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In-Flight Characteristics of the Topside Ionospheric Monitor (SSIE) on the DMSP Satellite Flight 2 and Flight 4

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FOR THE COMMANDER

John Howard

Chief Scientist

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instrument is limited during daytime operations by a large negative potential caused by the solar panels. During daylight operations, thermal ions are accelerated toward the ion sensor and thermal electrons are deflected away. On F4, a series of four floating bias potentials between the instruments and the spacecraft ground was installed and has proven successful. These bias potentials will be used for SSIE instruments on Flights 5 through 7. Additional design changes for Flights 8 through 10 are discussed. A format for archived data types for Flights 5 through 7 is described.

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In-Flight Characteristics of the Topside Ionospheric Monitor (SSIE) on the DMSP Satellite Flight 2 and Flight 4

1. INTRODUCTION

This is a status report on the Topside Ionosphere Plasma Monitors (SSIE) on the Defense Meteorological Satellite Program (DMSP) Flights 2 and 4 in the Block 5D series. The SSIE (Special Sensor for Ions and Electrons) measures thermal electrons with a spherical Langmier probe and measures thermal ions with a planar retarding potential analyzer. The SSIE is shown in Figure 1 in the F2 configuration. The design and functional characteristics of the F2 instrument and the procedure for analyzing the data have been given previously.[1]

The electron sensor is designed to measure the density, temperature, and variability of thermal electrons. It operates in two modes. In the resting mode (MODE 1) the sensor collects and measures electrons with a constant bias potential applied between the sensor and the spacecraft. In the Langmuir mode (MODE 2) the potential on the sensor is swept from accelerating to retarding potentials. Ideally, the fluctuations in electron current observed in MODE 1 are due to density fluctuations; MODE 2 determines the absolute density as well as the temperature and potential of the spacecraft with respect to the ambient plasma. In actual use,

(Received for publication 17 April 1980)

1. Smiddy, M., Sagalyn, R. C., Sullivan, W. P., Wildman, P. J. L., Anderson, P., and Rich, F. (1978) The Topside Ionosphere Plasma Monitor (SSIE) for the Block 5D/Flight 2 Satellite, AFGL-TR-78-0071, AD A058503.

the variation of the vehicle potential can significantly change the current measured in MODE 1.

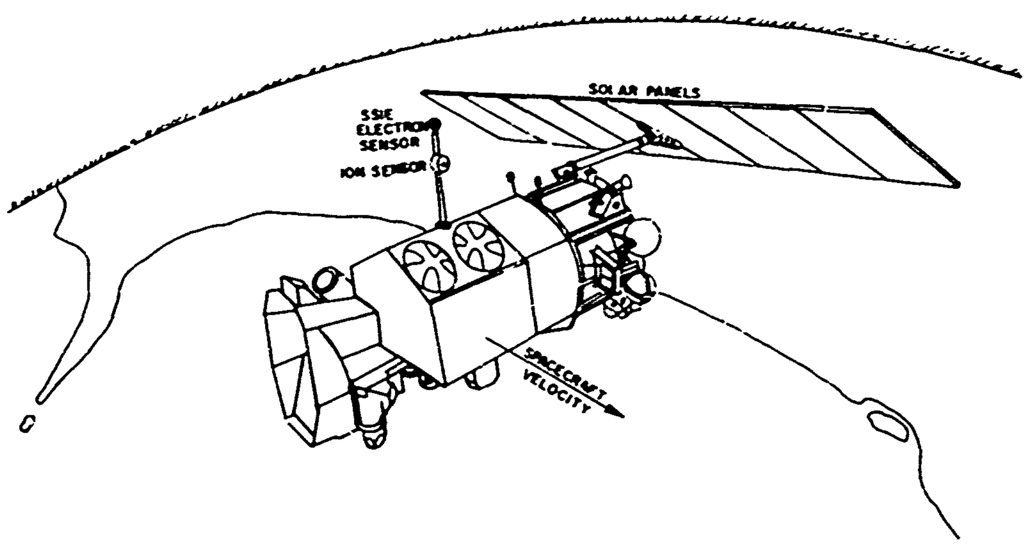

Figure 1. The DMSP Block 5D Spacecraft With the Topside Ionosphere Plasma Monitor (SSIE) in the In-flight Configuration for Flight 2

The ion sensor is designed to measure the density, temperature, average mass, and the variability of the thermal ions. The ion sensor also has a MODE 1 to determine thermal ion variations and a MODE 2 to measure the temperature, density, and average mass. The difference in design from the electron sensor is due to the fact that the spacecraft velocity is greater than the ambient ion thermal velocity and that there may be more than one specie of ion present.

After the launch of F2, it was discovered that the characteristics of the spacecraft were not completely compatible with the design of the SSIE. This report describes the problems in the SSIE data due to the incompatibility with the spacecraft, the uses that the data can be put to with these limitations, and the design changes of future SSIE instruments.

2. RESULTS FROM FLIGHT 2

The DMSP F2 spacecraft was launched in June 1977 into a circular orbit at 840 km. It was not injected into the required orbital plane; as a result the spacecraft had an unintentional drift in local time. At launch, the spacecraft was near 07 and 19 hr local time; in 1979, it was near 10 and 22 hr local time. Also, as a result of the early orbit problems, SSIE data were not available until August 1977.

The SSIE electronics and sensors have operated successfully from turn-on to the loss of the spacecraft in February 1980. Thus, with a few exceptions, there is a continuous data base covering 2-1/2 years. Typical examples of the kind of data available are shown in Figures 2a through 2d which show the total ion density at the spacecraft altitude vs time or latitude. The data have been plotted at the rate of one point per second although there are seven points available each second. Some of the most striking features from Figures 2a through 2d are:

(a) A relatively smooth variation in density at mid-latitudes.

(b) Highly variable density in both the northern and southern polar cap and auroral zones.

(c) The mid-latitude ionospheric trough, most clearly seen in the evening sector.

(d) A sharp, smooth density minimum near the sunrise equator on orbit 1522 and an irregular density minimum near the sunrise equator on orbit 1523 which is typical of "spread F" conditions.

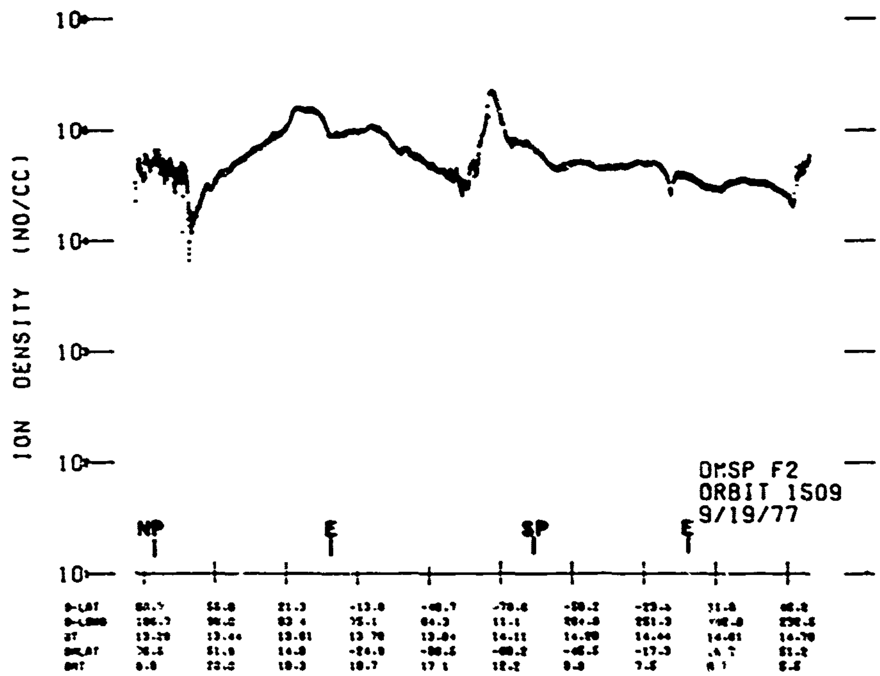

Figure 2a. The Total Ion Density Without Any Correction for Spacecraft Potential or Plasma Drift Speeds for Orbit Number 1509. The data are shown as functions of geographic latitude, geographic longitude, universal time, and corrected geomagnetic latitude and longitude at the projection of the trajectory along the surface of the earth. Data are plotted at a rate of one sample per second

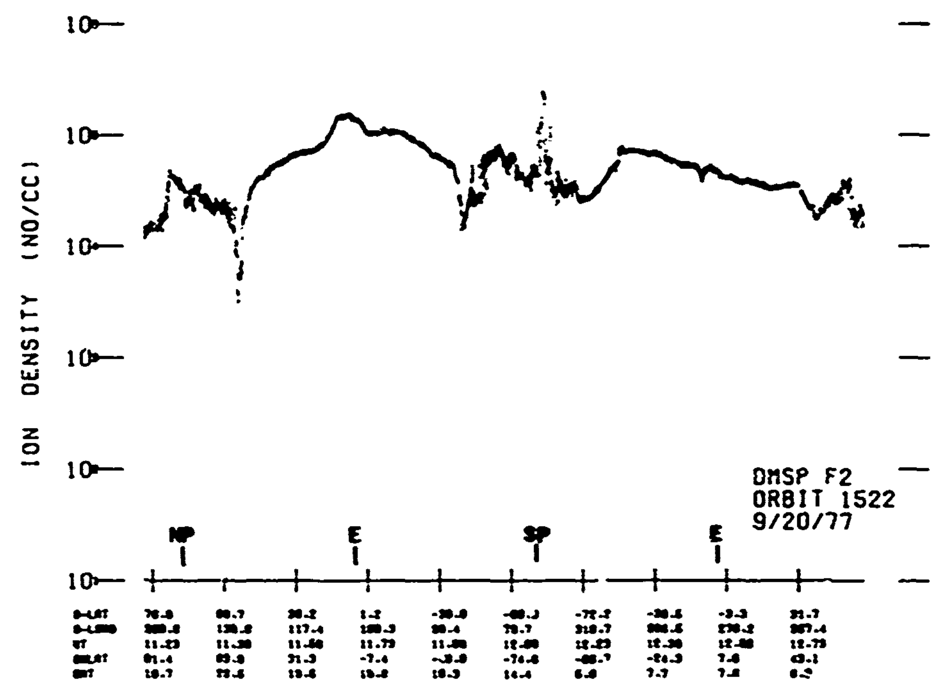

Figure 2b. Total Ion Density as in Figure 2a for Orbit Number 1522

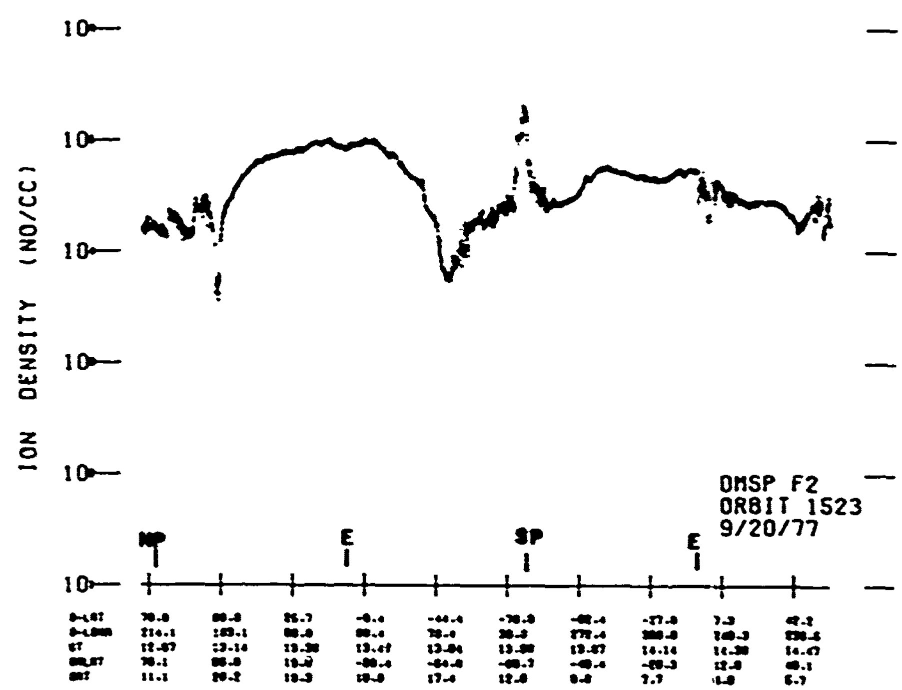

Figure 2c. Total Ion Density as in Figure 2a for Orbit Number 1523

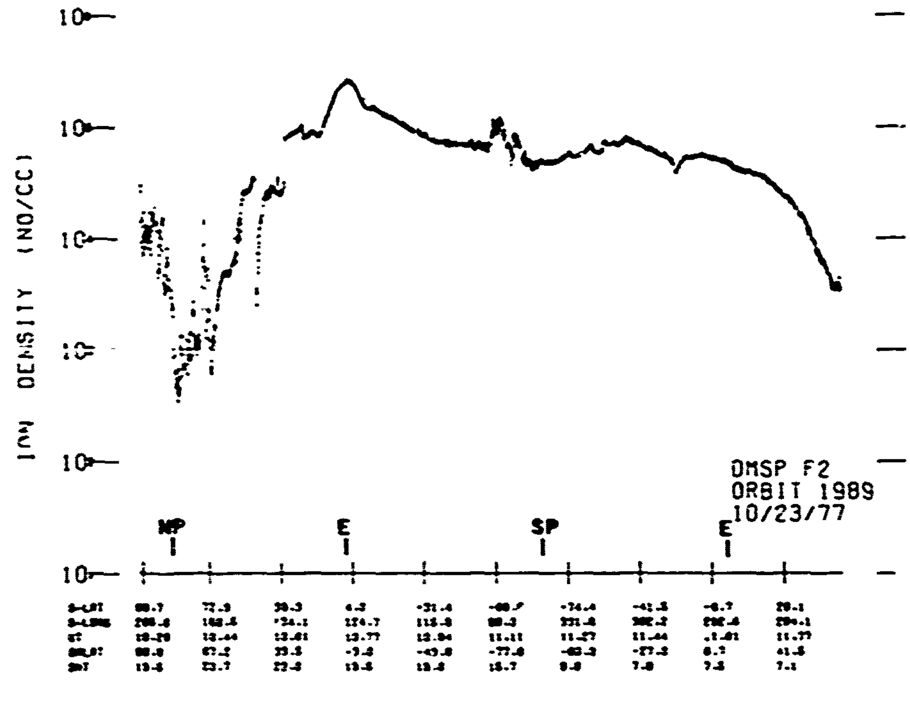

Figure 2d. Total Ion Density as in Figure 2a for Orbit Number 1989

Another feature about Figures 2a through 2d is the fact that the data from MODE 2 operation has been deleted. Although it may not be readily noticeable, there is a 12-sec gap in the ion data each 128 seconds. This is because the MODE 2 operation causes the current to the sensors to vary as a function of applied voltage instead of as a function of the geophysical environment. Figure 3a shows the complete data set during a time when the potential of the spacecraft and the sensors was negative by only a small amount. As noted in the previous report,[1] the event monitor changes level 2 sec before the beginning of the electron or ion sweep and then its reading is swept in sequence with the sweep potential on the electron sensor or on the retarding grid in the ion sensor. The difference in the electron density and ion density plotted during the MODE 1 operation is due to the fact that a significant quantity of thermal electrons are deflected away from the electron sensor by the vehicle potential. The ion sensor is not significantly affected because the energy gained by the ions falling through the potential is not significantly greater than the energy gained from the relative motion of the satellite with respect to the plasma ($\sim$ 0.3 eV for H^+ and 4.6 eV for O^+). In order to get an estimate of the electron density during MODE 1 operation, it is possible to multiply all electron measurements during MODE 1 by the ratio of the electron density deduced from MODE 2 by the uncorrected electron density measured during MODE 1 just before the beginning of the MODE 2 operation.

Figure 3b is an example of the data as the spacecraft travels from darkness to sunlight. In darkness, the spacecraft potential is slightly negative due to the greater mobility of ambient electrons. Prior to launch, it was expected that spacecraft potential in sunlight would increase toward zero potential due to the emission of photoelectrons from the vehicle. As seen in Figure 3b, the current to the electron sensor in MODE 1 operation decreases to minimum sensitivity as the vehicle enters sunlight. When the vehicle first enters sunlight, the accelerating phase of the MODE 2 operation of the electron sensor does collect a few electrons, but after a few minutes in sunlight no electrons are collected at any time. This indicates that the vehicle potential was significantly less than -6 V at the end of the period in Figure 3b. Since the ion sensor was able to retard some of the ion flux at the end of the period in Figure 3b, it would seem that the spacecraft potential was greater than -14 V. However, the ion current vs retarding voltage curve does not fit a theoretical curve well enough to determine the actual spacecraft potential. This failure of the ion sensor data to yield meaningful information is due to two effects: First, the ion density and temperature calculated from the MODE 2 data apply to the plasma in the immediate vicinity of the ion sensor. These values are equivalent to the values of the "ambient" plasma only if the plasma entering the instrument is not disturbed by the presence of the spacecraft. In the presence of large accelerating potentials between the plasma and the instrument, a sheath is formed around the instrument and particles are drawn to the ion sensor and case from all directions in the sheath. For a planar probe with a small surface area in the forward direction compared to the DeBye length of the plasma, the sheath is approximately spherical in shape. Thus it is difficult to relate plasma parameters measured in the sheath to the ambient conditions.

Second, the assumption that no potential from the retarding screens leaks through the aperture screens to the ambient plasma is slightly in error at the largest potential difference between the retarding screens and the aperture screens.

The sunlight conditions shown in Figure 3b are typical of most of the data from the SSIE on the F2 satellite since the majority of data are taken in sunlight. An unknown, large negative (< -14 V) potential invalidates all but the MODE 1 ion data. Even the MODE 1 ion data must be treated with caution since the ion flux to the sensor is enhanced by an unknown factor of the order of 100 percent by the effect of the large negative potential. Occasionally, a low flux of electrons is measured during sunlight conditions during both MODE 1 and MODE 2 operations. Generally, these fluxes have been found to be photoelectrons from the vehicle and sensor grids and/or super-thermal electrons which are typically found in the auroral zones and polar caps.

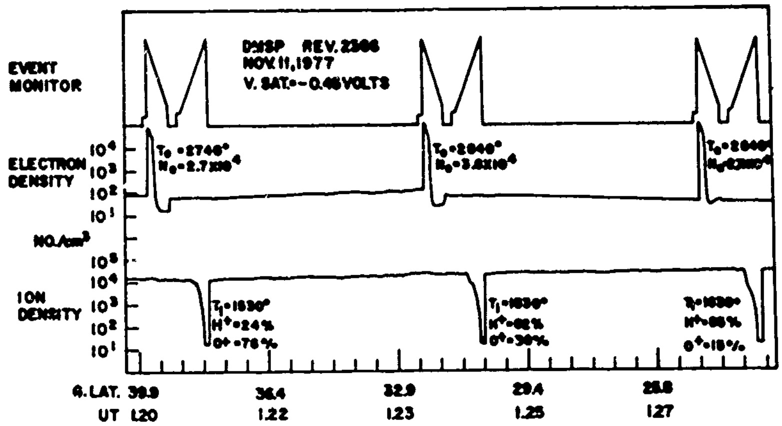

Figure 3a. Plot of All of the Data From the Event Monitor (six samples per sec), the Electron Sensor (seven samples per sec), and the Ion Sensor During Both MODE 1 and MODE 2 Operation. The temperature and densities displayed next to MODE 2 data represent the results of fitting the data to theoretical curves. All of this data was obtained while the F2 satellite was in darkness

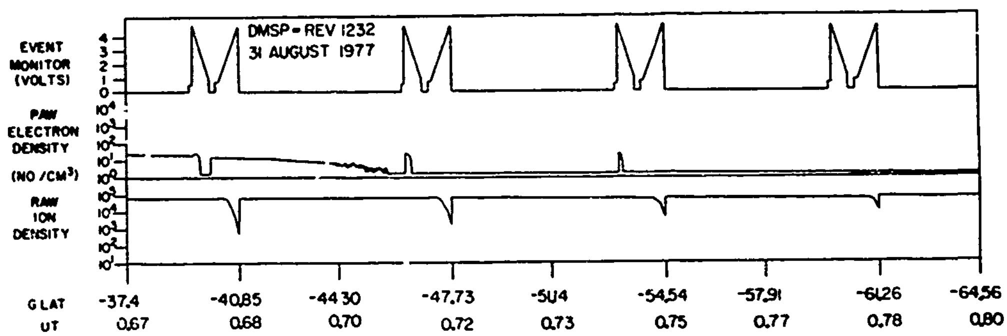

Figure 3b. Plot of All the Data From the SSIE Similar to Figure 3a Except That the Satellite is Crossing From Darkness to Sunlight. The vehicle potential goes more negative in sunlight which deflects electrons away from the sensor and accelerates ions approaching the sensor

2.1 Cause of Large Negative Potential on the Spacecraft

The large negative potential on the spacecraft encountered whenever the vehicle was in sunlight was found to be a result of two factors. First, there are a large number of interconnections between solar cells on the solar panels which are exposed to the ambient plasma. These interconnections can have potentials up to +30 V with respect to the spacecraft conducting frame which is the SSIE reference potential. Second, there is only a small conducting area ($\leq$ 300 in.^{2}) exposed to the ambient plasma on the entire F2 spacecraft. The result is that a large negative charge is drawn from the ambient plasma at the interconnections when the solar cells are operating and there is insufficient exposed conducting area on spacecraft to return the negative current to the plasma by drawing in ions or emitting photoelectrons.

The solar power system on the DMSP Block 5D spacecrafts is composed of solar cells 2 cm by 4 cm in size. Adjacent cells are connected by metal strips 4 cm by 0.04 cm. The cells are arranged in a rectangular matrix on a solar panel 191 cm by 64 cm in size. There are eight solar panels in the solar array as shown in Figure 1. The solar panel is connected to spacecraft ground at one end so that the potential at the other end of the array is +30 V when the solar cells are operating at full power. The actual potential on the end of the solar panel varies as a function of the solar panel attitude to the sun and the power demands of the spacecraft. Figure 4 shows a typical example of the potential across the solar panels as a function of time. The interconnectors between the solar cells have a total exposed area of 1670 cm^2. To provide a return current, there should be a grounded, exposed conducting area on the satellite at least 40 times greater and ideally 6000 times greater. Thus, an exposed conducting area of 1 m^2 would be required to counterbalance the effect of the current drawn to the interconnections.

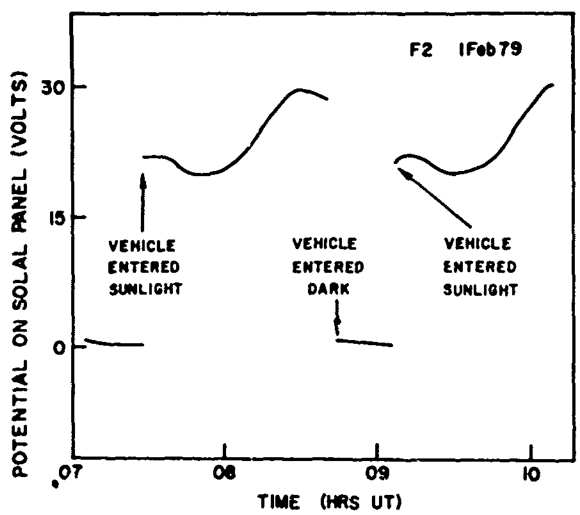

Figure 4. Potential Across the F2 Solar Panel as a Function of Time During a Typical Orbit Period

The large negative potential on the spacecraft could be eliminated by changing one or both of the factors involved. However, such a change or changes would result in a major redesign of the spacecraft which was impracticable. Thus, it has been necessary to design "work-around" characteristics into the SSIE instrument to compensate for the large negative spacecraft potential in sunlight. This has been done for F4 through F7 as described in Section 3.

2.2 Contribution of the F2/SSIE to the Technology Base

Despite some uncertainty in the absolute density of ions near the spacecraft, the MODE 1 ion data from the SSIE on the F2-DMSP spacecraft provides an excellent representation of the distribution of ionization in the topside ionosphere as a function of latitude, longitude, and season. Since the satellite is in a circular orbit, the data from one orbit to another, one day to another, or one season to another can be compared without adjusting for varying altitudes such as is necessary from most spacecraft observations. The collection of data has been nearly continuous so that a complete survey of longitudes can be made fron ch day's data set. Figures 2b and 2c provide an example of the repeatability of the data on consecutive orbits. Figures 2a and 2d provide an example of the seasonal variations in the ionization morphology. Since the satellite orbit is nearly sun-synchronous, it is not possible to survey the ionization variations with local time. This limitation does allow an investigator to compare sets which are separated by many months because local time is not significantly different over such time spans.

The topside ionospheric morphology as described by the DMSP/F2 SSIE instrument has not been thoroughly investigated to date. One feature that has been investigated[2, 3] is the ionization depletion region near the morning side equator near equinox. This feature can be seen in Figures 2a, 2b, and 2d. In Figure 2c, this feature is obscured by spread-F type ionization irregularities near the equator. A more detailed plot of this feature is shown in Figure 5. The feature has been interpreted as region of low nighttime ionization which has not been filled in due to the finite time for ionization to travel along field lines from the production region to the height of the satellite.

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2. Burke, W.J., Sagalyn, R.C., Rastogi, R.G., Ahmed, M., Rich, F., Donatelli, D.E., and Wildman, P.J.L. (1979) Postsunrise refilling of the low latitude topside ionosphere, J. Geophys. Res. 84, A8:4201-4206.

3. Burke, W.J., Sagalyn, R.C., Rastogi, R.G., Ahmed, M., Rich, F., Donatelli, D.E., and Wildman, P.J.L. (1979) Correction, J. Geophys. Res. 84, A12:7386.

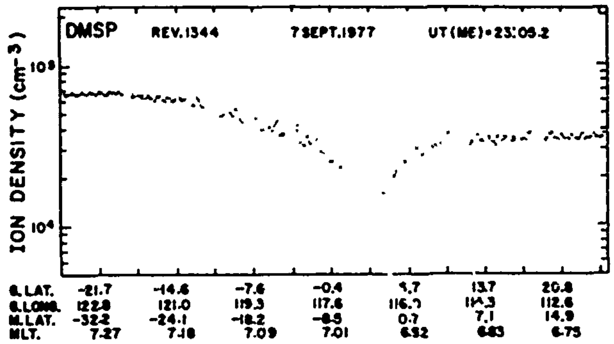

Figure 5. Total Ion Density in the Region of the Ionization Depletion Near the Morning Side Equator During the Equinox Season

3. REDESIGN OF SSIE FOR F4 THROUGH F7

In response to the large negative spacecraft potential on the DMSP Block 5D spacecrafts while they are in sunlight, the SSIE was redesigned to be more compatible with the spacecraft. The redesign was constrained by the need to change the weight, power, and size of the SSIE as little as possible in order to meet budget and scheduling requirements. Figure 6 shows the block diagram for the SSIE instruments for Flights 4 through 7. The most important change from the F2 instrument is the addition of a commandable set of bias potentials to float the SSIE sensor positively with respect to the DMSP spacecraft. Ideally, the bias voltages will be set so that the SSIE sensor will be within a few volts of the potential of the ambient plasma. Unfortunately this is not always possible for several reasons. First, there are only four possible bias voltage levels. This limitation allows the sensors to be as much as 6 V from the plasma potential even with the best possible setting of the bias voltage. Second, operational requirements dictate a scheduling of the bias levels changes weeks in advance where the spacecraft potential changes as a function of the potential across the solar panels (Figure 4) which is not known in advance. In fact, during most of the life of F4, the SSIE bias supply was set to MODE 2 (+6.3 V). During the week of 28 June 1979 to 5 July 1979, the other bias supply modes were exercised by placing the SSIE in one bias mode each day. This gave a base line upon which to schedule bias changes as a function of orbital positions which was accomplished during the week of 5 November 1979 to 12 November 1979. The four bias modes were cycled through each orbit in a manner that approximately followed the spacecraft potential. Third, the spacecraft potential as measured by the SSIE does not instantaneously follow the potential changes across the solar panel. For example, it has been found that it requires approximately 10 min after the entry into darkness for the spacecraft's excess negative potential to dissipate.

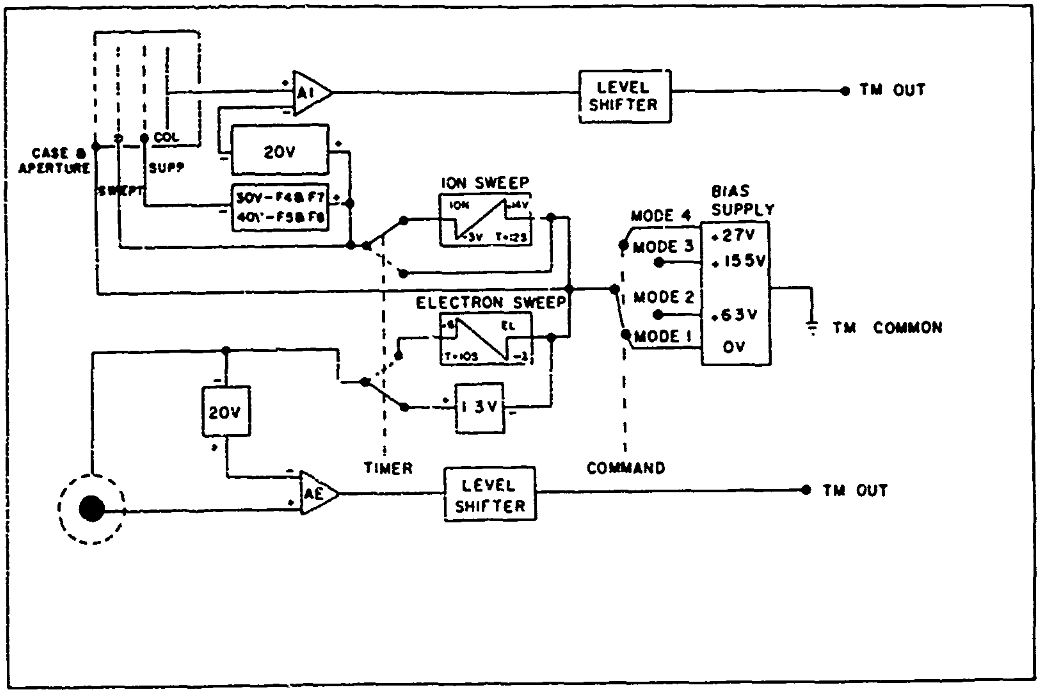

Figure 6. Block Diagram for the SSIE System for DMSP Block 5D Flights 4 Through 7

There are several other changes to the SSIE instrument besides the addition of the commandable bias supply for the instrument. The bias voltage to the electron sensor has been made so that it is always on during MODE 1 operations. The housekeeping word 49 is now used to output the bias mode for the whole instrument instead of the electron sensor bias mode. The outputs to the mode monitor are shown in Tables 1, 2, and 3 for the F4, F5, and F6 instruments. The pre-flight calibration of the ion and electron sensors for F4, F5, and F6 are also given in Tables 1, 2, and 3. The range of voltages have been changed to -3 V to +14 V for the ion sensor and +6 V to -6 V for the electron sensor. The timing sequence of the SSIE instruments are the same as the F2 instrument except that the repetition rate for the ion and electron sweeps (MODE 2 operations) has been changed from

128 sec to 64 seconds. For F5, F6, and F7, the bias supply monitor level is output on the event monitor during calibration 2. For F5 and F6, the electron suppressor voltage difference between the suppressor screen and the collector plate in the ion sensor has been increased from 10 V to 20 V.

Table 1. SSIE Laboratory Calibration, Block 5D, F4, +20°C

Event Monitor Levels

Calibration 1:	+0.20 V
Calibration 2:	+0.40 V
Electron Sweep Flag:	+0.60 V
Electron Sweep:	+5 V → +1 V
Ion Sweep Flag:	0.80
Ion Sweep:	+1 V → +5 V

Electron Sensor

Calibration 1 (10^{-6} A): 4.15 V
Calibration 2 (10^{-9} A): 0.83 V

-I	10^{-10}	10^{-9}	10^{-8}	10^{-7}	10^{-6}	10^{-5}
1	0.00	0.84	1.66	2.49	3.32	4.15
2	0.25	1.09	1.91	2.74	3.57	4.40
3	0.40	1.23	2.06	2.69	3.72	4.55
4	0.50	1.33	2.16	2.99	3.82	4.65
5	0.58	1.42	2.24	3.07	3.90	4.73
6	0.65	1.48	2.31	3.13	3.97	4.80
7	0.7	1.53	2.36	3.19	4.02	4.86
8	0.76	1.58	2.41	3.24	4.07	4.91
9	0.80	1.63	2.45	3.29	4.11	4.95
10	0.84	1.67	2.49	3.32	4.15	4.99

Ion Sensor

Calibration 1 (5×10^{-8} A) : 3.99 V
Calibration 2 (5×10^{-11} A): 1.00 V

+I	10^{-12}	10^{-11}	10^{-10}	10^{-9}	10^{-8}	10^{-7}
1	-	0.32	1.30	2.30	3.30	4.29
2	-	0.61	1.61	2.60	3.60	4.60
3	-	0.79	1.78	2.78	3.77	4.77
4	-	0.91	1.89	2.90	3.90	4.89
5	0.00	1.01	2.00	3.00	3.99	4.99
6	0.11	1.09	2.08	3.08	4.07	5.06
7	0.16	1.15	2.15	3.14	4.14	
8	0.21	1.20	2.20	3.20	4.20	
9	0.25	1.25	2.25	3.25	4.25	
10	0.30	1.30	2.30	3.30	4.29	

Table 2. SSIE Laboratory Calibration, Block 5D, F5, +20°C

Event Monitor Levels:

Calibration 1:	+0.20 V		
Calibration 2:	BIAS MODE 1	+0.00 V	
	BIAS MODE 2	+0.96 V	
	BIAS MODE 3	+2.41 V	
	BIAS MODE 4	+4.15 V	
Electron Sweep Flag:	+0.60 V		
Ion Sweep Flag:	+0.79 V		

Electron Sensor

Calibration 1 (10^{-6} A): 4.15 V

Calibration 2 (10^{-9} A): 0.85 V

-I	10^{-10}	10^{-9}	10^{-8}	10^{-7}	10^{-6}	10^{-5}
1	0.03	0.86	1.68	2.51	3.34	4.16
2	0.29	1.11	1.93	2.76	3.59	4.41
3	0.43	1.26	2.08	2.91	3.73	4.56
4	0.53	1.36	2.18	2.01	3.83	4.66
5	0.61	1.44	2.26	3.09	3.91	4.74
6	0.68	1.51	2.33	3.15	3.98	4.81
7	0.73	1.56	2.38	3.21	4.04	4.86
8	0.78	1.61	2.43	3.26	4.08	4.91
9	0.82	1.65	2.47	3.30	4.13	4.95
10	0.86	1.69	2.51	3.34	4.16	4.99

Ion Sensor

Calibration 1 (5×10^{-8} A): 4.01 V

Calibration 2 (5×10^{-11} A) 1.04 V

+I	10^{-12}	10^{-11}	10^{-10}	10^{-9}	10^{-8}	10^{-7}
1		0.37	1.34	2.33	3.32	4.31
2		0.66	1.64	2.63	3.61	4.61
3		0.82	1.81	2.80	3.79	4.78
4		0.94	1.93	2.93	3.91	4.90
5	0.05	1.04	2.03	3.02	4.01	5.00
6	0.15	1.10	2.11	3.10	4.09	
7	0.23	1.18	2.17	3.17	4.15	
8	0.28	1.24	2.23	3.23	4.21	
9	0.32	1.30	2.28	3.27	4.26	
10	0.38	1.34	2.33	3.32	4.31	

Table 3. SSIE Laboratory Calibration, Block 5D, F6, +20°C

Event Monitor Levels

Calibration 1:	+0.20 V	
Calibration 2:	BIAS MODE 1	+0.00 V
	BIAS MODE 2	+0.97 V
	BIAS MODE 3	+2.32 V
	BIAS MODE 4	+4.14 V
Electron Sweep Flag:	+0.60 V	
Ion Sweep Flag:	+0.79 V	

Electron Sensor:

Calibration 1 (10^{-6} A) +4.14 V

Calibration 2 (10^{-9} A) +0.84 V

+I	10^{-10}	10^{-9}	10^{-8}	10^{-7}	10^{-6}	10^{-5}
1	0.01	0.85	1.66	2.49	3.32	4.14
2	0.26	1.09	1.91	2.74	3.57	4.39
3	0.41	1.24	2.06	2.88	3.71	4.53
4	0.51	1.34	2.16	2.99	3.81	4.64
5	0.59	1.42	2.24	3.07	3.89	4.72
6	0.66	1.48	2.31	3.13	3.96	4.78
7	0.71	1.54	2.36	3.19	4.01	4.84
8	0.78	1.59	2.41	3.24	4.06	4.89
9	0.80	1.63	2.45	3.28	4.10	4.93
10	0.84	1.67	2.49	3.31	4.14	4.97

Ion Sensor

Calibration 1 (5×10^{-8} A) +4.00 V

Calibration 2 (5×10^{-11} A) +1.06 V

+I	10^{-12}	10^{-11}	10^{-10}	10^{-9}	10^{-8}	10^{-7}
1		0.33	1.33	2.33	3.31	4.30
2		0.63	1.63	2.62	3.61	4.60
3		0.81	1.81	2.77	3.78	4.77
4		0.93	1.93	2.92	3.91	4.89
5	0.02	1.04	2.03	3.01	4.00	4.99
6	0.12	1.12	2.10	3.09	4.08	5.07
7	0.18	1.18	2.17	3.16	4.15	
8	0.25	1.24	2.23	3.22	4.21	
9	0.29	1.28	2.28	3.27	4.25	
10	0.33	1.33	2.32	3.31	4.30	

In addition to the above mentioned changes to the SSIE electronics packages for F4 through F7, a flexible ring has been mounted around the ion sensor (Figure 7). The purpose of the ring is to provide a wide flat surface around the aperture of the ion sensor. The ring is 10 in. in diameter and 0.25 in. thick. The ring is composed of a space qualified foam rubber developed by RCA. The ring is covered with aluminum foil covered by Kaptan foil on both the front and back surfaces. The Kaptan surface on the front surface is covered with an additional layer of aluminum. The ring is clamped to the case of the ion sensor so that the front aluminum surface is in electrical contact with the ion sensor case and in turn with the SSIE system.

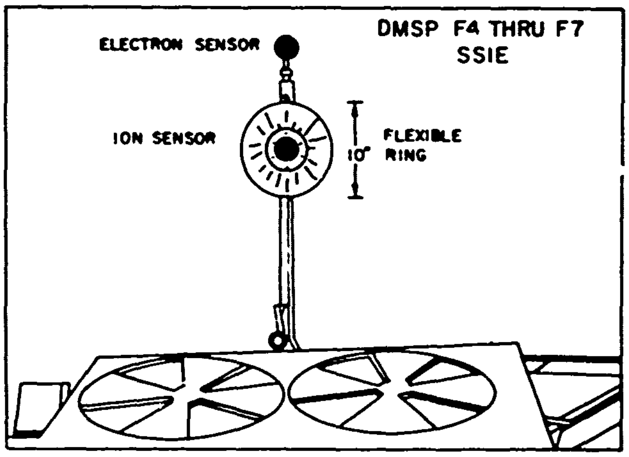

Figure 7. SSIE Instrument in the Deployed Configuration for Flights 4 Through 7

4. DATA REDUCTION FOR SSIE

Data from the SSIE are transferred at 1-sec intervals to the spacecraft digital data system (OLS) as described in the previous report[1] and stored in the onboard tape recorders. Approximately once per orbit the data are transferred to a ground station. Then from a ground station to a communications satellite which transmits the signal to Global Weather Central (GWC), Offutt AFB, Nebraska. Occasionally, only part of an orbit of data is transmitted to a ground station. The remaining data will be readout on a future ground station pass. As a result, a user may have to search two or three orbital records to find all the data from one orbit.

At GWC, the SSIE data is placed in a disk file which is designed to hold slightly more than one day's worth of data at a time. As a read-out of data is received at GWC, the oldest read-out of data is erased from the disk. Once a day, the SSIE data are dumped to a magnetic tape which is shipped to the Air Force Geophysics Laboratory (AFGL). (In the future, a second magnetic tape will be sent to NOAA to be archived.) If there is any hardware or software failure in making the SSIE magnetic tape, all the data for one day will be lost. The magnetic tape received by AFGL contains the raw data from the SSIE plus ephemeris information. There have been times when the time tag for the data is in error by one DMSP cycle (2 min). The only way to verify the time tag is to correlate ground features in the optical data with the time tags.

4.1 Processing Capabilities at AFGL

The SSIE data tapes received from GWC are stored until a request is made for a data set to be processed. The processed data is saved at AFGL and can be made available upon request to R.C. Sagalyn, AFGL-PHG, Hanscom AFB, MA 01731, USA.

The SSIE data can be processed into one or more of the forms described below. The raw output from the ion and electron sensor during MODE 1 operations can be converted into "uncorrected" densities using the in-flight calibration levels, but not adjusting for measurements of density found during MODE 2 operations. The densities are then plotted as a function of time as shown in Figures 2a through 2d for the ion data. The electron data can also be plotted in the same format as Figures 2a through 2d, but problems with negative vehicle potentials make the electron data less useable. The plots shown are drawn with a CALCOMP machine onto 11-in. wide paper. Typically the time scale is 10 min per in. in the length dimension with one data point each 5 sec plotted which is useful for making global surveys of the ionosphere morphology, but is not very good for small scale details. The plotting format in Figures 2a through 2d can be expanded to any length scale, but the program is limited to plotting no more than one point per second. Figure 4 shows all of the data obtained in a small time period but this plot format is not generally available. To display all of the data in a given time period it is necessary to use the format shown in Figures 3a and 3b. The data obtained from MODE 2 operations can be displayed separately as shown in Figure 8. The results of the analysis of the MODE 2 data to determine the electron and ion temperatures and the vehicle potential are printed out on paper which is saved with the plotted data. Due to the large negative vehicle potentials, there has been very little valid MODE 2 data to date, and thus the analysis of the MODE 2 data is often omitted.

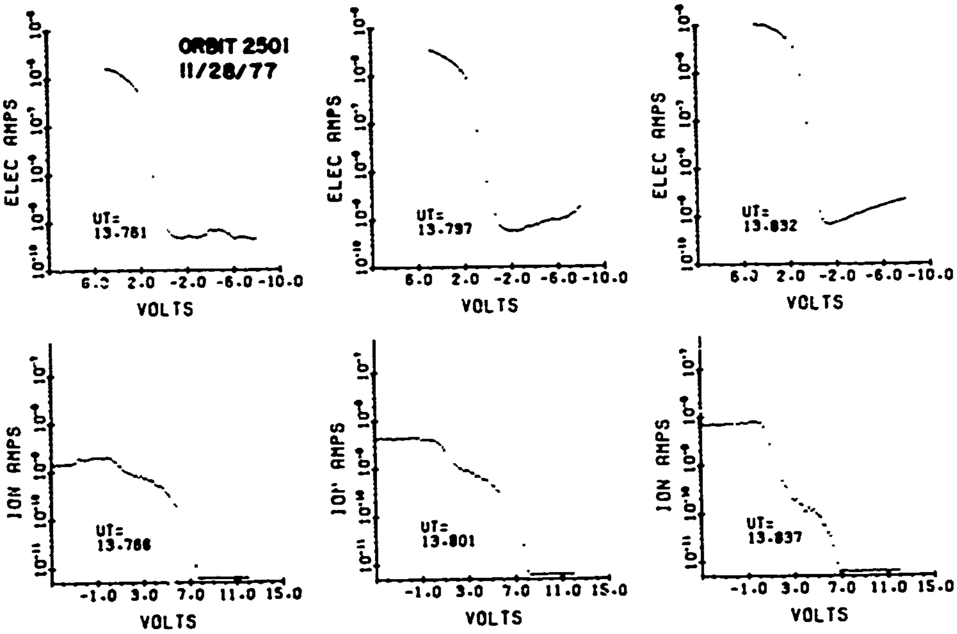

Figure 8. An Example of the MODE 2 Data (swept voltage operations) From the SSIE. The upper plots are from the spherical electron sensor and are typical of Langmuir probe data in a large Debye length with respect to the size of the instrument. The lower plots are from the ion sensor when it is in plasma composed of H^+ and O^+

4.2 MODE 2 Electron Data Reduction Procedure

The method of reducing the MODE 2 electron data has been found to be inappropriate for much of the SSIE data because the method previously given[1] did not appropriately account for the digitization of the data. The result was a computation of the vehicle potential that was 5 V too negative and an electron density that was too high by an order of magnitude when valid MODE 2 electron data were available. The electron temperature was generally accurate if the data were valid.

A new procedure for the analysis of the electron data is:

(1) The MODE 2 data are first searched for "gliches": (obvious random noise in the data stream) which are discarded,

(2) The maximum and minimum currents are found and all data obtained before the maximum current and all data after the minimum current were discarded. If the maximum current is equivalent to the instruments saturation level, all data in the saturation level is discarded,

(3) The first four points after the maximum current are fitted to a straight line,

(4) The span of valid data is searched by making a straight line fit through each group of four adjacent points in order to find the maximum absolute value of the slope of $\log_{10}$ (electron current) vs applied voltage. If two or more fits give equal maximum slopes, take the first maximum. Let the slope of this line be S.

(5) The intersection of the lines found in steps (3) and (4) is found and the potential at the intersection is labeled φ_o. The potential of the spacecraft with respect to the plasma (φ_p) is given as $-\varphi_o - \varphi_{bias}$ where φ_{bias} is the bias potential added to the SSIE instrumentation for F4 through F7.

(6) The electron temperature is given as

$$T_e = 5040 / S \ ^\circ K .$$

(7) The electron density is given as

$$N_e = 2I_o \sqrt{\pi} \times 10^6 / (Ae\alpha a) \text{ cm}^{-3}$$

$$= 6.896 \times 10^9 \ I_o S \text{ cm}^{-3},$$

where

I_o = electron current to the sensor at φ_o
A = surface area of the sensor
e = electron charge
α = transparency of the outer sphere = 0.80
a = $(2KT_e/me)^{1/2}$ = mean thermal speed of electrons.

(8) The solution is checked to insure reasonable values. The following are considered reasonable values for this sensor

$$500^\circ K \le T_e \le 20,000^\circ K$$

$$N_e > 200 \text{ cm}^{-3} .$$

If the calculated values are unreasonable, default values are substituted for the calculated results.

4.3 Data to be Archived by NOAA

It is intended that the SSIE data will be made available to the general public via the World Data Center operated by the National Oceanographic and Atmospheric Administration (NOAA). Data tapes will be made in a standard format at GWC and sent to NOAA. The tapes will consist of 420 words per record (36 bits per word). Each record will contain one minute's worth of data. The format of each record is given in Table 4. The SSIE data itself is given as PCM counts where each count is equivalent to 10 mV. (Data types for F2 and F4 are not and will not be made available from NOAA.)

Table 4. SSIE Data Tape Format for NOAA

Word No.	Word Type I = Integer F = Floating	Description of Contents
1	F	Latitude of s/c at T_1, -PI/2 to +PI/2
2	F	Longitude of s/c at T_1, 0 to 2 PI, CAST
3	F	Altitude at T_1, n. mi
4	I	Julian Date at T_1, 1-366
5	I	T_1, see from 0000z on J. D., at first data point in the record
6	F	Latitude of s/c at T_2
7	F	Longitude of s/c at T_2
8	F	Altitude of s/c at T_2
9	I	Julian Date atT_2
10	I	T_2, time at last data point in the record
11	F	x, earth centered coord., at T_1, unit vector
12	F	y, earth centered coord., at T_1, unit vector
13	F	z, earth centered coord., at T_1, unit vector
14	F	x, earth centered coord., at T_1, unit vector
15	F	y, earth centered coord., at T_1, unit vector
16	F	z, earth centered coord., at T_1, unit vector
17	F	Orbit anomaly angle, 0 to 2PI, at T_1
18	F	Orbit anomaly angle, 0 to 2 PI, at T_2
19	I	J. D. of latest sweep pair start time, 1-366 (The "latest" sweep pair is either the MODE 2 sweep pair that started in the present minute of data, or, if no sweep pair started in the present minute, the sweep pair that started in the preceding minute.)

Table 4. SSIE Data Tape Format for NOAA (Cont)

Word No.	Word Type I = Integer F = Floating	Description of Contents
20	I	T_0, sec from 0000z, time at the start of the latest electron sweep +5 seconds.
21	F	Calculated electron density from MODE 2 in preceeding minute, cm^{-3}
22	F	Calculated electron density from MODE 2 at T_0, cm^{-3}
23	F	Ratio of calculated electron density from MODE 2 at T_0, to the raw electron density during preceeding MODE 1
24	F	Ratio of calculated electron density from MODE in preceeding minute to the raw electron density during preceeding MODE 1
25	F	T_e, electron temperature calculated from MODE 2 at T_0, deg K
26	F	Vehicle potential calculated from MODE 2 at T_0, volts
27	F	H^+ density calculated from ion MODE 2 at T_0 +17 sec, cm^{-3}
28	F	O^+ density calculated from ion MODE 2 at T_0 +17 sec, cm^{-3}
29	F	T_i, average ion temperature calculated from ion MODE 2 at T_0 +17 sec, cm^{-3}
30	F	Average ion mass calculated from ion MODE 2 at T_0 +17 sec, amu
31	F	Vehicle potential calculated from ion MODE 2 at T_0 +17 sec, volts
32	F	Scale height calculated from MODE 2 at T_0 and T_0 +17 sec, Km
33	-	BLANK
34	-	BLANK
35	-	BLANK
36	-	BLANK
37	F	AINE, Conversion factor for electron sensor calculated from calibration times
38	F	BSLE, Conversion factor for electron sensor calculated from calibration times

Table 4. SSIE Data Tape Format for NOAA (Cont)

Word No.	Word Type I = Integer F = Floating	Description of Contents
39	F	AINI, Conversion factor for ion sensor calculated from calibration times
40	F	BSLI, Conversion factor for ion sensor calculated from calibration times
		(Current to the electron sensor I_e = AINE + BSLE * V_e(TM) * 0.01 Current to the ion sensor I_i = AINI + BSLI * V_i(TM) * 0.01 where V_e(TM) and V_i(TM) are the outputs to the telemetry for the electron and ion sensor, 0-5 V)
41-60	-	BLANK
61	I	First 16 bits are time in seconds from 0000z, for first second of data in the minute, divided by 2. Remaining bits are the synch word.
62	I	Data words 4, 3, 2, 1, from TM stream. The 4th word is in the first 9 bits, the 3rd word is in the second 9 bits, and so on.
63	I	Data words 8, 7, 6, 5 from TM stream for time in word 61
64	I	Data words 12, 11, 10, 9 from TM stream for time in word 61
65	I	Data words 16, 15, 14, 13 from TM stream for time in word 61
66	I	Data words 20, 19, 18, 17 from TM stream for time in word 61
		(Each of the three outputs from the SSIE are equally spaced throughout the 1-sec interval and arranged so that electron data is words 1, 4, 7, 10, 13, 16, 19; ion data words 2, 5, 8, 11, 14, 17, 20; and event monitor data is in words 3, 6, 9, 12, 15, 18.)
67-72	I	Same format as 61-66 for second second of data in the minute.
73-78	I	Same formst as 61-66 for third second of data in the minute.
	and so on	
415-420	I	Same format as 61-66 for 60th second of data inthe minute.

5. PRELIMINARY PLANS FOR SSIE/S

In order to meet the information requirements of the Air Force about the topside ionosphere and to fit the characteristics of the DMSP Block 5D satellite, a major redesign has been proposed and given the name Special Sensor for Ion and Electron Scintillation (SSIES). The major features of the new instrument consist of the addition of a scintillation meter ($\Delta N/N$), a drift meter and a micro-processor to determine in real time the vehicle potential, the ion and electron density and temperature, and the scale height-information. A schematic of the SSIES sensor array mounted on the boom is shown in Figure 9.

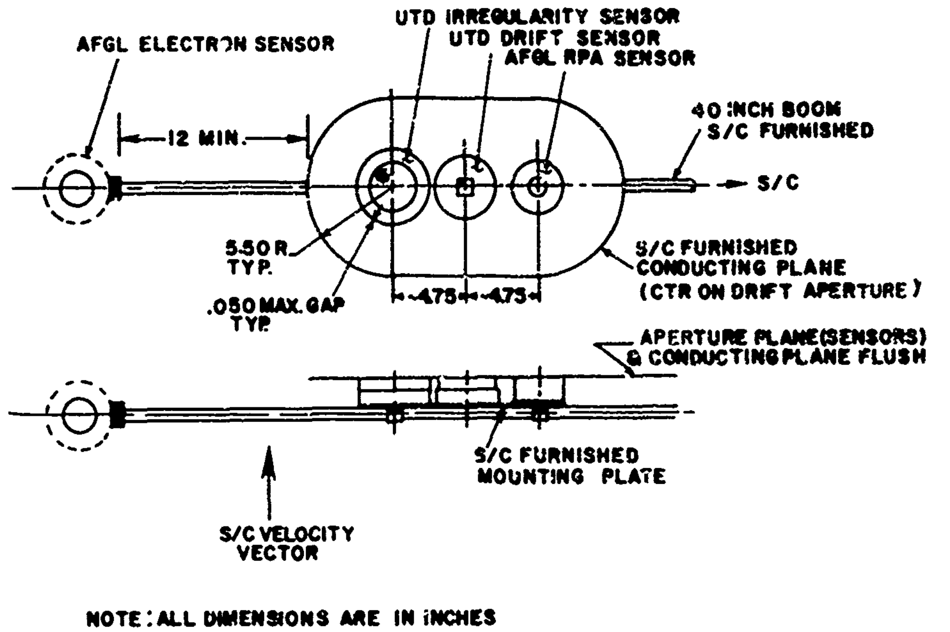

Figure 9. Schematic for SSIE/S Instrumentation

SPECIFICATIONS

Weight	-	16 lb
Power	-	10 W
Telemetry	-	1080 bits/sec (120, 9-bit words)
Commands	-	44
Electron Sensor	-	24 samples/sec
	-	MODE 2 -3 V to +3 V in 4 sec
	-	MODE 2 repetition rate 4 sec or 32 sec
	-	Density range 1000°K to 15,000°K
Scintillation Monitor		
	-	24 dc (MODE 1) sample/second
	-	9 ac filters for $\Delta N/N$ from 12 Hz to 12 KHz output once per second
	-	sensitivity range $\Delta N/N$ 0.01 percent to 100 percent
Drift Meter		
	-	12 samples per component per perpendicular to sensor
	-	range 50 m/sec to 1.6 km/sec
Microprocessor		
	-	calculates vehicle potential and other plasma parameter each 4 sec
	-	sets bias supply voltage in 1 V steps from -3 V to +28 V
	-	computes electron and ion densities and temperatures