two flags containing the spacecraft ID and the name of the subroutine used to process RPA data. The processed data follows in one minute blocks. Each block begins with the ephemeris for the minute, housekeeping flags, and counters indicating the number of data points from each of the four SSIES sensors. This is followed by

SSIES Phase II Program

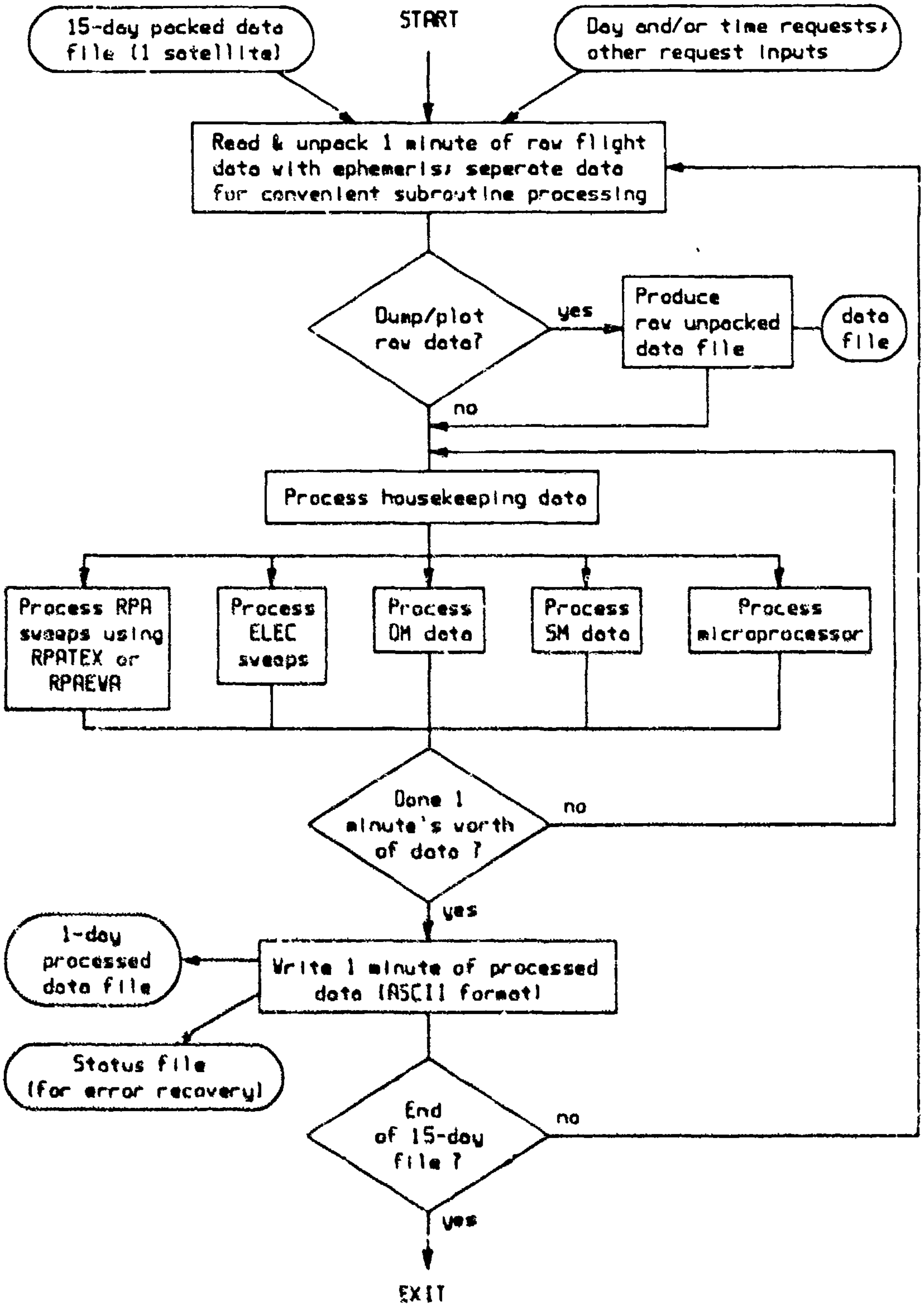


Figure 19

one minute of parameters calculated from each sensor, and finally by the plasma parameters calculated by the on-board microprocessor. Within each minute, parameters based on drift meter data are written to tape first, followed by those based on scintillation meter data, Langmuir probe data, and RPA data. This process is diagramed in Figure 19.

In the immediate future, programs will be developed to plot the data from the database on microfiche. We will make routine survey plots of the following quantities as functions of time: From the drift meter, the components of the drift velocity perpendicular to the satellite's velocity, and an initial computation of the electric fields and along-track potential from the drifts. From the scintillation meter, total ion density and power from the various filters. From the RPA, density of the different ion species, ion temperature, aperture potential, spacecraft potential, and downrange drift velocity. From the Langmuir probe, electron temperature and density and spacecraft potential. We also plan to plot the perpendicular components of the drift velocity and electric field and a better computation of the integrated cross-polar cap potential in geomagnetic polar coordinates. In the future, an interactive analysis program will be developed. This program will be menu driven, and will display data in more detail for short time periods.

TABLE XI: PHASE II PROGRAM VARIABLE NAMES

WORD 1 HKP(1,N)	2 SCIN(1,N)	3 RPA(1,N)	4 ELEC(1,N)	5 SWPMON (1,N)	6 DRIFT(1,N)	7 SCIN(2,N)	8 RPA(2,N)	9 ELEC(2,N)	10 SMFILT (1,N)
11 SMFILT(2,N)	12 SCIN(3,N)	13 RPA(3,N)	14 ELEC(3,N)	15 SWPMON (2,N)	16 DRIFT(2,N)	17 SCIN(4,N)	18 RPA(4,N)	19 ELEC(4,N)	20 SMFILT (3,N)
21 SMFILT(4,N)	22 SCIN(5,N)	23 RPA(5,N)	24 ELEC(5,N)	25 SWPMON (3,N)	26 DRIFT(3,N)	27 SCIN(6,N)	28 RPA(6,N)	29 ELEC(6,N)	30 SMFILT (5,N)
31 SMFILT(6,N)	32 SCIN(7,N)	33 RPA(7,N)	34 ELEC(7,N)	35 SWPMON (4,N)	36 DRIFT(4,N)	37 SCIN(8,N)	38 RPA(8,N)	39 ELEC(8,N)	40 SMFILT (7,N)
41 SMFILT(8,N)	42 SCIN(9,N)	43 RPA(9,N)	44 ELEC(9,N)	45 SWPMON (5,N)	46 DRIFT(5,N)	47 SCIN(10,N)	48 RPA(10,N)	49 ELEC(10,N)	50 SMFILT (9,N)
51 SMFILT (10,N)	52 SCIN(11,N)	53 RPA(11,N)	54 ELEC(11,N)	55 SWPMON (7,N)	56 DRIFT(6,N)	57 SCIN(12,N)	58 RPA(12,N)	59 ELEC(12,N)	60 HKP(2,N) DM LLB

TABLE XI: PHASE II PROGRAM VARIABLE NAMES (continued)

WORD 61 HKP(3,N)	62 SCIN(13,N)	63 RPA(13,N)	64 ELEC(13,N)	65 SWPMON (7,N)	66 DRIFT(7,N)	67 SCIN(14,N)	68 RPA(14,N)	69 ELEC(14,N)	70 HKP(4,N)
71 HKP(5,N)	72 SCIN(15,N)	73 RPA(15,N)	74 ELEC(15,N)	75 SWPMON (8,N)	76 DRIFT(8,N)	77 SCIN(16,N)	78 RPA(16,N)	79 ELEC(16,N)	80 HKP(6,N)
81 HKP(7,N)	82 SCIN(17,N)	83 RPA(17,N)	84 ELEC(17,N)	85 SWPMON (9,N)	86 DRIFT(9,N)	87 SCIN(18,N)	88 RPA(18,N)	89 ELEC(18,N)	90 HKP(8,N)
91 HKP(9,N)	92 SCIN(19,N)	93 RPA(19,N)	94 ELEC(19,N)	95 SWPMON (10,N)	96 DRIFT(10,N)	97 SCIN(20,N)	98 RPA(20,N)	99 ELEC(20,N)	100 HKP(10,N)
101 HKP(11,N)	102 SCIN(21,N)	103 RPA(21,N)	104 ELEC(21,N)	105 SWPMON (11,N)	106 DRIFT(11,N)	107 SCIN(22,N)	108 RPA(22,N)	109 ELEC(22,N)	110 HKP(12,N)
111 HKP(13,N)	112 SCIN(23,N)	113 RPA(23,N)	114 ELEC(23,N)	115 SWPMON (12,N)	116 DRIFT(12,N)	117 SCIN(24,N)	118 RPA(24,N)	119 ELEC(24,N)	120 HKP(14,N)

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