MEASUREMENT OF SPACE ENVIRONMENT ON SPACE FLYER UNIT

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ABSTRACT

SFU (Space Flyer Unit), a retrievable experiment platform, was launched by the third H-rocket in March 1995. It reached the mission orbit at the height of 486 km circular. The SFU carried totally 6 diagnostic packages to measure the gas, plasma, wave, micro-g, photo emission and magnetic field. The objectives of the diagnostic packages were ; 1) study of the interaction between spacecraft and the space medium, 2) evaluation of micro-g environment for the material experiment, and 3) acquisition of environmental data for the science and technology experiments. The diagnostic system was operated almost regularly for approximately 7 months. The plasma environment, surface potential, electromagnetic environment, density and composition of the surface gas, deterioration of test materials have been studied. This paper presents the preliminary results of the environmental data analysis. The efforts of scientific data analysis have been focused on ; 1) change of surface gas environment for more than half a year, 2) plasma density, potential and disturbances almost simultaneously measured at 4 different points, and 3) dynamic spectrum up to 30Hz of micro-g environment. The results will be applied to the research of the fundamental processes of plasma diffusion and its stability and the space plasma phenomena. They will also be applied to predict the environment of large space structures, such as the space station and solar power satellite.

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1. INTRODUCTION

Artificial space environment is induced surrounding spacecraft that moves with a high velocity more than ion acoustic velocity. Particle and electromagnetic environment generated by the interaction between spacecraft and the space medium is considerably different from the natural space environment. The study of the physical processes involved in the formation of spacecraft-induced environment is closely related to the fundamental plasma physics and space plasma physics. Since spacecraft-induced environment is the environment that the astronauts and instruments on spacecraft really experience, it is important to clarify the environment surrounding spacecraft in terms of utilization of space environment.

Varieties of particle and electromagnetic effects are induced surrounding spacecraft. In the ram side, ion beams are produced by plasma reflection at the spacecraft surface. The reflected particles will interact with the surrounding space plasma, generating a kind of shock structure in the front. A void region is formed downstream from which gas and plasma are excluded. The density gradient of plasma will excite plasma instabilities, electrostatic waves and associated plasma heating. The electric field near the spacecraft is controlled by the space potential of the spacecraft, which is determined by balancing the current flowing into the spacecraft from the space plasma and photoelectrons emission from the spacecraft surface. Gas leakage from the cabin, outgassing from the onboard instruments and thruster operation will induce gas-plasma interaction. Collisional interaction, such as charge transfer, will generate a plasma cloud moving with spacecraft. Gas-plasma interaction in the magnetic field may excite lower hybrid instability and associated gas ionization effect. Spacecraft with a high voltage system excites strong electromagnetic turbulence by accelerating the charged particles and generating current loops in the surroundings.

The spacecraft-induced environment is usually so much complicated because it involves a lot of physical processes. It is a kind of magnetosphere in miniature. It will be impossible to understand the whole structure of spacecraft-induced environment unless all the basic physical parameters are measured at many points surrounding spacecraft. The environment diagnostic system for SFU, consisting of a various kind of diagnostic sensors, was developed for the purpose of studying the spacecraft-induced environment.

The SFU diagnostic system has two packages (SEM and SPDP) on the platform exposed to the space environment and four small packages (PEM) inside the four payload storage boxes. SEM consists of 2 vacuum gauges, a mass spectrometer, 4 plasma probes, 4 potential detectors, 2 wave receivers, a micro-g meter. SPDP has a spectrometer, a magnetometer, and an electron density fluctuation detector. Both packages also carried test materials to study the surface-space medium interaction to be recovered and analyzed on the ground. PEM has a micro-g meter, pirani-type vacuum gauge and temperature sensor. The performance of the diagnostic instruments is summarized in Table 1. The location of the diagnostic packages on the SFU is shown in Fig.1

The diagnostic packages were first tested 1 week after launch and it was found all sensors except for high voltage parts worked correctly. The high voltage parts were verified one month later. During the 10 months mission of SFU, the diagnostic system was operated intermittently for 7 months. Typical operation time was 30 minutes each. In order to study the ram/wake environment in a systematic manner, the SFU was rolled at 2 degrees per second with respect to the velocity vector. This experiment was conducted twice in June 1995. The effects of thruster firings were studied by operating the thruster inside the view of the sensors of diagnostic package. This experiment was performed three times during the mission.

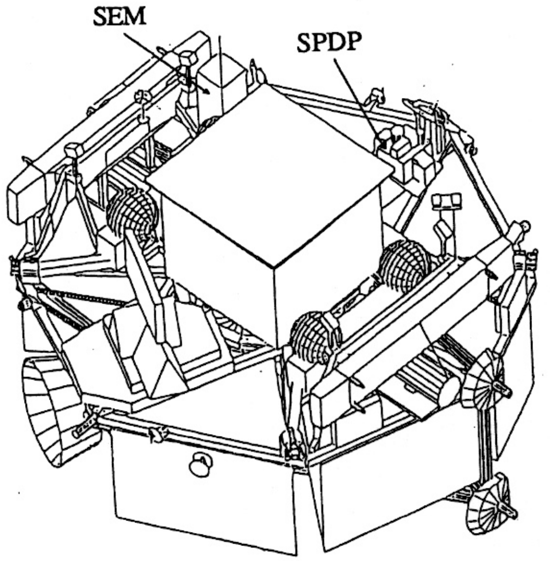

Fig.1 Location of the diagnostic packages on the SFU.

2. OBSERVATION

2.1 GAS ENVIRONMENT

Figure 2 shows the change of the pressure after launch measured by the two ionization gauges ; one (top) directs to the sun and the other (side) directs perpendicularly. The pressure measured by the sun-pointing gauge in the daytime is higher than that in the night time due to the effect of photo-electrons produced inside the gauge. The pressure measured by the side gauge is higher than that by the top gauge, possibly because of the outgassing effect of surrounding instruments. The outgassing effect was clearly observed for the first one month. Figure 3 shows

Table 1 Performance of SFU environment diagnostic system.

Instrument	Characteristics
Mission-Independent (EMS)	
Exposed (EMS-SEM)	
Pressure Gauge	Two Ionization Gauges $5 \times 10^{-4} \sim 10^{-8}$ Torr
Mass Analyzer	QP Sensor with CEM 2～100 AMU
Plasma Probe	4 Sensors Langmuir & Floating Modes
Impedance Probe	0-10 MHz
Wave Receiver	Two Receivers 0.1 kHz～10 MHz
Micro-g Meter	3-axes Servo Accelerometer ±10mg with 10 μ g resolution
In Payload Unit (EMS-PEM)	
Micro-g Meter	3-axes Servo Accelerometer ±1 mg with 10 μ g resolution
Pressure Monitor	Pirani Gauge 10 m Torr～1 Torr
Mission-Dependent (SPDP)	
Exposed	
Spectroscope	2000～8000 Å with 25 Å resolution Movable Object Mirror Test Material with Laser Diodes
Magnetometer	3-axes Fluxgate Type ±0.5 Gauss with 0.1% accuracy
Electron Density Fluctuation Detector	Langmuir Probe with CEM 1 Hz～30 kHz

the data obtained by the mass spectrometer which also directs to the sun. The major species detected are water, atomic oxygen and nitrogen molecule. This means the gas environment is controlled by the outgassing effect.

2.2 PLASMA ENVIRONMENT

The plasma environment was measured by the Langmuir probe and impedance probe. The impedance probe is capable of detecting the plasma density with a high accuracy. Figure 4 shows a typical example of the impedance probe data. The plasma density is derived from the peak of the capacitance shown near the bottom line. Figure 5 shows the data from the Langmuir probe near 25 of vertical axis and floating probe near 125. The sensors used for the Langmuir and floating modes are a spherical probe on the diagnostic package and three planar probes distributed over the SFU structure. The plasma density changed considerably depending on the SFU attitude and local time. The floating voltage varied within a range of 10 V.

2.3 ELECTROMAGNETIC ENVIRONMENT

Figure 6 shows the frequency spectrums obtained by the two wave receivers. The frequency

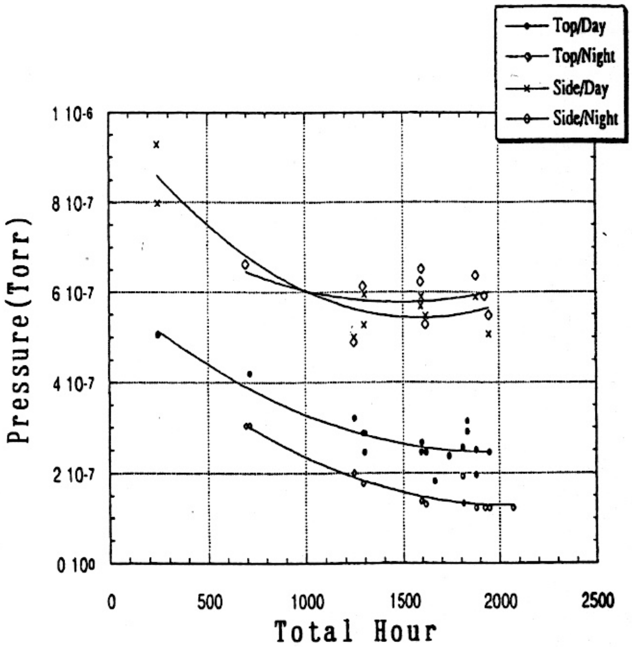

Fig.2 Change of the pressure in a long term.

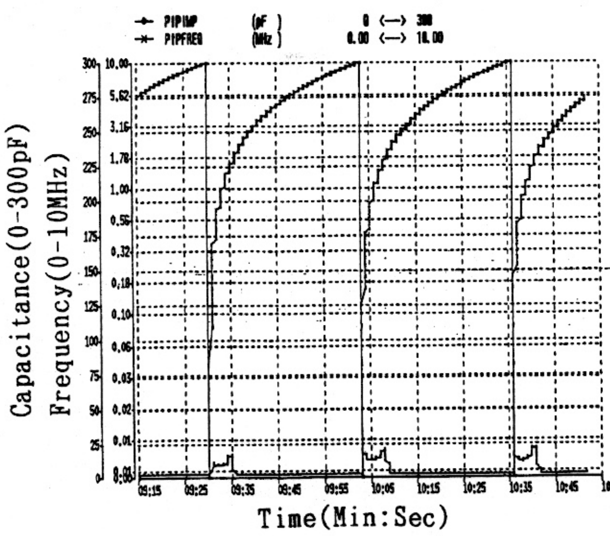

Fig.4 Typical data from the impedance probe.

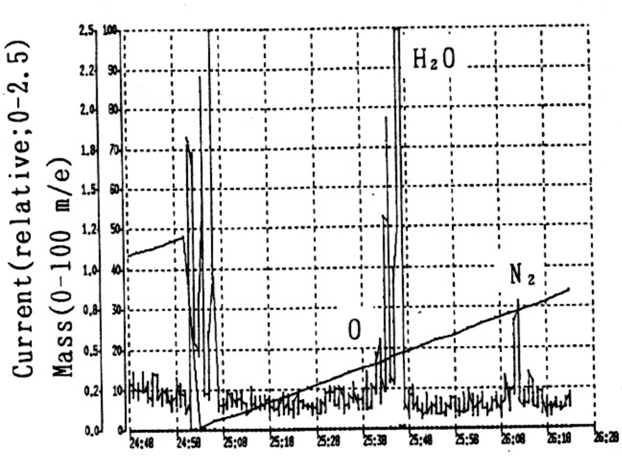

Fig.3 Data from the mass spectrometer.

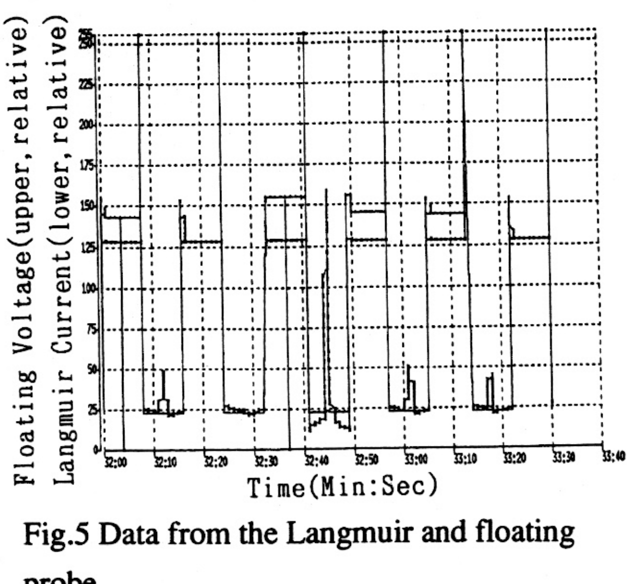

Fig.5 Data from the Langmuir and floating probe.

was swept from 3kHz to 10 MHz every 16 sec. The antenna was either a spherical probe on the diagnostic package or one of the three planar probes distributed on the SFU structure. Broad-band emission which is quite similar to the electrostatic noise observed by the space shuttle orbiter[2] was clearly detected.

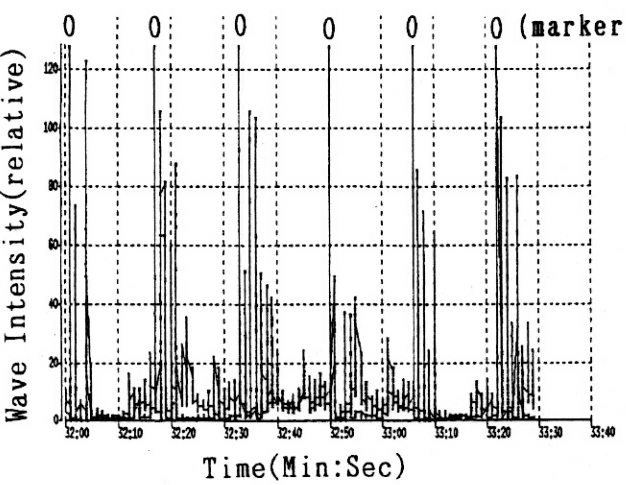

Fig.6 Data from the wave receivers.

2.4 MAGNETIC FIELD

Figure 7 shows a typical example of the magnetic field strength observed during 30 min. Since the SFU moved one third around the earth during 30 min, keeping the sun-pointing attitude, the three components of the geomagnetic field changed in a wide range.

2.5 SPECTROMETER

The spectrometer was used to detect the shuttle glow, the emission from electric propulsion experiment and the light emission from the thruster gas plume. Only visible emission from the earth has been identified so far. The spectrometer was also used to study the surface degradation of the test material. Three sets of thin transparent test material were installed on the top panel of the SPDP under which a laser diode was configured each. Polyimide, aluminized polyimide and gold-plated polyimide were used. The change of

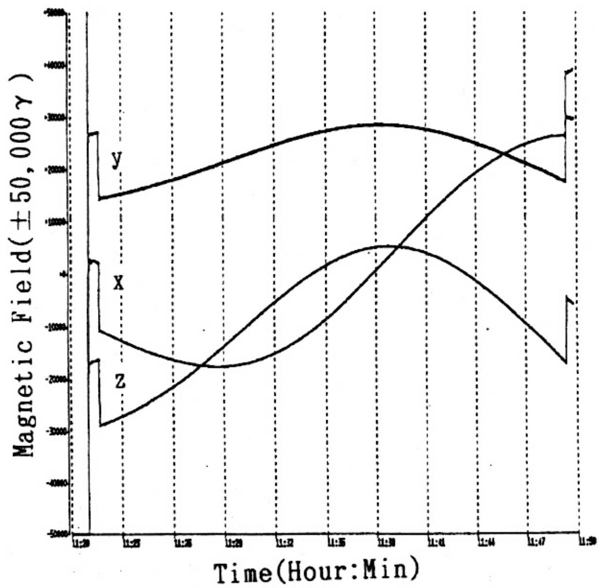

Fig.7 Data from the magnetic field sensors.

the laser light transmission indicates change of material property and surface contamination. Figure 8 shows an example of the laser light through the test material observed at 6300 Å . It was found that the light intensity considerably changed during the mission. Further analysis is required to derive the net effect of material change from the raw data which was quite sensitive to the temperature of the laser diode.

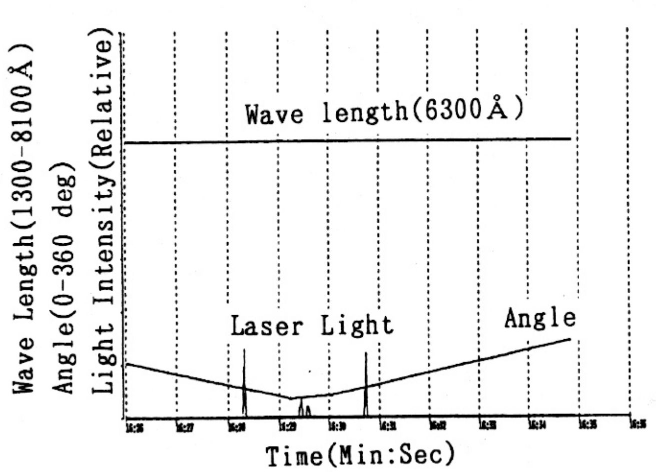

Fig.8 Signal of the laser light transmitted through the material.

2.6 MICRO-G ENVIRONMENT

Figure 9 shows an example of the micro-g environment measured by the micro-g meter inside the SEM package. The resolution of the sensor is 10 μ g. The air drag effect at the altitude

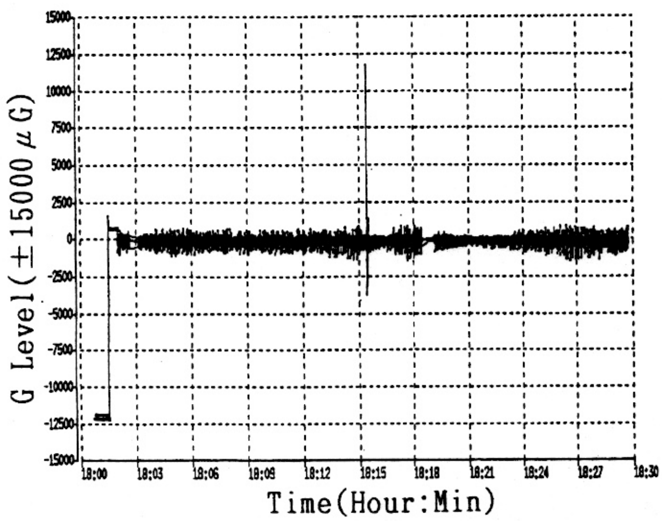

Fig.9 An example of micro-g environment.

of 480 km is estimated as low as 1 μ g. The measured fluctuation is attributable to the mechanical disturbance generated on the SFU. The pulse disturbance near the center was generated when the sun shield plate for the infrared telescope was deployed. Figure 10 shows an example of FFT analysis of the micro-g disturbances. The origin for each peak in the spectrum will be identified by comparing with the operation mode of the SFU. The peak below 1Hz is considered to be generated by the solar array paddles with a span of 24.4 m tip to tip.

3. CONCLUSION

The data from the SFU environment diagnostic system are reported. In the quick look analysis, several interesting results have been obtained ;

1) the surface gas environment was controlled by the outgassing effect at least for the first month,

2) broad band emission that was possibly excited near the SFU was observed almost all the time,

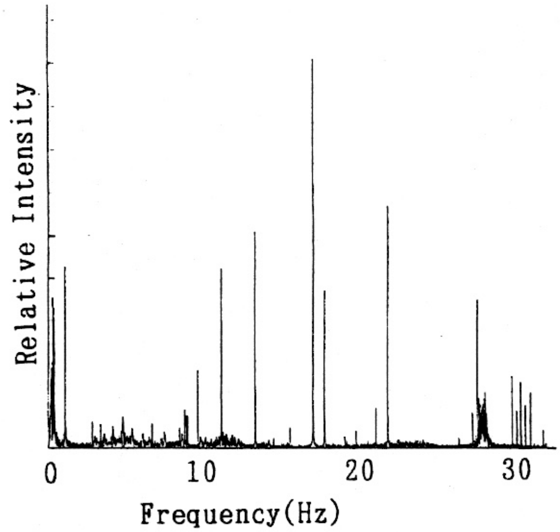

Fig.10 FFT analysis of micro-g disturbances.

3) strong micro-g disturbances were found more than expectation, and

4) change of transmittance of test materials was identified during the flight, which could show the time history of material change.

Further analysis for the environment data obtained during the mission is planned using a newly developed high-speed analysis software. The 11 pieces of the test materials, together with the surface materials (MLI and paints), are to be studied using optical, mechanical, and chemical analysis equipments.

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