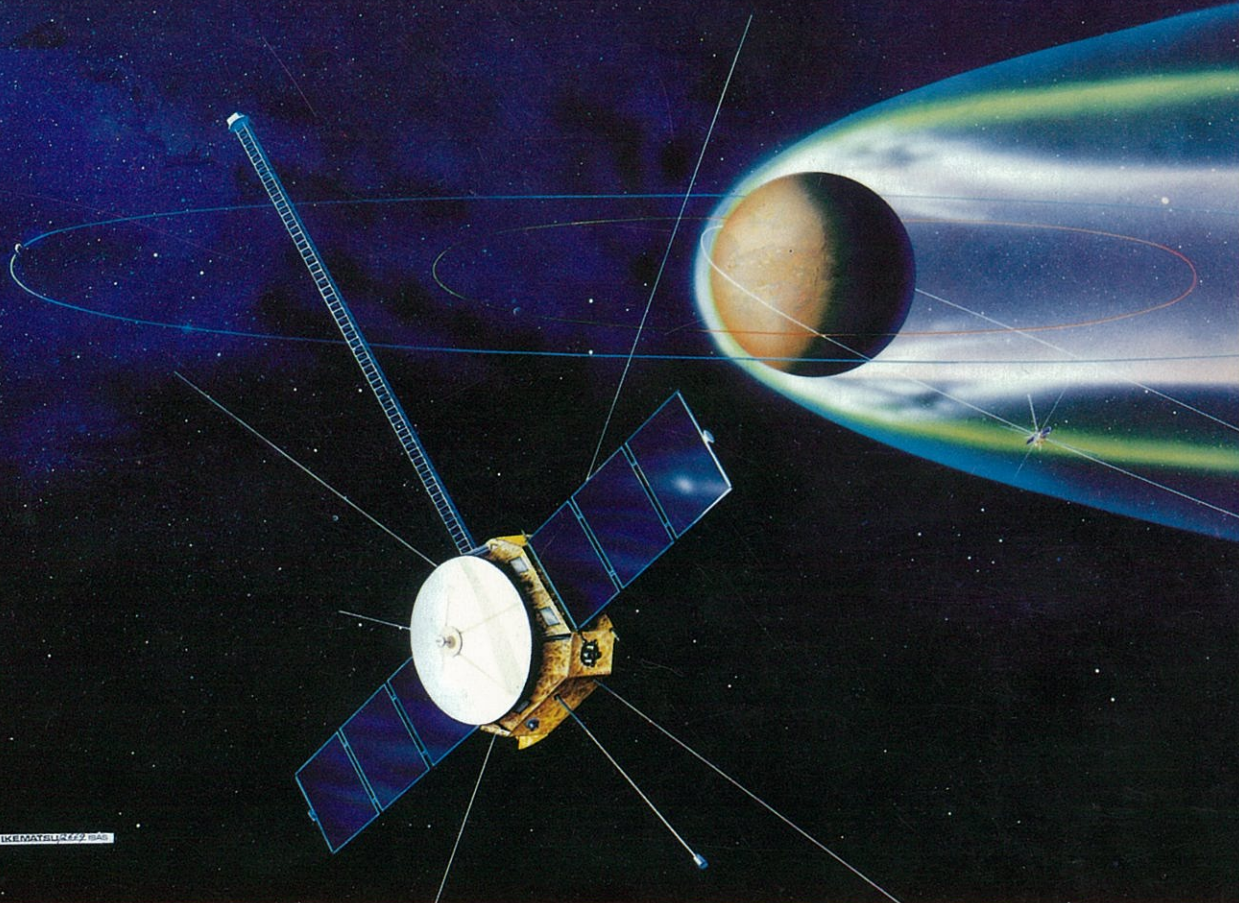


PLANET-B INTERIM REPORT

February 1995



Institute of Space and Astronautical Science
SES Data Center

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Preamble

Development of the ISAS new launcher M-V has made it possible for the Japanese planetary science community to explore the moon and the nearby planets by its own vehicles. The PLANET-B program is the third of the M-V based programs which starts with the launch of the radio astronomy satellite MUSES-B in 1996. Long before the official start of the program, a working group on the exploration of the terrestrial planets was formed in 1985 and made a feasibility study of exploring Venus and Mars. The working group was reorganized to the PLANET-B project team when the PLANET-B project was approved in 1992. The objectives of the PLANET-B project are twofold, scientific objectives are to study the structure and dynamics of the Martian upper atmosphere and its interaction with the solar wind, and engineering objective is to develop basic technology for the planetary exploration. Except for the measurements by the two Viking landers, the Martian upper atmosphere has been left unexplored for more than three decades. The measurements by PLANET-B will, for the first time, shed light upon to our outer neighbor's upper atmosphere. Comparison with the Venus upper atmosphere which was studied extensively by the Pioneer Venus Orbiter will lead us to deeper understanding of the direct interaction between the planetary atmosphere and the solar wind. One of the serious engineering challenges for the PLANET-B project is to overcome the mass limit by the development of light weight – high performance instruments. The technology developed in this challenge mission will become assets for the ISAS's future planetary missions.

PLANET-B is scheduled for the launch in the summer of 1998 from Kagoshima Space Center. The arrival at Mars is in October 1999. The Russian Mars94 and American Mars Surveyor which are scheduled for 1996 launch will be already in the orbit of Mars when PLANET-B arrives. Collaborations with these programs will be mutually beneficial and pursued.

1. Summary

1.1 Mission

K. Tsuruda and T. Yamamoto (ISAS)

1.1.1 Mission Objectives

The primary objective of the program is to study the Martian aeronomy, putting emphasis on the interaction of the Martian upper atmosphere with the solar wind. It is believed that Mars has no intrinsic magnetic field strong enough to stand off the solar wind far above the atmosphere. The knowledge of the Venus upper atmosphere accumulated by the PVO (Pioneer Venus Orbiter) suggests that the Martian upper atmosphere is strongly controlled by the solar wind. The two existing in situ measurements of the Martian ionosphere profiles made by the two Viking landers, however, do not show clear feature of the interaction with the solar wind as is seen in the Venusian ionosphere. The analysis of the Martian bow shock position shows dissimilarity with that of Venus. The mean distance to the sub solar shock at Mars is larger than at Venus when normalized by the respective planetary radius. The clear dependence of the shock position on the solar cycle observed at Venus is not seen at Mars. These results could be interpreted as an indirect evidence for the presence of weak but significant intrinsic magnetic field at Mars. However, discussions against this interpretation are also possible. We expect that the PLANET-B magnetic field experiment gives the final resolution to this problem.

The Martian upper atmosphere remain unexplored by the spacecraft equipped with a set of in situ instruments. Except for two Viking landers, the 'Phobos 2' periapsis altitude of 850 km is the lowest but it is still too high for the measurements of the most important altitude range of 150 – 300 km. The scarcity of the in situ measurements at Martian upper atmosphere has made it difficult to compare the structure and physical processes in the upper atmosphere of the two planets, Venus and Mars. If Mars has weak but significant intrinsic magnetic field, the interaction of the upper atmosphere with the solar wind at Mars would be quite different from either at the Earth or at Venus. On the other hand, if Mars is non magnetized as is Venus, the dissimilarity in the solar wind interaction at the two planets has to be explained. Measurements by PLANET-B will make the similarity and dissimilarity clearer and comparison of the two planets will be done on more firm experimental basis.

In order to cover the altitude range of interest, the periapsis altitude is chosen as low as 150 km. The effects of the solar wind on the ionosphere will be largest at the sub-solar point where the dynamic pressure of the solar wind is maximum. The orbit is designed so that the periapsis comes close to the sub-solar point at least twice during the designed lifetime of the spacecraft.

The importance of the plasma measurements in the nightside tail region of Mars is demonstrated by the finding of escaping ionospheric ions by 'Phobos 2'. The total mass flux and energy flux carried away by the escaping ions are found to be so enormous that, if the escape occurs continuously, significant effects are expected on the evolution of the atmosphere. PLANET-B will carry out extensive and systematic measurements of energetic ions in the tail region. The apoapsis of 15 Mars radii is suited for the observation in the tail.

The Martian upper atmosphere is known to be controlled by the meteorological activities in the lower atmosphere. Monitoring of the dust storms and the growth and decay of polar ice is necessary. Visible camera onboard PLANET-B is used for this purpose.

Although the primary research area for the PLANET-B program is the Martian aeronomy, the researches in other fields are also included in the PLANET-B program. The visible camera is used, as mentioned above, as a tool for the study of Martian meteorology. It can also be used to take photographs of Martian surface with moderate resolution of 100m per pixel. The orbit of PLANET-B intersects several times with those of Phobos and Deimos. If we are lucky, close up image of those satellites can be taken by the camera. A very light weight instrument 'dust counter' observes dusts

during the cruise phase and also in the orbit of Mars. With this instrument, there is a possibility to detect the dust ring of Mars or set an upper limit of the dust ring density.

In addition to the scientific objectives, the PLANET-B program has engineering objectives to develop key technologies for the ISAS's future planetary missions. ISAS is developing new launching vehicle M-V which will replace the current M-3S-II series and be used as a base line carrier for the ISAS's planetary missions. The launch capability of M-V is moderate and one of the engineering challenges in the PLANET-B program is to realize a light weight but high performance spacecraft. The net weight of the PLANET-B spacecraft without propulsion system is around 186 kg. Extremely light weight on-board equipment both for the bus and science instruments is necessary to realize the science objectives within this weight limit.

1.1.2 Scientific Instruments

The 14 instruments listed in the Table 1 below are installed on PLANET-B. Some of them make observations in the parking orbit and during the cruising phase. But the full-scale observations start after deployment of antennas and boom which will be made shortly after the injection of the spacecraft into Mars orbit in October 1999.

Table 1 Scientific Instruments

Magnetic Field (MGF)	3-axis, 0.1 nT accuracy
Energetic Electrons (ESA)	5 eV – 22 keV
Energetic Ions (ISA)	10 eV – 20 keV/q
Energetic Ion Mass (IMI)	0.5 eV – 40 keV/q
High Energy Particles (EIS)	40 – 500 keV (e, p, He, O)
Thermal Ion Drift (TPA)	0.1 – 100 eV, drift velocity
Electron Temperature (PET)	Electron Temperature Probe
UV Spectra (UVS)	H, O, CO, CO ₂ , imaging, D/H ratio
Sounders and HF Waves (PWS)	Electron density profile, HF waves
Plasma Waves (LFA)	VLF/ELF waves
Visible Camera (MIC)	Visible image, 3 colors
Dust Counter (MDC)	Dust counter
EUV Spectrometer (XUV)	He ⁺ ion contents
Neutral Gas Mass (NMS)	Neutral gas mass spectrometer
Radio Science	Radio occultation measurement

1) Composition of upper atmosphere

The neutral mass spectrometer (NMS) and ion mass spectrometer (TPA and IMI) measure the composition of neutral atmosphere and ionospheric ions, respectively, along the track of the spacecraft and the ultra violet imaging photometer (UVS) measures some of the constituents remotely. The altitude profile of electron density measured by top side sounder technique as well as in situ measurement (PWS) will also give the information on the ionospheric composition.

2) Altitude profile of electron density and temperature

In order to estimate the 'strength' of the Martian ionosphere against the impinging solar wind, the knowledge of electron temperature is inevitable. One of the argument made for the presence of the Martian magnetic field is the low ionospheric pressure measured by the Viking probe compared to the solar wind dynamic pressure. The electron temperature measured by PET combined with the electron density measurement by PWS will give good estimates of the strength of the ionosphere.

3) Magnetic field

If Mars has the intrinsic magnetic field of the order of 50 nT at the ionospheric altitude, the interaction of the ionosphere with the solar wind at Mars would become a quite different one from that at Venus. Existence of the intrinsic magnetic field also suggests that the dynamo action in the Martian core is still working. This will impose a bounding condition to the thermal history of Mars. Even when the intrinsic magnetic field is absent, the solar wind magnetic field would pile up on the dayside and drape toward the night side of Mars forming Martian tail. The magnetic field sensor is deployed 5 m from the spacecraft in order to avoid interferences generated from the currents in the spacecraft.

4) Drift velocity of thermal ions

Solar wind will transfer part of their momentum to the ionospheric ions during the interaction. Neutral wind will also interact with ions. Although PLANET-B has no instrument to measure neutral wind directly, the thermal ion drift velocity measured by TPA can be used to construct dynamical features of neutral atmosphere and ionosphere.

5) Solar wind and pick-up ions

The solar wind approaching Mars will first encounter hot ionospheric atoms before reaching the main body of the ionosphere. Some of these atoms will be ionized by the charge exchange and solar UV in the solar wind and transported with the solar wind. The rate of this ion pick up process has not been measured at Mars experimentally. The small radius of Mars compared with the gyro radius of pick up ions produces asymmetric distribution of energetic ions. EIS and high energy channel of IMS and ISA measure the pick up ions.

6) Plasma waves

Effective collisions given rise to by plasma waves are considered to play important roles in the interaction with the solar wind. Many of particle acceleration mechanisms are known to involve wave particle interactions. Lightning activity associated with dust storms is expected in the lower atmosphere. This can be measured by the same instrument. Plasma waves in the ELF to HF range are measured by PWS and LFA using two pairs of tip to tip 50 meters antenna.

7) Energetic ions and electrons

Interaction with the solar wind produces energetic electrons and ions of a few hundred eV to a few tens keV. The escaping oxygen ion beam found in the tail region by 'Phobos 2' has been accelerated to a few keV. Measurements of energy spectra, pitch angle distribution and mass will be done by the combination of ESA, ISA, IMI and EIS.

Items from 1) through 7) above are intended mainly for the study of Martian aeronomy and the interaction with the solar wind. The following measurements aim at contributing to the other research area.

8) Interplanetary dust and Martian dust ring

Dust distribution in the space between the Earth and Mars is measured by the dust counter (MDC) along the trans Mars orbit. MDC is also used for the detection of dust rings which might exist along the orbits of Martian satellite Phobos and Deimos.

9) Cloud, haze, dust storm and polar ice

As a monitor for the meteorological activities in the lower atmosphere, which is considered to modify the upper atmosphere significantly, a camera (MIC) of moderate resolution is installed. This camera will be used to take a global image of Mars from a large distance at least once per orbital period. This image will give crude information of cloud distribution, polar haze activity, dust storms, and growth and decay of polar ice and can be used for the study of large scale dynamics of Martian

atmosphere. The image from the periapsis altitude has the resolution of 100 m. Though the chance of taking high resolution images is restricted by the capacity of telemetry, it is planned to increase the frequency of taking high resolution images on special events, such as the onset of dust storm.

10) Image of Martian surface and Phobos and Deimos

Camera is also used for the study of the surface science. Selecting targets of interest, high resolution images will be taken. Study of weathering effect will be one of the research targets which can be done by comparing with the Viking images. The orbit of PLANET-B intersects those of Phobos and Deimos and there are several chances of close encounter with those satellites during the lifetime of the spacecraft. It is planned to take close up images of these satellites at the encounters.

11) Reflectivity of Mars at radio frequency

The RF radio waves transmitted from the top side sounder (PWS) penetrates the ionosphere at high frequency end and surface echo will be received at these frequencies. Analysis of surface echo is expected to give some information on the sub-surface structure.

12) Interplanetary helium glow and Martian helium ion content

Interplanetary glow at Helium II line (304 Å) is measured during the cruise phase by XUV. This measurement is included primarily to provide basic data for the future magnetospheric imaging technology but it also gives Helium ion contents in the Martian upper atmosphere. Helium contents is one of the key parameters for the study of thermal history of Mars.

13) D to H ratio of the upper atmosphere

D/H ratio in the upper atmosphere is one of the key information to the evaluation of water loss from the Martian atmosphere. D/H ratio is measured by absorption cell technique by as a part of the UVS instrument.

1.1.3 Mission Strategy

Observations in the low altitude ionosphere, the Martian tail, and the near Mars solar wind are important for the understanding the structure of the Martian upper atmosphere and its interaction with the solar wind. The highly elliptical PLANET-B orbit with periapsis altitude of 150 km and apoapsis distance of 15 Martian radii makes it possible to observe all of these three regions of interest. The orbital inclination of 170 degrees with respect to the ecliptic plane is chosen so that the subsolar ionosphere can be sampled at least one of the PLANET-B periapsis path during the design life and also to keep the solar eclipse time within the allowed period limit. The periapsis segment of the orbit is extremely important for the PLANET-B science objectives. Most of the scientific instruments will be operated at their maximum capability during this short time period near the periapsis. In order to accommodate with the rush of data stream from the instruments, a solid state data recorder of 100 Mbits capacity is employed. This capacity is sufficient to store the data with 64 kbps during the passage of periapsis. The data stored in the data recorder during the periapsis path are played back and transmitted to Earth during the rest of the orbit where the data rate from the instrument can be made lower.

The PLANET-B orbit crosses the orbits of Martian satellites, Phobos and Deimos and with small trimming of the orbit will make PLANET-B encounter these Martian satellites several times during its life time. Taking this opportunity, close up images of Phobos and Deimos will be taken by the onboard camera and the near satellite environment will be measured other instruments.

The prime tracking station for the PLANET-B spacecraft is UDSC (Usuda Deep Space Center) with 64mφ antenna. Japanese Kagoshima Space Center (J-KSC) is a backup station. The telemetry and ranging data obtained at UDSC / J-KSC are sent via ground line to SSOC (Sagamihara Spacecraft Operation Center) where data processing is carried out. Telemetry data monitoring, science data analysis, orbit / attitude determination and control and command sequence generation are carried out at SSOC. The generated command data is sent via the ground line to UDSC / J-KSC and is sent to the

spacecraft. Although the operation of the PLANET-B spacecraft assumes Japanese stations, support from the NASA Deep Space Network (DSN) will contribute greatly to secure the mission success and also to increase the science return.

The design life time of PLANET-B is one Martian year (two Earth years). The most critical to the mission life is the amount of the fuel to maneuver the attitude of the spacecraft which is necessary to direct the body mounted communication dish to Earth. The operation of the spacecraft after the nominal mission life of one Mars year depends on the available fuel at that time and is not determined.

1.1.4 Observation Planning and Data Analyses

The planning for observations and the policy of data usage are determined by the 'PLANET-B science working group meeting' (PLANET-B SWG meeting) which consists of the principal investigators, co-investigators, and those responsible for the PLANET-B project. The PLANET-B SWG meeting is chaired by the project scientist and will be held approximately every two or three months.

The raw data acquired from the spacecraft are archived in the ISAS data system and distributed to the experimenter groups along with the ancillary data. The evaluation of the raw data is the responsibility of the respective principal investigator and his group. The evaluated data are to be returned and registered in the ISAS data system within TBD time. All data obtained by the PLANET-B project are considered as a common assets not only for the PLANET-B scientists but for anyone interested in them. Time and method of data release are determined by the PLANET-B SWG meeting.

1.1.5 International Collaboration

The following organizations are collaborating with ISAS in the development of the onboard instruments;

- Canadian Space Agency in the development of Thermal Plasma Analyzer,
- Munich Technical University in the development of Mars Dust Counter,
- Swedish Institute of Space Physics in the development of Ion Mass Imager,
- European Space Agency in the data compression technique for Mars Imaging Camera, and
- National Space and Aeronautical Agency in the development of Neutral Mass Spectrometer.

In order to secure the mission success and increase the science return, supports of the NASA Deep Space Network for the orbit determination during the phases critical to the mission and for the science data acquisition are being discussed.

The collaborations in the data analysis phase has not been discussed in detail but will be discussed in the PLANET-B STM.

1.2 Spacecraft System Design

I.Nakatani (ISAS)

NEC Corporation

1.2.1 Overview

PLANET-B is a spin-stabilized spacecraft with a 1.6m ϕ high gain antenna (HGA) fixed onto the top. Two-wing solar cell paddles are also fixed to the body. The overall spacecraft configurations during launch phase and Mars orbiting phase are shown in Figure 1.2.1-1 and Figure 1.2.1-2 respectively.

The spacecraft spin axis, which coincides with the HGA boresight direction, is controlled towards the earth. The angle between the earth and the sun seen from the Mars orbit is within $\pm 45^\circ$, so we can fix both the HGA and the solar paddles to the spacecraft body thus eliminating movable parts to reduce the weight and increase the reliability. For large orbit maneuvers, 500N bi-propellant thruster is used which is on the bottom of the spacecraft. Immediately after injection of the Mars orbit, four 25m-long wire antennas, 5m mast and 1m boom are deployed.

The total wet weight of the spacecraft is 536kg and the dry weight 258kg. One of the most challenging items for technology development is the reduction of the spacecraft weight. Examples of the newly introduced technologies to name a few are:

- 1) Light weight HGA dish using 3-axis weaving of composite material,
- 2) Surface-mount technique for electronics circuits,
- 3) High-efficiency (18%) solar cells,
- 4) Nickel-Metal-Hydride battery and
- 5) Composite material He tank for bi-propellant thruster system.

Figures 1.2.1-3 and 1.2.1-4 are the system block diagram and component list respectively. The PLANET-B function list is shown in Table 1.2.1-1.

1.2.2 Scientific Instruments

Eight science instruments (PSA, PWA, MPM, MIC, IMI, MDC, TPA, NMS) are onboard the PLANET-B spacecraft for scientific mission. These instruments have 12 sensors and three extendible systems(WANT-1~4, MST and TPA-S).

Four Japanese scientific instruments (PSA, PWA, MPM, MIC) have the same standalized CPU boards and power supply units. The onboard programs for them are stored in the backup file memory (BFM) area in the data handling unit (DHU).

The other foreign scientific instruments (IMI, MDC, TPA, NMS) have CPU systems and DC/DC converters, respectively. The onboard programs for them are stored in the ROM of themselves.

1.2.3 Power System

The power system consists of :

- Solar Cell Paddles (SCP)
- Batteries (BAT-A,B)
- Power Controller & Distributor (PCD)
- Power Supply Units (PSUs)
- Shunt Dissipaters (SHNT-A,B)

The 18% efficiency silicon cells (Size : $2\text{cm} \times 4\text{cm} \times 0.1\text{mm}^t$) with cover glasses coated with conductive material are installed on the solar cell paddles which consist of dual wings each of which has three rigid panels. Generated power is more than 200watts through the mission period.

PLANET-B has a battery system for the operations in the shadow. It consists of two 15AH batteries using nickel metal hydride (NiMH) cells. Analog sequential shunt dissipaters are used for over-voltage controll.

The power controller & distributor controls the power bus voltage to be 16.3 volt~27.5 volt and distributes the primary power for each components. And it also has the functions of current limiting and circuit breaking for each power bus line and charge / discharge controlling. The PCD collects the telemetry from each component of the power system and sends to the DHU through the PIM.

PSU is a DC/DC converter with switching regulation and supply secondary power, which is regulated at several secondary voltages for each user. The switching frequency is 300kHz~480kHz.

1.2.4 Communication System

The communication system consists of :

- S/X-band High Gain Antenna (HGA)
- S-band Low Gain Antennas (LGA-A,B)
- S-band Switches (SSW-A,B)
- S-band Diplexer (SDIP-A,B)
- S-band Receivers (SBR-A,B)
- S-band Transmitter (TMS)
- X-band Transmitter (TMX)
- X-band power Amplifier (XPA)

PLANET-B uses two RF bands (S:2GHz & X:8GHz) and three communication links, S-up, S-down and X-down links. PM is used for all links.

HGA is a light weight integrated system which consists of 1.6m diameter parabolic mesh antenna with S/X common feed system, XPA and LGA-A. X-band downlink has 5watt transmission power and 38.5dBi HGA peak gain. It is used for high rate communication. The bit rate for X-band is 2048bps~32,768bps. S-band downlink has 2.5watt and 28dBi HGA peak gain. It is used for low rate communications for the house keeping telemetry monitoring. The bit rate for S-band is 64bps~1024bps.

The commands from the earth stations to the PLANET-B are sent via S-band uplink. The bit rate is 15.625bps / 125bps. Either S or X band is used for ranging downlink. Ranging can be carried out concurrently with telemetry transmission.

1.2.5 Command and Data Handling System

The data handling system consists of :

- Data Handling Unit (DHU)
- Peripheral Interface Modules (PIM)
- Command Decoder (CMD)
- Data Recorder (DR)
- Telemetry and Command Interface (TCI)

TCI is the telemetry and command interface for the communication system and EPT/INS. TCI sends commands to them and corrects telemetry data from them and sends them to DHU through PIM.

CMD demodulates uplink signal, decodes its PN code and sends commands to DHU. CMD can be used for two uplink bit rates (15.625bps / 125bps).

The data recorder is the solid state recorder with 134 Mbits capability. It can be used for recording and reproducing, simultaneously.

The data handling system consists of DHU and PIMs. This system sends commands to each PIM user under its priority control. Also it corrects and edits the data from PIM users. The telemetry transfer format for PLANET-B is based on the CCSDS AOS format. DHU has the functions of telemetry/command data handling including DR interface (recording / reproducing of telemetry data to/from the data recorder) and autonomous control of spacecraft.

1.2.6 Launch Operation System

The launch operation system consists of :

- Electrical Programmable Timer-Satellite (EPT-SA)
- Instrument-Satellite (INS-SA)

EPT-SA controls to ignite pyro devices in accordance with the planned time sequence. INS-SA measures the environmental conditions during launch and send the telemetry to the ground through the launch vehicle and spacecraft.

1.2.7 Attitude and Orbit Control System

The attitude and orbit control system consists of :

- Attitude and Orbit Control Electronics (AOCE)
- Spin Type Sun Aspect Sensor (SSAS)
- Two Dimensional Sun Aspect Sensor (TSAS)
- Star Scanner (SSC)
- Gas Rate Sensor (GRS)
- Accelerometers (ACM-A~D)
- Nutation Damper (ND)
- Reaction Control System (RCS)
- Orbit Maneuvering System (OMS)

ND is a hoop partially filled with silicon oil and is used to damp spacecraft nutation caused mainly by attitude maneuver.

GRS is used for active nutation control during power flight with the 4th stage of M-V launch vehicle.

SSAS, TSAS and SSC acquire the data for spacecraft attitude determination.

ACMs are used for measuring delta-V of spacecraft.

RCS is the mono-propellant / controlled pressure system with hydrazine with ten 2.3N thrusters. OMS is the bi-propellant / controlled pressure system with hydrazine and NTO and has one 500N thruster. RCS / OMS includes five big tanks, two of which are for hydrazine, another two for NTO and one for GHe.

AOCE controls all the sensors and actuators automatically and/or by command. And it corrects all the telemetry data from sensors and actuators and send them to DHU through PIM.

1.2.8 Structure and Thermal Design

Main structure consists of a truss assembly ,base panel and eight side panels. The truss assembly consists of FRP tubes. The base and side panels are sandwich panels with aluminum honeycomb and FRP/aluminum facesheet.

Thermal control system consists of heater control electronics, heaters and passive control devices (paint, blankets, doublers, isolators, thermal conductors and so on.)

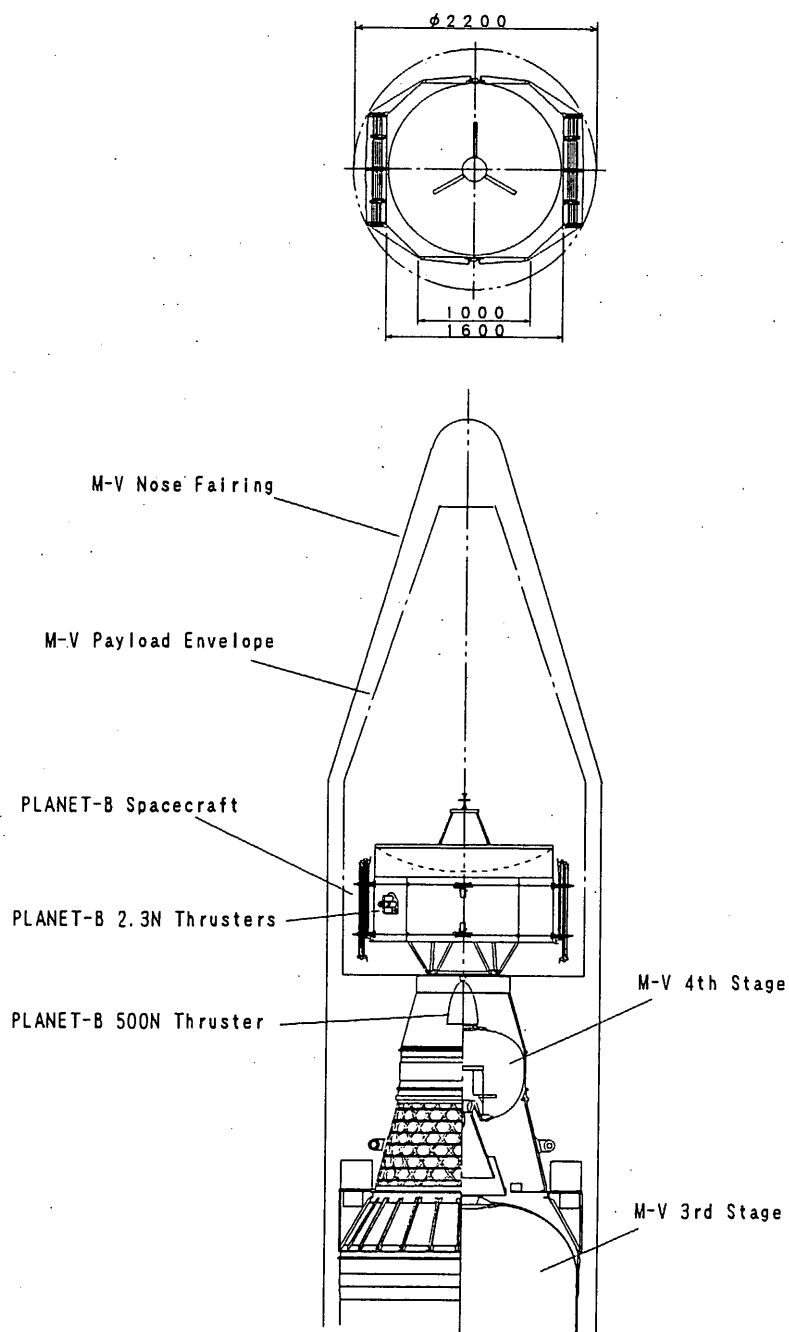
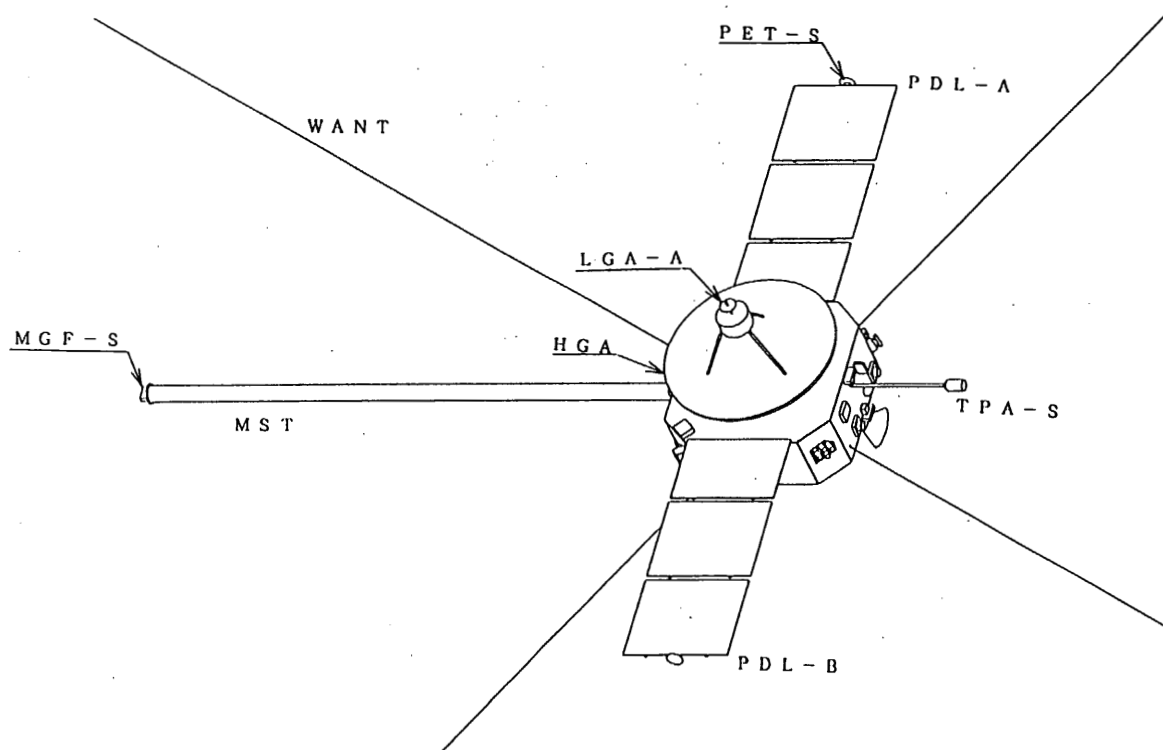


Figure 1.2.1-1 Launch Configuration



Total size : $\square 1.6\text{m} \times \text{H}0.58\text{m}$ (main body)
 : 52m (WANT tip-to-tip)
 : 6.22m (PDL tip-to-tip)

Figure 1.2.1-2 On-orbit Configuration

PLANET-B

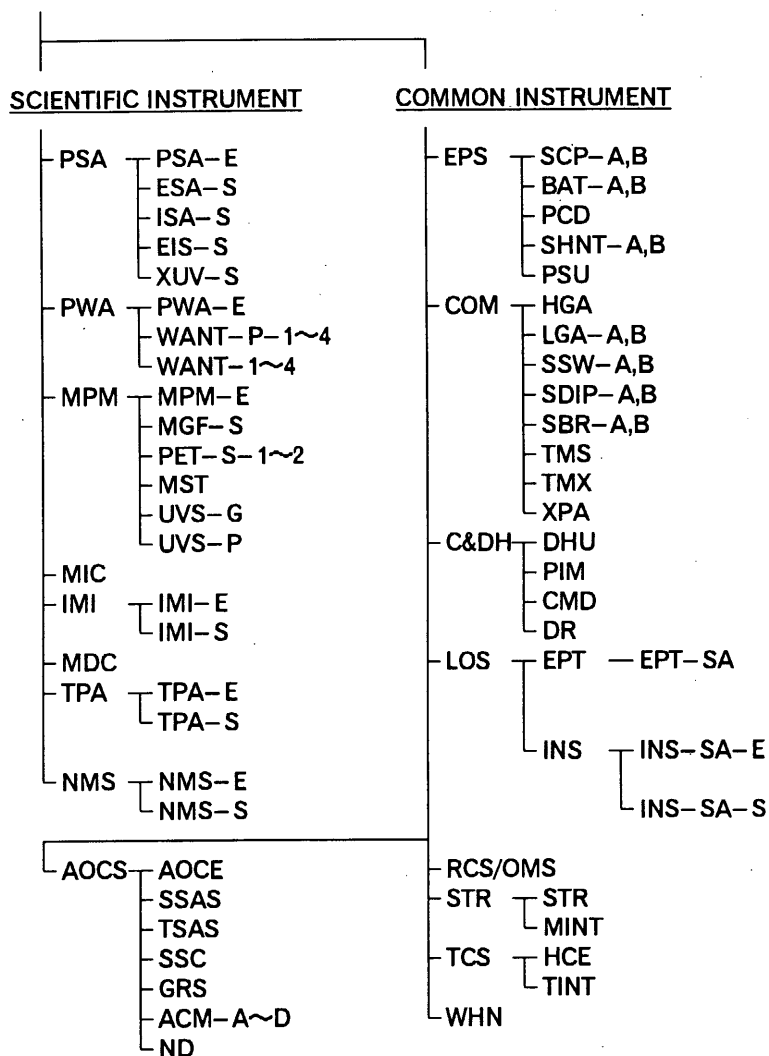


Figure 1.2.1-4 Component List

Table 1.2.1-1 PLANET-B 's functions (1/10)

1. Scientific Instruments

1.1 PSA

PSA-XUV/ISA/EIS/ESA

(1)XUV (Extremely Ultra Violet Scanner)

Wave Length : 304 Å
 FOV : $\pm 5.6^\circ$
 Detection Efficiency : 0.3%

(2)ISA (Low Energy Particle Detector for Ion)

Energy Range : 20eV/q $\sim$ 22keV, 32 Steps
 Energy Resolution : 10 %
 FOV : $6^\circ \times 360^\circ$
 Angular Resolution : $6^\circ \times 6^\circ$
 Time Resolution : Spin Period
 G-Factor : $10^{-4} \text{ cm}^2 \cdot \text{sr} \cdot \text{eV/eV}$

(3)EIS (Electron and Ion Composition Spectrometer)

FOV : $\pm 13.1^\circ$ Corn
 Time Resolution : 1.0ns (TAC)
 Type : Ion-Implanted Type

(4)ESA (Electron Spectrum Analyzer)

Energy Range : 5 eV $\sim$ 22 keV, 32 Steps
 Energy Resolution : 10 %
 FOV : $6^\circ \times 180^\circ$
 Angular Resolution : $6^\circ \times 6^\circ$
 Time Resolution : Spin Period
 G-Factor : $10^{-4} \text{ cm}^2 \cdot \text{sr} \cdot \text{eV/eV}$

Table 1.2.1-1 PLANET-B 's functions (2/10)

1.2 PWA

PWA-PWS/LFA/WANT

(1)PWS (Plasma Wave and Sounder Experiment)

NPW Rx Frequency	:	20KHz~7MHz
Band Width	:	±2KHz
SPW Tx/Rx Frequency	:	SPW NORMAL 20KHz~7MHz
	:	SPW H 8MHz~10MHz
	:	ALT 9MHz
Band Width	:	±2KHz
Tx Power	:	High/Low 600W/60W
ALT Phase Accuracy	:	5' (Resolution : 1.4')
NEI Capacity	:	1pF ~ 1000pF

(2)LFA (Low Frequency Analyzer)

Frequency Range	:	OFA 10Hz ~ 30KHz
	:	WFC-M 10Hz~1KHz
	:	WFC-D 0.1Hz~15Hz

(3)WANT (Wire Antenna)

Length	:	25m(Tip to Tip) × 4
Tip Mass	:	20g × 4

Table 1.2.1-1 PLANET-B 's functions (3/10)

1.3 MPM

MPM-MGF/PET/MST/UVS

(1)MGF (Magnetic Field Measurement)

Measurement Range : $\pm 65536\text{nT}/\pm 1024\text{nT}/\pm 256\text{nT}/\pm 16\text{nT}$

Resolution : $8.0\text{nT}/0.125\text{nT}/0.016\text{nT}/0.002\text{nT}$ (14bits)

Linearity : $<10^{-3}$

(2)PET (Probe for Electron Temperature)

Measurement Range : $500 \sim 4000^\circ\text{K}$

(3)MST (Extendible Mast)

Length : 5m (MGF-S mounted on its tip)

(4)UVS (Ultra Violet Spectrometer)

Spectro Scope Wave Length Range : $115.0\text{nm} \sim 310.0\text{nm}$

Wave Length Resolution : 1.5nm

Space Resolution : $1.43^\circ \times 0.7^\circ$

FOV : $0.09^\circ \times 1.43^\circ$

Photometer Wave Length : $121.566\text{nm}(\text{H Ly } \alpha)$

: $121.533\text{nm}(\text{D Ly } \beta)$

FOV : $3^\circ \times 0.5^\circ$

1.4 MIC (Mars Imaging Camera)

FOV : 53°

Resolution : $82.6''$

CCD : 5000 Pixel

Table 1.2.1-1 PLANET-B 's functions (4/10)

1.5 TPA (Thermal Plasma Analyzer)

Particles Detected	: Electrons AND Ions
Energy Resolution	: $\Delta E/E = 0.1$
Mass Resolution	: $\Delta M/M = 0.2/\sqrt{M}$
Angular Resolution	: $\Delta \theta = \Delta \phi = 0.05\text{rad}$
Temporal Resolution	: 1/4 spin period (Complete 3D Distribution) : 0.01 sec (Parameterized Distribution)

1.6 IMI

Max. Energy Range	: 0.5~40000eV/e , 64 Steps
Energy Resolution	: 0.07 (FWHM)
Angular Resolution	: El.=5° , Az.=11° (32Directions)(FWHM)
FOV	: 5° × 360°
Mass Range	: 1~10 ¹² Amu/e
Mass Resolution	: m/Δ m=6~1 (HOT), 4~30 (COLD)
Time Resolution	: 1/2 Spin Period → Full 3D Distribution
Conversion Factor	: CF(11°) 1 × 10 ⁻⁴ (cm ² srkeV/keV) : CF(360°) 3.2 × 10 ⁻³ (cm ² srkeV/keV)
Dynamic Range	: 0.1~10 ⁶ cts/s (Full Particle Image)

1.7 MDC (Mars Dust Counter)

Sensing items	: dust number, mass, relative velocity and direction
Minimum Velocity	: 1 km/sec

1.8 NMS (Neutral Mass Spectrometer)

T.B.D.

Table 1.2.1-1 PLANET-B 's functions (5/10)

2. Electrical Power Subsystem

2.1 SCP (Solar Cell Paddle)

Paddle Type	: 3 Rigid Panels × 2 Wings
Generating Power	: 200 W min. (Solar Range 2.5AU, $\theta_s=45^\circ$)
Cell Type	: 20×40mm · 100 μ mt Si
Cover Glass Type	: 100 μ mt Conductive Coating Cover Glass
Cell Efficiency	: 18.0%
Paddle Size	: 4.28 m ² (1m×2.3m×2 Wings)

2.2 BAT (Battery)

Cell Type	: Ni-MH 15AH CELL
BAT Configuration	: 16 Cells Series × 2 Units
DOD Limitation	: 50%
BAT Efficiency	: 1.05

2.3 PCD (Power Controller & Distributor)

Bus Voltage	: 16.3 V ~ 27.5 V
Under Voltage Control(UVC)	: T.B.D. levels
Over Voltage Control(OVC)	
Power Bus Distribution	: 13 Lines
Each Line Current Monitor & ON/OFF Control with Circuit Breaker	
Each Line Current Limitation	
Charge/Discharge Control	: High Rate Charge 3.0 A (1/10C)
	: Trickle Charge 0.6 A (1/50C)
Battery Reconditioning	
Ampere-Hour Meter	
Battery Charge/Discharge Current Monitor	
Battery Voltage Monitor	

2.4 PSU (Power Supply Unit)

2nd Power Source Regulation	
Output Voltage	: +5V, ±12V, +29V

2.5 SHNT (Shunt Dissipater)

Type	: Analog Sequential Shunt (2 units)
Capacity	: T.B.D. W max. (full shunt)

Table 1.2.1-1 PLANET-B 's functions (6/10)

3. Communication Subsystem

3.1 HGA-S, X (S/X-band High Gain Antenna)

Type : ϕ 1.6m Parabolic Mesh Antenna
 Gain : S-Tx 28.0 dBi min. (peak)/ $\pm 2.7^\circ$ (-3dB)
 : X-Tx 40.0 dBi min. (peak)/ $\pm 0.75^\circ$ (-3dB)

3.2 LGA-A, B (S-band Low Gain Antenna)

Type : Crossed Dipole
 Gain : 0 dBi min. ($\pm 45^\circ$)
 : -10 dBi min. ($\pm 90^\circ$)

3.3 SSW-A, B (S-band Switch)

Insertion Loss : 0.2 dB max.

3.4 SDIP-A, B (S-band Diplexer)

Insertion Loss : 1.0 dB max. (Tx)/0.9 dB max. (Rx)

3.5 SBR-A, B (S-band Receiver)

Frequency : 2.1 GHz
 Signal : COMMAND and/or RNG
 Noise Index : 2.6 dB
 Demodulation : PM $\rightarrow$ PSK (Refer to next page)

3.6 TMS (S-band Transmitter)

Frequency : 2.2 GHz
 Tx Power : 2.5 W
 Signal : TLM and RNG
 Modulation : PM (Refer to next table)

3.7 TMX (X-band Transmitter)

Frequency : 8.4 GHz
 Power : 5.0 W(With XPA)
 Signal : TLM
 Modulation : PM (Refer to next page.)

3.8 XPA (X-band Power Amplifier)

Output Power : 5.0W

Table 1.2.1-1 PLANET-B 's functions (7/10)

Transmission Signal Detail

LINK (BAND)	SIGNAL	BIT RATE (bps)	MOD. FORM	SUBCARRIER FREQ.	MOD. INDEX (rad)	CODING
UP (S)	CM	15.625 / 125	PCM-PSK-PM	4kHz	0.7 (CM) 0.5(CM/RNG)	
	RNG		TONE-PM	516kHz	1.2 (RNG) 0.7 (CM/RNG)	
DOWN (S)	TLM	64-1024	PCM-PSK-PM	8kHz	1.0	Convolution+RS
	RNG		TONE-PM	516kHz	0.5	
DOWN (X)	TLM	2048-32768	PCM-PM	-	1.2	Convolution+RS
	RNG		TONE-PM	516kHz	0.5	

Table 1.2.1-1 PLANET-B 's functions (8/10)

4. Command and Data Handling Subsystem

4.1 CMD (Command Decoder)

Bit Rate : 15.625/125 bps

Demodulation : PSK→PCM

4.2 DHU (Data Handling Unit)

Function with PIM :

Individual Command Operation	DC : 252 items/PIM
	BC : 255 bytes/Command Block
Organized Command Operation	OP : 2 (1 OP=512 OG)
	OG : 128 (1 OG=16 Command Block)
Onboard Command Generation	: Telemetry Edition Mode Changing
	: TI Counter Reset
	: Power Consumption Control
	: Safe Hold Mode
Onboard Memory Handling	: Onboard Memory Verification
	: Onboard Memory Dump
	: Memory Rewriting from BFM
Packet Telemetry Handling	: transfer frame length=512bytes
	: 1 packet / transfer frame
	: 432 bytes data area / packet
	: Bit Rate and Edition Format Control
	: DR Control
Modulation and Coding	: Refer to the table in previous page.
Back-up File Memory	: Onboard Program Loading & Checking
	: 512 kbytes IC Memory

4.3 PIM (Peripheral Interface Module)

DHU-PIM : Serial Interface

PIM-USER : Parallel Interface

4.4 DR (Data Recorder)

Function	: Record, Reproduce, Rec&Rep
Type	: 134 Mbits IC Memory
Data Rate	: 65 kbps max. (REC)
	: 32 kbps max. (REPRO)

Table 1.2.1-1 PLANET-B 's functions (9/10)

5. Launch Operation Subsystem

5.1 EPT-SA (Electrical Programmable Timer-Satellite)

Function : Signal/Command Generation to Igniter/INS-SA in accordance with
planned sequence

5.2 INS-SA (Instrument-Satellite)

Function : Launch Environment Measurement of Kick Motor and Spacecraft

6. Attitude and Orbit Control System

6.1 AOCE (Attitude & Orbit Control Electronics)

Function : Attitude Sensor control & Data Processing
: RCS/OMS Drive/Control
: Spin(Axis Direction/Rate) Control
: ΔV Control : Active Nutation Control
: Auto Earth Pointing : Earth Re-orientation
: Abnormal Condition Detection

6.2 SSAS (Spin Type Sun Aspect Sensor)

FOV : $170^\circ \pm 2^\circ$ (Two Fan Beam Type)
Resolution : Better than 0.02°

6.3 TSAS (Two Dimensional Sun Aspect Sensor)

FOV : $\pm 50^\circ \times \pm 50^\circ$ Resolution : 0.0015°

6.4 SSC (Star Scanner)

FOV : $\phi 72^\circ$ (Primary), $\phi 110^\circ$ (Secondary)
Detector : Photo Diodes Resolution : 10 Arcmin

6.5 GRS (Gas Rate sensor)

Range : $\pm 100^\circ$ /sec

6.6 ACM-A~D (Accelerometer)

	Purpose	Full Scale
ACM-A/B	: RCS ΔV	$\pm 40\text{mG}$
ACM-C	: M-V 4th Stage ΔV	$\pm 20\text{G}$
ACM-D	: OMS ΔV	$\pm 20\text{G}$

6.7 Nutation Damper)

Type : Hoop with Silicon Oil Time Constant : T.B.D.

Table 1.2.1-1 PLANET-B 's functions (10/10)

7. Propulsion Subsystem

7.1 RCS (Reaction Control System)

Type	: Mono Propellant / Pressure Control System
Fuel/Gas	: N ₂ H ₄ /GHe
Tank	: Common Use with OMS System
Thrusters	: 2.3N × 10 (Axial × 4, Radial × 2, Tangential × 4)

7.2 OMS (Orbit Maneuvering System)

Type	: Bi Propellant / Pressure Control System
Fuel/Gas	: N ₂ H ₄ , NTO/GHe
TANK	: N ₂ H ₄ Tank(Tear Drop) × 2
	: NTO Tank(Tear Drop) × 2: GHe Tank(Sphere) × 1

8. Structural Subsystem

8.1 STR (Structure)

Shape : Octagonal Pole	M-V Interface : 4-Separation Bolts
Primary Structure : Truss and Deck Component Panel : 8-Side Panels, Deck	

8.2 MINT (Mechanical Integration)

Brackets for Components, Fasteners for Component Installation,
Balance Weight

9. Thermal Control Subsystem

9.1 HCE (Heater Control Electronics)

Function	: Active Thermal Control with Heaters
	Control Channel : T.B.D.

9.2 TINT (Thermal Integration)

Function	: Passive Thermal Control
Control Method	: Thermal Blankets, Radiators, Paint, Thermal Dissipater, Thermal Isolators

10. Wire Harness

Main Harness (Power, Data Bus)

Connector Type	: MDM / D-sub
Wire Type	: Twisted Pair Shield Wire
Wire Material	: Cu, BeCu, Al
Co-axial Cable	:for RF Signal, a part of Cable between SI

1.3 Spacecraft Property

I.Nakatani(ISAS)
NEC Corporation

1.3.1 Mass

PLANET-B WEIGHT OF SUBSYSTEMS (1/2)

(UNIT:kg)				
S/S NAME	UNIT NAME	'94.06.01	TARGET	REMARK
SCIENTIFIC INSTRUMENTS		34.14	33.00	
PSA	(TOTAL)	5.82	TBD	
	PSA-E	2.07		
	ESA-S	1.20		
	ISA-S	1.20		
	EIS-S	0.95		
	XUV-S	0.40		
PWA	(TOTAL)	8.67	TBD	
	PWA-E	5.50		
	WANT 1-4	2.52		
	WANT-P-1-4	0.65		
MPM	(TOTAL)	8.41	TBD	
	MPM-E	2.80		
	MGF-S	0.58		including sensor cable
	PET-S	0.18		two set, except sensor cables
	MST	2.34		mounting to side panel
	UVS-P/G	2.51		
MIC	(TOTAL)	2.00	TBD	
	MIC	2.00		
TPA	(TOTAL)	3.00	TBD	
	TPA-E	1.35		
	TPA-S	2.03		including BOOM(1.0m) 0.469kg
IMI	(TOTAL)	2.95	TBD	
	IMI-E	1.45		
	IMI-S	1.50		
MDC	(TOTAL)	0.60	TBD	
	MDC	0.60		
NMS	(TOTAL)	2.50	TBD	
	NMS-E	1.50		
	NMS-S	1.00		

PLANET-B WEIGHT OF SUBSYSTEMS (2/2)

		(UNIT:kg)		
S/S NAME	UNIT NAME	'94.11.18	TARGET	REMARK
COMMON INSTRUMENTS		224.24	223.16	
POWER S/S		43.01	43.15	
SCP	PDL	12.00	13.40	2-wings,200W
	CELL	7.20	7.20	18% Si cell
BAT	BAT-A,B	17.50	15.00	15AH(16cells), 2units
PCD	PCD	4.70	5.50	including DIST,BCCU
SHNT	SHNT-A,B	1.00	1.40	
PSU	PSU-2/XPA-PS	0.61	0.65	HCE/TCI/DR/BFM/EPT-SA/INS-SA,RF
COMMUNICATION S/S		13.33	13.83	
HGA	HGA	7.00	7.20	Mesh antenna
LGA	LGA-A	0.14	0.14	
	LGA-B	0.25	0.25	
SBR	SBR-A,B	2.20	2.80	
TMS	TMS	1.20	0.80	2.5W
TMX	TMX	1.50	1.20	
XPA	XPA	0.30	0.70	5.0W(TM+XPA)
SDIP	SDIP-A,B	0.64	0.64	
SSW	SSW-A,B	0.10	0.10	
XSW	XSW-A,B	DELETE	←	
COMMAND,DATA S/S		9.90	8.70	
CMD	CMD	1.70	1.70	including CSS
DHS	DHU	4.60	4.20	including BFM
	PIM	0.85	0.75	Four FSI and DR -->Total 5 units
DR	DR	1.05	1.05	
TCI	TCI	1.70	1.00	
LAUNCH OPERATION S/S		3.62	4.02	
EPT-SA	EPT-SA	1.50	1.90	including relay
INS-SA	INS-SA	2.12	2.12	E+S= 1.836kg, cable(1m)=0.285kg
AOCS		12.30	10.08	
AOCE	AOCE	6.70	5.50	including AOCP
SSAS	SSAS	0.35	0.32	including SENSOR
TSAS	TSAS	0.90	0.76	
SSC	SSC	2.43	2.00	including mounting flange
RGA	RGA-A/B	0.32	0.10	
ACM	ACM-A/B/C/D	0.40	0.40	
ND	ND	1.20	1.00	
PROPULSION S/S		66.45	72.00	
RCS/OMS	RCS	21.15	TOTAL	
	OMS	27.40	72.00	
	MINI/TINT	17.90		
WIRE HARNESS		7.35	7.00	
WHN	WHN	7.35	7.00	
STRUCTURE		56.80	54.50	
STR	STR	44.80	43.00	including Separation Nut(2kg)
MINT	MINT	7.00	6.50	
	BALANCE WT	5.00	5.00	
THERMAL		11.48	9.88	
HCE	HCE	3.30	2.20	32 Heater channels
TINT	TINT	8.18	7.68	
CONTINGENCY		0.42	1.84	
TOTAL AMOUNT	DRY	258.38	258.00	
	FUEL(N2H4)	277.20	278.00	
	FUEL(NT0)	↑	↑	
	WET	535.58	536.00	

1.3.2 Moment of Inertia

PLANET-B MOMENT OF INERTIA (k g · m²)

Phase	I _x	I _y	I _z
S/C separation Fuel Full	1 1 2	1 3 4	2 0 1
After deployment of PDL Fuel Full	1 1 4	2 0 5	2 6 8
Trans-Mars Fuel Consumption N ₂ H ₄ 26 kg NTO 10.2kg	1 1 0	2 0 1	2 6 0
Mars Orbit Insertion Fuel Consumption N ₂ H ₄ 140 kg NTO 109.3kg	8 5	1 7 4	2 1 6
End of Life After deployment of MAST, TPA-S, WANT Fuel Empty	1 3 7	2 0 0	2 9 4

1.3.3 Power Consumption

TABLE 1.3.3-1 POWER CONSUMPTION (1/5)

S/S NAME	MODE	S/S POWER+5V	S/S CURRENT (mA)				PSU LOSS	BUS POWER(+19V)		BUS POWER(+27V)		R (OHM)
			+12V	-12V	+29V	BUS+19V		(mA)	(W)	(mA)	(W)	
PSA	STBY1(CPU+H32)	4.94	790	34	25		1.47	337	6.40	237	6.40	
	STBY2(CPU+H32+SI)	15.32	1178	427	288	0	4.41	1039	19.74	731	19.74	
	XUV HV ON	15.60	1178	447	290	0	4.50	1058	20.10	744	20.10	
	ALL HV/SV ON	17.27	1185	557	308	0	4.98	1171	22.25	824	22.25	
	EIS HEATER ON	N/A	0	0	0	0	0.00	106	2.01	151	4.07	179
	ESA HEATER ON	N/A	0	0	0	0	0.00	211	4.01	300	8.10	90
	ISA HEATER ON	N/A	0	0	0	0	0.00	211	4.01	300	8.10	90
PWA	XUV HEATER ON	N/A	0	0	0	0	0.00	137	2.60	195	5.26	139
	STBY(CPU ON)	3.39	500	33	25	0	1.00	231	4.39	162	4.39	
	LFA+ALT+WANT_PRE	26.50	885	761	535	250	7.48	1893	35.97	1332	35.97	
	LFA+SPW+WANT_PRE	27.36	885	671	535	250	7.13	1815	34.49	1277	34.49	
	LFA+NPW+WANT_PRE	19.85	855	671	535	0	5.61	1340	25.46	943	25.46	
	NEI+NEI PRE	12.16	832	383	227	0	3.50	824	15.66	580	15.66	
	WANT DRV ON	16.80	580	40	20	0	1.14	N/A	N/A	664	17.93	
MPM	SPW HEATER ON	5.88	0	0	0	200	1.18	371	7.06	261	7.06	
	STBY(CPU ON)	3.22	380	51	44	0	0.94	219	4.16	154	4.16	
	MGF/PET ON	5.72	405	154	127	0	1.63	387	7.35	272	7.35	
	MGF/PET/MIST DRV ON	16.84	500	166	139	0	1.87	N/A	N/A	693	18.71	
	MGF/PET/UVS ON	12.23	782	326	311	0	3.47	827	15.71	582	15.71	
	MGF/PET ON +UVS UV	12.65	782	348	322	0	3.59	855	16.25	602	16.25	
	MGF/PET ON +UVS PM	20.54	782	350	325	266	5.17	1353	25.71	952	25.71	
MIC	MGF/PET ON +UVS OVER	20.88	782	361	341	266	5.27	1376	26.15	968	26.15	
	MST HEATER ON	N/A	6	8	8	0	0.07	70	1.34	100	2.70	270
	UVS HEATER ON	N/A	0	0	0	0	0.00	0	0	0	0.00	
	STBY(CPU ON)	2.52	346	31	23	0	0.74	171	3.26	121	3.26	
	IMAGING	16.77	1952	244	262	0	4.87	1139	21.64	801	21.64	
	MIC HEATER ON	N/A				TBD	0.00	0	0.00	185	5.00	

TABLE1.3.3-1 POWER CONSUMPTION (2/5)

S/S NAME	MODE	S/S POWER	S/S CURRENT (mA)			PSU LOSS	BUS POWER(+19V)		BUS POWER(+27V)		R (OHM)	REMARK
			+5V	+12V	-12V		(mA)	(W)	(mA)	(W)		
TPA	SLEEP						114	2.16	79	2.16		Initialization
	DEPLOY						653	12.41	451	12.41		
	BOOT						235	4.46	162	4.46		
	IDLE						136	2.58	94	2.58		peak power
	MEASUREMENT				N/A		516	9.80	356	9.80		
	TELEMETRY						136	2.58	94	2.58		
IMI	STANDBY						153	2.90	107	2.90		Heater only
	IMI ON(HV OFF)						232	4.60	163	4.40		
	IMI HV ON						605	12.80	426	11.50		
MDC	MDC ON(HV OFF)						132	2.50	93	2.50		doesn't have heater
	MDC HV ON						184	3.50	130	3.50		
NMS	STANDBY									TBD		
	NMS ON									12.00		
SI TOTAL(MAX) ; Except heater power							17.72			121.17		

TABLE1.3.3-1 POWER CONSUMPTION (3/5)

S/S NAME	MODE	S/S POWER+5V	S/S CURRENT +12V	-12V	+29V	BUS+19V	BUS+27V	PSU LOSS	BUS POWER(+19V) (mA)	(W)	BUS POWER(+27V) (mA)	(W)	R (OHM)	REMARK
PCD	ON	2.86	60	100	100	0	TBD	0.79	192	3.65	135	3.65		Non Turning off power
SBR	SBR-A/B ON	6.48	480	170	140	0		1.86	439	8.34	309	8.34		
CMD	ON	1.08	60	60	0	0		0.32	74	1.40	52	1.40		
TMS	OFF	0.03	5	0	0	0		0.01	2	0.03	1	0.03		
TMX	ON LOW	4.64	5	205	15	62		1.20	308	5.84	216	5.84		
	ON HIGH	12.88	5	210	15	340		2.85	828	15.73	583	15.73		
	OFF	0.01	1	0	0	0		0.00	0	0.01	0	0.01		
	ON	11.02	90	760	70	0		3.26	752	14.28	529	14.28		
XPA	ON	20.87	0	0	0	710		4.17	1318	25.05	928	25.05		
DHU	CPU A ON/BFM OFF	12.37	2334	0	0	0		3.71	846	16.08	596	16.08		
	CPU A ON/BFM ON	13.15	2482	0	0	0		3.95	900	17.10	633	17.10		
	CPU A/B ON/BFM OFF	13.48	2544	0	0	0		4.04	923	17.53	649	17.53		
	CPU A/B ON/BFM ON	14.27	2692	0	0	0		4.28	976	18.55	687	18.55		
TCI	ON	3.54	491	39	21	6		1.03	240	4.57	169	4.57		
DR	OFF	0.03	5	0	0	0		0.01	2	0.03	1	0.03		
	STANDBY	1.59	300	0	0	0		0.48	109	2.07	77	2.07		
	REC	2.23	420	0	0	0		0.67	152	2.89	107	2.89		
AOCE	REPRO	2.23	420	0	0	0		0.67	152	2.89	107	2.89		Critical operation only
	REC/REPRO	2.65	500	0	0	0		0.80	181	3.45	128	3.45		
	CHECK	2.65	500	0	0	0		0.80	181	3.45	128	3.45		
	AOCE ON	6.51	270	200	200			1.83	439	8.34	309	8.34		
SSAS	AOCP AorB ON(IPL)	12.89	1100	0	0	240		3.16	845	16.05	594	16.05		
	AOCP AorB ON(NOML)	12.36	1000	0	0	240		3.00	808	15.36	569	15.36		
	AOCP A&B ON(IPL)	18.72	2200	0	0	240		4.91	1243	23.63	875	23.63		
	AOCP A&B ON(NOML)	17.66	2000	0	0	240		4.59	1171	22.25	824	22.25		
TSAS	ON	3.03	0	0	0	103		0.61	191	3.63	135	3.63		
	ON	3.03	0	0	0	103		0.61	191	3.63	135	3.63		

TABLE1.3.3-1 POWER CONSUMPTION (4/5)

S/S NAME	MODE	S/S POWER	S/S CURRENT (mA)					PSU LOSS	BUS POWER(+19V)		BUS POWER(+27V)		R (OHM)	REMARK
			+5V	+12V	+15V	+29V	BUS+19V		(mA)	(W)	(mA)	(W)		
SSC	ON	0.41	3	18	14	0		0.11	28	0.53	20	0.53		
	ACM-A/B ON	1.27	0	50	50	0		0.35	85	1.62	60	1.62		
	ACM-C ON	0.64	0	25	25	0		0.17	43	0.81	30	0.81		Launch,OMS only
RGA	ACM-D ON	1.02	0	50	30	0		0.29	69	1.30	48	1.30		
	RGA-A/B ON	1.65	120	40	40	0		0.47	112	2.12	79	2.12		
	EPT-SA ON	0.76	0	60	0	0		0.23	52	0.99	37	0.99		Launch only
INS-SA	SIGNAL OUT	6.35	0	500	0	0		1.91	434	8.26	306	8.26		
	INS 1 ON	2.57	5	130	70	0		0.73	173	3.29	122	3.29		
	INS 2 ON	4.60	5	210	150	0		1.28	310	5.88	218	5.88		
RCS	ON	2	0	0	0	0	68	0.40	126	2.40	89	2.40		TNK press monitor
	RCS THRUSTER ON	24	0	0	0	0	800	4.70	1485	28.22	1045	28.22		Max two thrusters
	OMS F/O ON	63	0	0	0	0	2138	12.57	3970	75.43	2794	75.43		
	LATCH VALVE OPN/CLS	36	0	0	0	0	1208	7.10	2243	42.62	1578	42.62		
HCE	LVm OPN/CLS	16	0	0	0	1000	0	0.00	816	15.50	574	15.50		Launch only
	ON(HEATER ALL OFF)	1.07	60	20	35	1		0.29	72	1.36	50	1.36		
	ON(HEATER ALL ON)	1.69	140	30	45	0	TBD	0.48	114	2.17	81	2.17		
CI TOTAL(MAX)									20.91			124.28		

TABLE1.3.3-1 POWER CONSUMPTION (5/5)

S/S NAME	MODE	S/S POWER		S/S CURRENT (mA)					PSU		BUS POWER(+19V)		BUS POWER(+27V)		R (OHM)	REMARK
		+5V	+12V	-12V	+15V	+29V	BUS+19V	BUS+27V	LOSS	(mA)	(W)	(mA)	(W)			
CI HTR	RCS TNK HTR ON													Total		
	RCS PIPE HTR ON													61.00		
	RCS VLV-M HTR ON															
	RCS EM HTR ON															
	RCS OME VLV HTR ON													20.00	36	
	RCS TH BED AXI HTR ON													20.00	36	
	RCS TH BED RAD HTR ON													10.00	73	
	RCS TH BED TAN HTR ON													25.00	29	
	RCS OME INJEC HTR ON															
SI HTR	SSC HTR ON	N/A	0	0	0	0	0	247	352		247	4.70	352	9.49	77	
	XPA HTR ON	N/A	0	0	0	0	0	311	441		311	5.90	441	11.91	61	
	BAT-A1 HTR ON	N/A	0	0	0	0	0							2.50		
	BAT-A1/A2 HTR ON	N/A	0	0	0	0	0							5.00		
	BAT-B1 HTR ON	N/A	0	0	0	0	0							2.50		
	BAT-B1/B2 HTR ON	N/A	0	0	0	0	0							5.00		
	EIS HEATER ON	N/A	0	0	0	0	0	106	151	0.00	106	2.01	151	4.07	179	
	ESA HEATER ON	N/A	0	0	0	0	0	211	300	0.00	211	4.01	300	8.10	90	
	ISA HEATER ON	N/A	0	0	0	0	0	211	300	0.00	211	4.01	300	8.10	90	
	XUV HEATER ON	N/A	0	0	0	0	0	137	195	0.00	137	2.60	195	5.26	139	
	SPW HEATER ON	5.88	0	0	0	200	0	0	0	1.18	371	7.06	261	7.06		
	MST HEATER ON	N/A	6	8	8	0	0	70	100	0.07	70	1.34	100	2.70	270	
	UVS HEATER ON	N/A						TBD	TBD							
	MIC HEATER ON	N/A						TBD	185				185	5.00	146	
	TPA HEATER ON	N/A														
	IMI HEATER ON	N/A														
HEATER TOTAL										1.24				192.68		

TABLE1.3.3-2 POWER BUDGET (1/6)

S/S NAME	MODE	BUS POWER		PARKING ORBIT		TRANSFER ORBIT		MARS INSERTION		MARS ORBIT									
				SUNLIT SHADOW		SUNLIT		OMS RCS		SUNLIT		SHADOW							
		+27V	+19V	STBY	STBY	STBY	STBY	REAL			STBY	EXT	MANUEVER	REAL	REC	STBY	REAL	REC	
PSA	STBY(CPU+H32)	6.40	←	*	*	*	*	*	6.40	6.40	*	6.40	*	6.40	*	6.40	*		
	STBY2(CPU+H32+SI)	19.74	←	*	*	*	*	*			*	19.74	*						
	XUV HV ON	20.10	←	*	20.10	20.10	20.10	20.10	*										
	ALL HV/SV ON	22.25	←	*	*	*	*	22.25	*					22.25	*		22.25	*	
	EIS HEATER ON	4.07	2.01	▲	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
	ESA HEATER ON	8.10	4.01	See Table(5/6) in detail	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
	ISA HEATER ON	8.10	4.01	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
XUV HEATER ON	5.26	2.60	▼	*	*	*	*	*	*	*	*	*	*	*	*	*	*		
PWA	STBY(CPU ON)	4.39	←	*	4.39	4.39	4.39	4.39	4.39	4.39	*	4.39	*	4.39	*				
	LFA+ALT+WANT_PRE	35.97	←	*	*	*	*	*						35.97	*	35.97	*	35.97	
	LFA+SPW+WANT_PRE	34.49	←	*	*	*	*	*						*	*	*	*	*	
	LFA+NPW+WANT_PRE	25.46	←	*	*	*	*	*						*	*	*	*	*	
	NEH+NEI_PRE	15.66	←	*	*	*	*	*						*	*	*	*	*	
	WANT DRV ON	17.93	←	*	*	*	*	*						(17.93)	*	*	*	*	
	SPW HEATER ON	7.06	←	*	See Table(5/6) in detail	*	*	*	*	*	*	*	*	*	*	*	*	*	
MPM	STBY(CPU ON)	4.16	←	*	4.16	4.16	4.16	4.16	4.16	4.16	*	4.16	*	4.16	*	4.16	*	*	
	MGF/PET ON	7.35	←	*	*	*	*	*						*	*	*	*	*	
	MGF/PET/MST DRV ON	18.71	←	*	*	*	*	*					18.71	*	*	*	*	*	
	MGF/PET/UVS ON	15.71	←	*	*	*	*	*						*	*	*	*	*	
	MGF/PET ON +UVS UV	16.25	←	*	*	*	*	*						*	*	*	*	*	
	MGF/PET ON +UVS PM	25.71	←	*	*	*	*	*						*	*	*	*	*	
	MGF/PET ON +UVS UV/PM	26.15	←	*	*	*	*	*						*	*	*	*	*	
MIC	MST HEATER ON	2.70	1.34	▲	See Table(5/6) in detail	*	*	*	*	*	*	*	*	*	*	*	*	*	
	UTS HEATER ON	T.B.D.	T.B.D.	▼	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
	STBY(CPU ON)	3.26	←	*	3.26	3.26	3.26	3.26	3.26	3.26	*	3.26	*	3.26	*	3.26	*	*	
	IMAGING	21.64	←	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
	MIC HEATER ON	5.00	T.B.D.	See Table(5/6) in detail	*	*	*	*	*	*	*	*	*	*	*	*	*	*	

NOTE:1) REAL = Record + S-REAL + X-Repro 2) Mark "*" indicates the using mode in each operation. 3)unit W

TABLE 1.3.3-2 POWER BUDGET (2/6)

S/S NAME	MODE	BUS POWER		PARKING ORBIT		TRANSFER ORBIT		MARS INSERTION		MARS ORBIT								
		+27V	+19V	SUNLIT		SHADOW		SUNLIT		OMS	RCS	SUNLIT		SHADOW				
				STBY	STBY	STBY	REAL	STBY	EXT			MANUEVER	REAL	REC	STBY	REAL	REC	
TPA	SLEEP	2.16	←	*	2.16	*	2.16	*	2.16	*	2.16	*	2.16	*				
	DEPLOY	12.41	←											(12.41)				
	BOOT	4.46	←											4.46				
	IDLE	2.58	←											*	*	2.58	*	
	MEASUREMENT	9.80	←											*	*	9.80	*	
	TELEMETRY	2.58	←											*	*	*	*	
IMI	STANDBY	2.90	←	*	2.90	*	2.90	*	2.90	*	2.90	*	2.90	*		2.90		
	IMI ON(HV OFF)	4.40	←											*	*	*	*	
	IMI HV ON	11.50	←											*	*	11.50	*	
MDC	MDC ON(HV OFF)	2.50	←	*	2.50	*	2.50	*	2.50	*	2.50	*	2.50	*	11.50	*	11.50	*
	MDC HV ON	3.50	←		*	3.50								*	*	3.50	*	
NMS	STANDBY	TBD	←	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	NMS ON	12.00	←											*	*	12.00	*	
SI TOTAL Except heater power (W)		39.46	42.96	39.46	57.33	25.76	25.76	25.76	25.76	25.76	25.76	25.76	55.95	25.76	142.81	21.80	142.81	142.81

NOTE: 1) REAL = Record + S-REAL + X-Repro

2) Mark "*" indicates the using mode in each operation.

3) unit W

TABLE 1.3.3-2 POWER BUDGET (3/6)

S/S NAME	MODE	BUS POWER		PARKING ORBIT		TRANSFER ORBIT		MARS INSERTION		MARS ORBIT							
										SUNLIT				SHADOW			
		+27V	+19V	SUNLIT	SHADOW	SUNLIT	SHADOW	OMS	RCS	STBY	EXT	MANUEVER	REAL	REC	STBY	REAL	REC
PCD	ON	3.65	←	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65
SBR	SBR-A/B ON	8.34	←	8.34	8.34	8.34	8.34	8.34	8.34	8.34	8.34	8.34	8.34	8.34	8.34	8.34	8.34
CMD	ON	1.40	←	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40
TMS	OFF	0.03	←					0.03	0.03	0.03				0.03			0.03
	ON LOW	5.84	←														
	ON HIGH	15.73	←	15.73	15.73	15.73	15.73				15.73		15.73		15.73		
TMX	OFF	0.01	←	0.01	0.01			0.01						0.01	1.00		0.01
	ON	39.33	←			39.33			39.33	39.33	39.33		39.33				39.33
XPA	including TMX on	↑															
DHU	CPU A ON/BFM OFF	16.08	←								16.08				16.08		
	CPU A ON/BFM ON	17.10	←														
	CPU A/B ON/BFM OFF	17.53	←					17.53	17.53			17.53		17.53		17.53	17.53
	CPU A/B ON/BFM ON	18.55	←	18.55	18.55	18.55	18.55						18.55				
TCI	ON	4.57	←	4.57	4.57	4.57	4.57	4.57	4.57	4.57	4.57	4.57	4.57	4.57	4.57	4.57	4.57
DR	OFF	0.03	←												0.03		
	STANDBY	2.07	←			2.07					2.07						
	REC	2.89	←					2.89	2.89		2.89			2.89			2.89
	REPRO	2.89	←														
	REC/REPRO	3.45	←										3.45			3.45	
	CHECK	3.45	←	3.45	3.45												
AOCE	AOCI ON	8.34	←														
	AOCF AorB ON(IPL)	16.05	←														
	AOCF AorB ON(NOML)	15.36	←							15.36			15.36	15.36	15.36	15.36	15.36
	AOCF A&B ON(IPL)	23.63	←														
	AOCF A&B ON(NOML)	22.25	←	22.25	22.25	22.25	22.25	22.25	22.25		22.25	22.25					
SSAS	ON	3.63	←	3.63		3.63		3.63	3.63	3.63	3.63	3.63	3.63	3.63	3.63	3.63	3.63
TSAS	ON	3.63	←	3.63		3.63		3.63	3.63	3.63	3.63	3.63	3.63	3.63	3.63	3.63	3.63

NOTE: 1) REAL = Record + S-REAL + X-Repro 2) Mark "*" indicates the using mode in each operation. 3) unit W

TABLE 1.3.3-2 POWER BUDGET (4/6)

S/S NAME	MODE	BUS POWER		PARKING ORBIT		TRANSFER ORBIT		MARS INSERTION		MARS ORBIT					
				SUNLIT		SHADOW		OMS	RCS	SUNLIT			SHADOW		
		+27V	+19V	STBY	STBY	STBY	STBY			STBY	EXT	MANUEVER	REAL	REC	REC
SSC	ON	0.53	←	* 0.53	* 0.53	* 0.53	* 0.53	* 0.53	* 0.53	* 0.53	* 0.53	* 0.53	* 0.53	* 0.53	* 0.53
ACM	ACM-A/B ON	1.62	←												
	ACM-C ON	0.81	←					* 0.81							
	ACM-D ON	1.30	←					* 1.30							
RGA	RGA-A/B ON	2.12	←												
EPT-SA	ON	0.99	←												
INS-SA	SIGNAL OUT	8.26	←												
	INS 1 ON	3.29	←												
	INS 2 ON	5.88	←												
RCS	ON	2.40	←	* 2.40	* 2.40	* 2.40	* 2.40	* 2.40	* 2.40	* 2.40	* 2.40	* 2.40	* 2.40	* 2.40	* 2.40
	RCS THRUSTER ON	28.22	←					* 28.22				* 28.22			
	OMS F/O ON	75.43	←					* 75.43							
	LATCH VALVE OPN/CLS	42.62	←												
HCE	LVal OPN/CLS	15.50	←												
	ON(HEATER ALL OFF)	1.36	←												
	ON(HEATER ALL ON)	2.17	←	* 1.09	* 2.17	* 1.09	* 1.09	* 2.17	* 1.09	* 1.09	* 1.09	* 1.09	* 1.09	* 2.17	* 2.17

CI TOTAL (W)	89.22	83.04	127.17	128.54	150.58	141.12	102.11	128.59	140.29	121.65	65.06	71.27	114.45	58.88

NOTE: 1) REAL = Record + S-REAL + X-Repro

2) Mark "*" indicates the using mode in each operation.

3) unit W

TABLE1.3.3-2 POWER BUDGET (5/6)

S/S NAME	MODE	BUS POWER		PARKING ORBIT		TRANSFER ORBIT		MARS INSERTION		MARS ORBIT								
				SUNLIT	SHADOW	SUNLIT	SHADOW	OMS	RCS	SUNLIT		SHADOW						
		+27V	+19V	STBY	STBY	STBY	STBY	REAL			STBY	EXT	MANUEVER	REAL	REC	STBY	REAL	REC
CI HTR	RCS T/K HTR ON	▲			▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	RCS PIPE HTR ON		Total	▲	Total	▲	Total	▲	Total	▲	Total	▲	Total	▲	▲	▲	▲	▲
	RCS VLV-M HTR ON		61.00	▲	TBD	▲	TBD	▲	TBD	▲	TBD	▲	TBD	▲	3.50	▲	61.00	▲
	RCS EM HTR ON		0.00															22.00
	RCS OME VLV HTR ON	▼			▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼
	RCS TH BED AXI HTR ON		20.00	←														
	RCS TH BED RAD HTR ON		20.00	←														
	RCS TH BED TAN HTR ON		10.00	←														
	RCS OME INJEC HTR ON		25.00	←														
SI HTR	SSC HTR ON		9.49	4.70	3.13	4.70	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	4.70	4.70	4.70
	XPA HTR ON		11.91	5.90		5.90										5.90	0.00	5.90
	BAT-A1 HTR ON		2.50															
	BAT-A1/A2 HTR ON		5.00												5.00	0.00	0.00	0.00
	BAT-B1 HTR ON		2.50															
	BAT-B1/B2 HTR ON		5.00												5.00	0.00	0.00	0.00
	EIS HEATER ON		4.07	2.01	1.02	2.01	1.02	2.01	2.01	2.01	1.02	1.02	1.02		2.01	2.01	2.01	2.01
	ESA HEATER ON		8.10	4.01	2.02	4.01	2.02	4.01	4.01	4.01	2.02	2.02	2.02		4.01	4.01	4.01	4.01
	ISA HEATER ON		8.10	4.01	2.02	4.01	2.02	4.01	4.01	4.01	2.02	2.02	2.02		4.01	4.01	4.01	4.01
	XUV HEATER ON		5.26	2.60	1.31	2.60	1.31	2.60	2.60	2.60	1.31	1.31	1.31		2.60	2.60	2.60	2.60
	SPW HEATER ON		7.06	←	1.76	7.06	1.76	0.00	0.00	0.00	1.76	1.76	1.76		7.06	7.06	7.06	7.06
	MST HEATER ON		2.70	1.34	0.68	1.34	0.68	1.34	1.34	1.34	0.68	0.68	0.68		1.34	1.34	1.34	1.34
	UVS HEATER ON		TBD															
	MIC HEATER ON		5.00												5.00		5.00	5.00
	TPA HEATER ON																	
IMI HEATER ON																		
HEATER TOTAL (W)				14.45	31.63	14.45	39.45	18.35	20.43	35.27	15.27	11.95	24.96	24.96	92.63	52.73	58.63	

NOTE: 1) REAL = Record + S-REAL + X-Repro

2) Mark "*" indicates the using mode in each operation.

3) unit W

TABLE1.3.3-2 POWER BUDGET (6/6)

ITEMS		MARS ORBIT																							
		PARKING ORBIT				TRANSFER ORBIT				MARS INSERTION				MARS ORBIT											
		SUNLIT		SHADOW		SUNLIT		SHADOW		SUNLIT		SHADOW		SUNLIT		SHADOW		SUNLIT		SHADOW		SUNLIT		SHADOW	
		STBY	REAL	STBY	REAL	STBY	REAL	STBY	REAL	STBY	REAL	STBY	REAL	STBY	REAL	STBY	REAL	STBY	REAL	STBY	REAL	STBY	REAL	STBY	REAL
CI + SI	W	128.69	126.01	166.63	185.87	176.34	166.88	176.34	166.88	176.34	166.88	176.34	166.88	176.34	166.88	176.34	166.88	176.34	166.88	176.34	166.88	176.34	166.88	176.34	166.88
HEATER TOTAL	W	14.45	31.63	14.45	39.45	18.35	20.43	18.35	20.43	18.35	20.43	18.35	20.43	18.35	20.43	18.35	20.43	18.35	20.43	18.35	20.43	18.35	20.43	18.35	20.43
PCD LOSS	W	3.64	5.81	4.61	5.74	7.17	4.77	7.17	4.77	7.17	4.77	7.17	4.77	7.17	4.77	7.17	4.77	7.17	4.77	7.17	4.77	7.17	4.77	7.17	4.77
CABLE LOSS	W	1.41	3.58	2.25	3.49	5.46	2.41	5.46	2.41	5.46	2.41	5.46	2.41	5.46	2.41	5.46	2.41	5.46	2.41	5.46	2.41	5.46	2.41	5.46	2.41
SUBTOTAL	W	146.78	163.44	185.69	231.06	201.87	192.08	201.87	192.08	201.87	192.08	201.87	192.08	201.87	192.08	201.87	192.08	201.87	192.08	201.87	192.08	201.87	192.08	201.87	192.08

PLANET-B TOTAL POWER

BATTERY MODE	In the case of Trickle Charge	W	162.98	201.89	247.26	183.50	221.10	198.73	312.99	254.95															
	1/50C;16.2W @BUS 27.0V	A	6.04	7.48	9.16	6.80	8.19	7.36	11.59	9.44															
	In the Case of Full Charge	W	195.38			215.90		231.13	345.39	287.35															
	1/10C;48.61W @BUS 27.0V	A	7.24			8.00		8.56	12.79	10.64															
In case of Discharge																									
BAT voltage @ 20.0V		A		8.10			10.29	9.79														9.81	16.45		13.83
MAX SHADOW TIME		min		18.60			TBD	TBD														65.00	65.00		65.00
BATTERY DOD		%		8.37																		35.43	59.40		49.95

TOTAL=TBD %

NOTE: 1) REAL = Record + S-REAL + X-Repro

2) Mark "*" indicates the using mode in each operation.

1.4 Spacecraft Operations

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NEC Corporation

1.4.1 Earth Parking Phase

(1) Initial Operation Plan

- ① launch mode set
- ② launch
- ③ ACM integration start just before 3rd-Stage burn-out (by a timer)
- ④ active nutation control by GRS/RCS
- ⑤ 4th-Stage ignition → spacecraft separation
- ⑥ on-board Δv correction just after separation (if necessary)
- ⑦ auto Solar pointing
- ⑧ spin down → solar paddles deployment → spin up (tbd)
- ⑨ Δv correction from ground station (if necessary)

(2) Orbit Control Plan

	TIME(UTC)	ΔV (m/s)
Insertion to Trans.-Lunar	08.06 17:12	
1st Apogee	08.12 06:36	13.6
2nd Apogee	08.23 05:03	18.0
2nd Perigee	08.28 16:38	3.4
1st Swing-by	09.24 16:41	
5th Apogee	11.04 04:48	5.3
2nd Swing-by	12.18 07:12	
Insertion to Trans.-Mars	12.20 07:34	19.5

— RCS/OMS sequence

ΔV	RCS/OMS	Sequence
10m/s $\geq$	RCS	Re-ori. → nutation damp → Δv → nutation damp → Re-ori.
> 10m/s	OMS	spin up → same as above → spin down

(3) Orbit Outline

Orbit (Typical)	: 1000km × 400,000km (orbit period=11days)
	: Apogee 1.71mkm (between 1st&2nd swing-by)
Staying Period	: 4 months (1998.8~1998.12)
Spacecraft Attitude	: solar pointing (except $\angle V$)
Max. Shadow	: 22 minutes
Communication Link	: LGAs(A/B) in S-band
	: uplink 125bps/downlink 1024bps
Primary Operation	: function check (CI→SI→HV)
	: normally stand-by mode
For Next Phase	: lunar swing-by → 1,500,000km →
	lunar swing-by → $\angle V$ for next phase
	: $\theta_s = 119^\circ$ at $\angle V$
	: $\angle V = 420$ m/s (altitude 7288 km)
	: $\angle V$ = shadow & invisible from udsc

1.4.2 Cruising Phase

(1) Phase 1 (first 75 days after the insertion into trans-Mars orbit)

Earth Range	: 7288km → 15,000,000km
Sun-Earth Angle	: $110^\circ \sim 45^\circ$
Staying Period	: 75 day (1998.12~1999.2)
Spacecraft Attitude	: solar pointing
Max. Shadow	: no shadow
Communication Link	: LGAs(A/B) in S-band
	: uplink 125bps/downlink 64bps(min.)
Primary Operation	: normally stand-by mode

(2) Phase 2 (Trans.-Mars period after phase 1)

Earth Range	: 15,000,000km → 1.7au (250mkm)
Solar Range	: 1.0au → 1.5au (220mkm)
Sun-Earth Angle	: $45^\circ \sim 15^\circ$
Coasting Period	: 7 months (1999.2~1999.10)

Spacecraft Attitude	: earth pointing 5.5deg/10days (typ.)
Max. Shadow Period	: no shadow
Communication Link	: HGA in S-band
	: uplink 125bps/downlink 64bps(min.)
Primary Operation	: normally XUV-S operation mode
For Next Phase	: $\theta_s=89\text{deg}, \theta_e=128\text{deg}$ at $\angle V$
	: $\angle V=1257 \text{ m/s}$
	: $\angle V=\text{shadow \& invisible from udsc}$

(3) Orbit Control Plan

$\angle V$ plan during the trans.-mars phase is as follows.

30days after departure from the earth
150days after departure from the earth
10days before Mars orbit insertion

1.4.3 Mars Orbiting Phase

(1) Orbit Outline

Orbit	: $150\text{km} \times 14\text{RM}$ (altitude)
Earth Range	: $0.5\text{AU} (70\text{Mkm}) \rightarrow 2.5\text{AU} (375\text{Mkm})$
Solar Range	: $1.5\text{AU} (220\text{Mkm})$
Sun-Earth Angle	: $0\text{deg} \sim 45\text{deg}$
Staying Period	: 2 years (1999.10~2001.9)
Spacecraft Attitude	: earth pointing
Max. Shadow Period	: 65 minutes
Communication Link	: HGA-S (down) 1024bps~64bps/(up) 125bps
	: HGA-X (down) 65536bps~2048bps

(2) Operation Plan

a. Nominal

deployment sequence : TPA boom→MAST→WANT
nominal maneuvering : earth pointing maneuver
1.4deg/day (typ.) just after LOS
visible from udsc : 8 hours/1 Rev.(25 hours)
observation : All SI data storing from MIC & MDC to DR will
be performed as the temporary mode.

b. Sun-Conjunction

period : 22 days ($\theta \leq 16' \times 7$ times)
situation : TLM/CM not used
operation plan : spin up or periapsis up→occultation experiment→
spin down or periapsis down→auto earth pointing
occultation exp. : TMX, TMS coh. mode→Tx auto start→
Tx auto stop

c. Opposition

Period : TBD days ($\theta \leq 16' \times \text{TBD times}$)
Situation : no use of HGA Tx
Operation plan : same as nominal (except uplink rate=15.625bps)

1.4.4 Telemetry Format

See Appendix-A for detail.

1.4.5 HK Items

See Appendix-B for detail.

1.4.6 Command Items

See Appendix-C for detail.

2. Scientific Instruments

2.1 Particle Spectrum Analyzer (PSA)

<u>Team Members :</u>	<u>Affiliation</u>	<u>ESA</u>	<u>ISA</u>	<u>XUV</u>	<u>EIS</u>
Shinobu Machida	Kyoto U.	PI	Co-I		
Hajime Hayakawa	ISAS	Co-I	PI		
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Toshio Terasawa	U. of Tokyo	Co-I	Co-I		Co-I
Masato Nakamura	U. of Tokyo			Co-I	
Masafumi Hirahara	U. of Tokyo	Co-I	Co-I	Co-I	
Toshihiro Ogawa	U. of Tokyo			Co-I	
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Koichiro Tsuruda	ISAS	Co-I	Co-I		
Toshifumi Mukai	ISAS	Co-I	Co-I		
Tatsundo Yamamoto	ISAS			Co-I	
Masahiro Hoshino	ISAS	Co-I	Co-I		
Yoshifumi Saito	ISAS	Co-I	Co-I	Co-I	
Kiyoshi Maezawa	Nagoya U.	Co-I	Co-I		Co-I
Masaki Fujimoto	Nagoya U.	Co-I	Co-I		Co-I
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Supriya Chakrabarti	Boson U.			Co-I	
Manufacturers :					
Meisei Electric Co., Ltd.					
Mitaka-Koki Co., Ltd.					
Hamamatsu Photonics K.K.					

2.1.1 Observation Objectives

2.1.1.1 Electron Spectrum Analyzer (ESA)

The ESA sensor measures three dimensional velocity distribution functions in the Martian environment and in the interplanetary space. It is intended to achieve our understandings on the following subjects.

1) Martian Bow Shock

The structure of the bow shock such as its scale size, dissipation mechanism, and particle acceleration processes in the shock. Excitation of waves due to an anisotropic electron velocity distribution. Verification of Rankine -Hugoniot relations. Mass, momentum, and energy transport across the shock.

2) Structure of Ionopause

Ionization of neutral particles due to electron impact, and subsequent plasma supply into the Martian magnetosphere. Transport of the mass, momentum, and energy of the solar wind across the ionopause.

3) Martian Ionosphere

Spatial profile of the electron density and temperature at high altitude day-side and night-side region of the Martian ionosphere. Comprehension of the ionosphere as a plasma source of the Martian magnetosphere.

4) Martian Aurora

Direct detection of the primary electrons which produce auroral (atmospheric glow due to particle precipitation). Synthesized study on the generation mechanism of Martian aurora and its electric current system.

5) Magnetopause and Boundary Layer

Study of the characteristics and structure of the magnetopause, categorizing whether it is rotational discontinuity or tangential discontinuity etc., and study of the expected electron acceleration and heating processes at the boundary.

6) Tail Region

Origin of the plasma supplied to the nightside extended magnetosphere, and characteristic density and temperature distribution of electrons in that region, Also to study how particles escape into the interplanetary space.

7) Solar Wind

Structure of the solar wind at quite time as well as disturbed time. Study on interplanetary shocks, flux ropes, tangential discontinuity, rotational discontinuity, and current sheets etc. in the solar wind.

2.1.1.2 Ion Spectrum Analyzer (ISA)

The ion spectrum analyzer (ISA) aims to measure 3-D moment data and 3-D velocity distribution function of low energy Ions in the Marsian environment as well as in the solar wind. The major scientific objects for ISA are :

1) Solar Wind

Since gravity of the Mars is small, neutral oxygen atoms can escape from ionosphere into the solar wind. Part of these oxygen atoms are photo-ionized by the solar UV flux. The ionized particles are accelerated up to twice of the solar wind velocity by the solar wind electric field. These accelerated ions are called as pick up ion and have either beam or ring distribution in the velocity space with the solar wind velocity as the center of the ring. Though the highest energy of these accelerated ions exceeds proposed measurement range of the ISA (10eV - 20keV) in the upstream region of the Marsian bow shock, main body of the distribution can be observed by the ISA. In the down stream region of the bow shock, whole part of the velocity distribution of the pick up ion is expected in the measurement energy range of the ISA. ISA also can measure the 3 dimensional velocity distribution of the decelerated solar wind due to the mass loading effect of the pick up ions simultaneously. These measurements give the information of the escaping mechanism and the interaction between the solar wind and the Marsian atmosphere.

2) Ionopause

Based on the Venus observations, solar wind magnetic field occasionally penetrate deeply into the ionosphere. Same kind phenomena is expected to occur on the Marsian ionosphere. Combination of the ISA, ESA, and MGF experiments give us the information of the interaction processes between ionosphere and the solar wind.

3) Marsian Tail

One of the remarkable observations of the Phobos-2 mission was the discovery of the keV energy range oxygen ion beam flowing downward in the Marsian magnetotail. Generation mechanism of the oxygen ion flows is not yet understand. ISA can measure the oxygen ion flows in the wide range of the Marsian magnetotail both in radial and azimuthal directions. The origin and the acceleration mechanism of these oxygen ions can be studied with ISA

measurements in the Marsian tail.

2.1.1.3 Electron and Ion Spectrometer (EIS)

The EIS detectors measure ions in the energy range of 30 keV - 1 MeV and electrons in the energy range 30 - 400keV. Generally speaking, particles in this energy range constitute a high energy tail of the main plasma distribution, since solar wind protons with 1 keV energy are one of the major plasma sources of the planetary magnetospheres. Observations in the Earth's magnetosphere have established that these higher energy particles carry important and unique information on the dynamical processes occurring in the planetary environment. For example, detailed features of the substorm processes have been clarified through the analysis of the energetic particle layer of the distant plasma sheet and of energetic injection events in the near-earth magnetosphere. On the other hand, observation of energetic particles has been prerequisite to the identification of acceleration processes occurring at the earth' bow shock and magnetospheric boundaries. Overall, detailed information on energetic particles is indispensable for correct understanding of the solar-wind magnetosphere interaction.

As compared to the earth's magnetosphere, Martian magnetosphere is expected to be different in two important aspects. Firstly, because of its low gravity, Mars is expected to have an extended corona of oxygen atoms. Certain percentage of these atoms are photo-ionized and picked up by the solar wind, thereby obtaining energy exceeding 30 keV, detailed values of which depends on the solar wind and IMF conditions. Therefore energetic ions of planetary origin may contribute significantly to the energy transport in the Mars environment. Secondly, because of the small size of the magnetosphere and weak magnetic field, gyro radius of the energetic particles may become comparable to the spatial scale of the magnetosphere. This means that these ions may seem unmagnetized for interaction processes occurring locally at the interface between the solar wind and the magnetosphere and/or ionosphere.

Our main objective of the EIS experiment is to clarify these rather unexplored aspects of the solar-wind interaction occurring in the Martian environment and compare them with our knowledge accumulated on the earth's environment. Specifically, we list below the main targets of the EIS measurements for the Planet-B mission.

1) Ion pick-up processes

Mars is expected to possess an extended oxygen corona (Nagy and Cravens, 1988; Ip, 1988). Because of the low gravity, oxygen atoms produced through dissociative recombination of O_2^+ in Martian ionosphere may extend deeper into the exosphere as compared to the case of Venus. The oxygen density decreases with the distance from the planet but is expected to remain as high as 30 cm^{-3} even at the distance of a few Martian radii

from the surface (Ip, 1988). Part of these oxygen atoms are photo-ionized and accelerated by the motional electric field of the solar wind up to energies beyond 30 keV. Simulation results (Luhmann and Schwingenschuh, 1990) indicate that the absolute flux of these ions in the tailward solar wind may exceed $10^4 \text{ cm}^{-2} \text{ s}^{-1}$, depending on the magnitude and direction of the IMF. A highly anisotropic nature of these ions (mono-energetic beams basically confined in the plane perpendicular to the IMF) would make the identification of the pick-up processes relatively easy, but the chance of the observation strongly depends on the satellite position. The energy coverage and the wide field-of-view of EIS detectors (owing to the satellite spin) are well suited for the detection of heavy picked-up ions and will add significantly to the observation results of Phobos-2 mission, for which the field-of-view of energetic particle detectors was limited (Kirsch et al., 1991).

2) Acceleration at the bow shock

It has been suggested that energetic particles appear preferentially near the Martian bow shock (Afonin et al., 1991). Such acceleration processes have also been detected at the earth's bow shock and other planetary bow shocks. For the earth's case, two different mechanisms have been proposed for ion acceleration at the bow shock, namely, drift and diffuse acceleration mechanisms. An interesting point for the case of Martian bow shock is the way Oxygen ions influence the shock dynamics. It is expected that the upstream solar wind is already contaminated by the picked-up Oxygen ions. The presence of these ions may lead to electromagnetic fluctuations both upstream and downstream of the shock and hence influence the degree of ion scattering. Large gyroradius of these heavy ions may also influence the structure of the shock itself. It is necessary to evaluate the importance of the shock acceleration to the overall budget of acceleration and transport processes around Martian magnetosphere for different IMF conditions and compare it to the case of earth. Of course, careful analysis is needed to distinguish the bow-shock accelerated ions from picked up ion population of planetary origin.

3) Acceleration processes in the magnetospheric tail

Phobos-2 observation has established that Mars has an induced magnetic tail consisting of draped IMF field lines (Riedler et al., 1989). It also established that there is a significant escape of heavy ions from the planet, confined inside the tail. Since Martian atmosphere is rather thin, the ion escape could have influenced the historical evolution of Martian atmosphere. The energy of these ions is reported to be comparable to that of the solar wind protons, and hence is significantly larger than the thermal ion energies in the ionosphere; thus there is a need for a powerful acceleration mechanism(s) operating in the magnetic tail of Mars.

Limited information derived from Phobos observations indicates that ions of different mass

gain the same amount of energy through the acceleration processes. This fact supports the view that the acceleration is somehow related to an electric field potential produced along the field line. However, if the acceleration mechanisms are related to the induced bulk motion of plasma, as in the case of a release of magnetic tension, heavy ions can be accelerated up to the local Alfvén velocity and gain energies of the order of a few tens of keV. The presence of this kind of acceleration mechanism cannot be denied from previous observations, and constitutes an important target of the EIS observation in the magnetotail.

4) Identification of reconnection processes

Although Mars does not have a strong magnetic field, there remains a possibility that Mars has a weak intrinsic magnetic moment which would stop the solar wind before it reaches the dayside ionosphere. The presence of a weak or partial magnetosphere produced in this way will lead to a number of possibilities that energetic phenomena similar to those occurring in the earth's magnetosphere can also be observed around Mars. Firstly, magnetic reconnection can take place between the IMF and magnetospheric field lines at the dayside magnetopause and accelerate ions and electrons locally. Secondly, the transport of reconnected field lines toward the tail will lead to an enhancement of tail magnetic tension, and then trigger tail reconnection just like it does in the earth's magnetotail. (Even if Mars does not have an intrinsic magnetic field, tail reconnection may be triggered by similar enhancement of magnetic tension in the induced magnetic tail.) These reconnection processes will accelerate ions and electrons via the induced electric field produced by rapid changes in the magnetic field configuration. Although the Martian magnetotail has a smaller spatial scale as compared to the earth's magnetosphere, the induced electric field would be capable of accelerating particles up to the energies of the IES detectors. Analysis of energy spectra and anisotropies of accelerated particles by EIS will contribute to clarifying the detailed mechanisms of such reconnection processes.

5) Transport and energization of solar particles

Transport and modulation of solar energetic particles around the Mars orbit is another point of interest. Monitoring of solar energetic events from Mars and earth orbits by Planet-B and other spacecraft will provide new insights into the transport of energetic particles in the interplanetary medium. Compression of the solar wind and IMF near the Martian magnetopause/ionopause around the subsolar point will lead to energization of particles due to the conservation of the first adiabatic invariant. A shadow effect can be expected on the rear side of the planet (Afonin et al., 1989). Some of the solar particles and Jovian electrons may be trapped or quasi-trapped if Mars possess an intrinsic magnetic field. Contribution of these ions and electrons of exterior origin to energetic population around Mars is an important subject that should be addressed by the Planet-B mission.

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2.1.1.4 eXtra Ultra Violet imager (XUV)

We are planning to measure the abundance and distribution of Helium gas and Helium ions in the Martian ionosphere with the extreme ultra violet scanner (XUV). Neutral Helium gas and Helium ions scatter the 58.4nm (He I emission) and 30.4nm (He II emission) EUV light from the sun. The XUV measures these scattered light which is proportional to the column density of these components of the Martian atmosphere and ionosphere. As this measurement is carried out from the outside of the Martian ionosphere, we can decide the total abundance and the height distribution of the neutral Helium gas and Helium ions.

No observations of neutral Helium gas has been made on previous Mars missions, and Helium ions have been observed only by Phobos 2. On Planet-B, these components are measured *in situ* by the plasma instruments and neutral particle mass spectrometer. Simultaneous observation of the XUV with these instruments will be very valuable since both local and global information will be available.

1) Importance of neutral Helium gas measurement on Mars

The internal activity of the Mars has been discussed for many years. If the volcanic activity and/or water circulation just below the planetary surface is not active, the Helium gas which is created from radioactive materials in the Mars, i.e., U and Th, cannot come out to its surface. As the Helium gas is easy to escape to space due to its light weight and small gravity of the Mars, the total amount of Helium gas should be very small if there is no activity in the Mars. On the other hand, if Helium gas will be observed in its atmosphere, it would prove the activity of the Mars. In 1993, the EUV telescope on the Extreme Ultraviolet Explorer satellite (EUVE) was pointed to the Mars for 3 days, and measured the 58.4nm scattered light from the neutral Helium gas. They have concluded that the Martian atmosphere is Helium rich. Thus we expect that the neutral Helium gas observation by the XUV instrument on Planet-B will give information of the activity of the Mars from measurement of the total abundance, seasonal variation, height distribution of the neutral Helium gas.

2) Importance of Helium ion measurement on Mars

The Helium ion measurement in the Martian ionosphere was done only by Phobos 2 mission. They have observed 1-10keV Helium ions at 500km altitude from the Martian surface. However no low temperature Helium ions were measured *in situ* so far. Our interest is in the ionization process of the Helium gas and its escape from the ionosphere to the outer space. As the Mars has no magnetic field (or very small magnetic field), the escaping process of the Helium ions should be much different from that of the earth and the comparison of these two cases will give a lot of information of the behavior of the space plasma.

Another interest is the observation of the pick-up ions. As the Martian ionosphere is directly interact with the solar wind due to the absence of the magnetic field, the Helium ions of Martian atmospheric origin are picked up by the magnetic field flowing with the solar wind. On the other hand He^{++} in the solar wind become He^+ after the charge exchange with the neutral particles in the Martian ionosphere and could be detected by the XUV instrument. Such measurement is important in the study of the space plasma.

3) Observation of the Plasmasphere of the earth

Planet-B will be put into a parking orbit around the earth for 3 months before the insertion into the transfer orbit to the Mars. During this period, the XUV will be turned on and

measure the Helium ion distribution of the plasmasphere. Such observation of the plasmasphere from several tens of earth radii has not been done so far. The global image of the plasmasphere from the XUV will give a lot of knowledge of the formation of the plasmasphere.

4) Observation of the Interplanetary He I and He II emissions

On the way from the earth to the Mars, the XUV will measure the emission from the interplanetary Helium ions and neutral Helium atoms. The a particle (He^{++}) will make charge exchange with interstellar Hydrogen atoms and become He^+ and He. Helium ions (He^+) are flowing with the solar wind and due to the Doppler shift effect, we do not expect they scatter solar EUV light effectively. However, the Helium atoms (He) may lose its momentum through the charge exchange process and may scatter 58.4nm EUV light effectively so that we may observe this emission. This measurement will give a lot of information of the efficiency of the charge exchange process between Helium ions in the solar wind and interstellar Hydrogen atoms in the interplanetary space.

2.1.2 Instrument Specifications

2.1.2.1 ESA

Energy Range	6.6 eV ~ 20 keV
Energy Steps	32 steps
Energy Resolution	$\Delta E/E \sim 4 \%$
Field of View	4.5 deg x 200 deg
Angle Resolution	4.5 deg x 4 deg
Time Resolution	3 dim. velocity distribution function / min. (maximum)
G-factor	$10^{-4} \text{ cm}^2 \text{ sr eV/eV}$ at 22.5 deg x 4 deg

2.1.2.2 ISA

Energy Range	10 eV/q ~ 20 keV/q
Energy Steps	32 steps
Energy Resolution	$\Delta E/E \sim 10 \%$
Field of View	4.5 deg x 200 deg
Angle Resolution	4.5 deg x 4 deg
Time Resolution	3 dim. moment data / spin (maximum) 3 dim. velocity distribution function / min. (maximum)
G-factor	$3 \times 10^{-5} \text{ cm}^2 \text{ sr eV/eV}$ at 4.5 deg x 4 deg

2.1.2.3 EIS

Particles	Energy
Electron	30-350 keV
H	30-400 keV
He	30-400 keV/n
C,N,O	30-400 keV/n
Ne,Mg,Si	30-400 keV/n
Z>16	30-400 keV/n

Field of View	TOF-E	$\pm 8^\circ$	
	$\Delta E \times E$	SiA	$0^\circ \sim +20^\circ$
		SiB	$-20^\circ \sim 0^\circ$
S Ω	TOF-E	$0.01 \text{ cm}^2 \text{ sr}$	
	$\Delta E \times E$	SiA	$0.0235 \text{ cm}^2 \text{ sr}$
		SiB	$0.0235 \text{ cm}^2 \text{ sr}$

[1] TOF-E System

Function	Heavy Ion Identification	
	Time of Flight / Energy Measurement	
Flight Path	40 mm	
Thin Foil	$\sim 20 \mu\text{g} / \text{cm}^2$	
	parlyane (Carbon) Foil	
Entry Window	12 mm ϕ (eff.)	
Grid(Mesh)	Stainless Steel	
	Transparency	90 %
MCP	Gain	$\sim 5 \times 10^6$
Time Resolution	$\sim 1.0 \text{ ns}$	
Collimator	Buffled Structure, Aluminium	
Si-Detector (E-Detector)	Size	14 mm ϕ
	Thickness	460 μm
	Type	Ion-Implanted

[2] $\Delta E \times E$ Si-Detector System

Function	Electron / Ion Identification	
	Energy loss $\Delta E \times E$ Measurement	
	Size	3.0 mm ϕ

Si-Detector	Δ E-Detector	Thickness	10 μ m
		Type	Ion-Implanted
	E-Detector	Size	14.0 mm ϕ
		Thickness	460 μ m
		Type	Ion-Implanted

2.1.2.4 XUV

Size	95 f x 177mm
(Including pre-Amp. and control circuit)	
Mirror aperture	60mmf
Focal length	70mm
MCP aperture	5mmf
View angle	1°, 2°
Total efficiency of photon detection	1%
Weight (Including control circuit)	400g
Power consumption	3.5W

2.1.2.5 PSA-E

PSA-E is constructed from following four parts ,i.e. (1)Power Converter, (2)SICPU/PIM board, (3)EIS control board, and (4)PAX control board.

(1) Power Converter

Type 2 Power Supply Unit (PSU) is used as Power Converter.

Detailed description of PSU is given in Section 6.5.2.

(2) SI-CPU/PIM board

This unit controls commands and telemetry interface between s/c system. Commands are decoded in this unit and distributed to EIS and PAX control boards. HK data and EIS telemetry data are compiled in this unit and transferred to DHU. PAX data is transferred from PAX control board to DHU through this unit. 80C86 8Mhz CPU with 512kB RAM is used as SI-CPU. Detailed description of PIM is given in Section 4.4.

(3) EIS control board

This unit converts digital control signals into analog signals and pass them to the sensor. This unit also converts sensor analog output to digital data and accumulate the data into

corresponding RAM address. The data stored in RAM is processed by SI-CPU and sent to DHU.

(4) PAX control board

This unit controls ESA, ISA, and XUV sensors. H32 OBC with 6Mhz clock and 512kB RAM is placed in this unit to control sensor HVs and data handling. Commands passed from SI-CPU are decoded in a FPGA and passed to H32 OBC. Onboard calculation of plasma moment data (density, velocity, and temperature) and compression of velocity distribution function, compilation of XUV data are also performed in H32 OBC.

2.1.3 Instrument Configuration

PSA instrument consists of 5 packages, i.e. PSA-E, ESA-S, ISA-S, EIS-S, and XUV-S. The control electronics for each sensors are gathered into one package (PSA-E).

2.1.3.1 ESA-S

The sensor employs a method of a top hat electrostatic analyzer placing a pair of flat disks which works as a collimator at the entrance and toroidal electrodes inside as illustrated in Fig 2.1.3.1-1. The acceptance angle of the particles is geometrically specified and limited by the collimator. The collimator and the outer spherical shell of the electrode are grounded, while the inner toroidal electrode is supplied with high voltage which is swept between 1.2 V and 3000 V with high speed where the sampling time for one energy step is ~ 4 msec.

The electrons coming through the collimator are attracted down toward the inner electrode by the action of the applied potential. However, only the electrons with specific energy range can further travel down to the exit slit of the electrodes. There also placed a mesh supplied with slightly negative voltage (~ -6 V) to reflect the secondary electrons which give spurious counts. The electrons passing through the electrode enter to Micro-Channel Plate (MCP) and intensified to detectable charge pulses. Finally, the charge pulses are received by position sensitive anode. The positions where the charge pulses are detected correspond to the incident directions of the electrons. The supplied voltage to the electrodes is related to the energy of the incident electrons, and the measured energy range is from 6.6 eV to 21 keV with the energy resolution $dE/E = 4.0\%$. The intrinsic angular resolution of the sensor is 1.0 deg in polar direction, and 1.8 deg. in azimuthal direction.

2.1.3.2 ISA-S

The ISA sensor uses same type of top hat electrostatic analyzse as ESA-S. The sensor configurations are basically same as that of ESA-S. Due to ion measurement, polarity of the



Figure 2.1.3.2-1

● 明星電機株式会社

Metel Electric Co., Ltd.

日期	年月日	地点	承批
1			一

sweep HV and polarity of the HV applied to the MCP are reversed from that of ESA-S. Also deflection angle of the spherical energy analyzer is different from that of ESA-S due to the difference of the required geometrical factor for the sensors. Schematic drawing of the sensor is shown in Figure 2.1.3.2-1.

2.1.3.3 EIS-S

The EIS in the PSA instrumental package is designed to measure the composition of electron and heavy ions in the Mars and interplanetary environment from energies from 30 keV/n to >400 keV/n. This system contains two types of energetic particle telescopes, shown schematically in Fig. 1. One is a TOF-E telescope which employs time-of-flight/energy analysis to determine the ion mass. Another is the $\Delta E \times E$ telescopes based on the well established $\Delta E \times E$ method. The TOF-E telescope looks in the 0° direction while a pair of $\Delta E \times E$ Si-detector telescopes are oriented in the 180° direction. The TOF-E telescope mainly measures the composition of low energy ions (H, He, CNO, NeMgSi, Fe) and $\Delta E \times E$ telescopes are mainly used to measure ion composition at higher energies and electron component. The EIS subsystems are described below.

1. The TOF-E Telescope

The EIS TOF-E telescope consists of aluminum collimator followed by a thin foil and Si detector with an effective geometric factor of $0.01 \text{ cm}^2 \text{ sr}$. The thin parylene front foil (about 20 mg/cm^2 in total thickness), which is mounted on about 90% transparency stainless steel grid, is doubly aluminized to reject both light and scattered La-ray background. The TOF-path determined by the foil and the rear Si-detector is 4 cm. The incoming charged particle strikes the foil and emits a number of secondary electrons out of the thin foil and these are electrostatically accelerated and reflected through 90° into microchannel plates (MCPs) and start the timing measurement. The incident particle are stopped in the Si-detector. The pulse height from the detector signal provides the particle kinetic energy E . Secondary electrons from the front surface of the Si-detector enter another MCP after the deflection at electrostatic mirror and provide the stop signal for the timing measurement. Using the time and energy information, particle species are identified and mass of the ions is obtained. The MCPs used in the telescope are 14mm diameter, 12mm pore size, a-ratio=40, 300MW plates and a gain of 7×10^6 (@2kV).

Fig.2 shows the TOF-Energy relation for various elements. The resolution depends on the atomic number Z and the particle energy E . At higher Z and lower energy, the resolution limit is set by the spread of pulse-height-defect in the E-detector, while at higher energies the limiting factor is the timing resolution of about 1.0 ns in the TOF system. Spectral and elemental resolution resolution is obtained from 256-channel pulse-height analysis of the

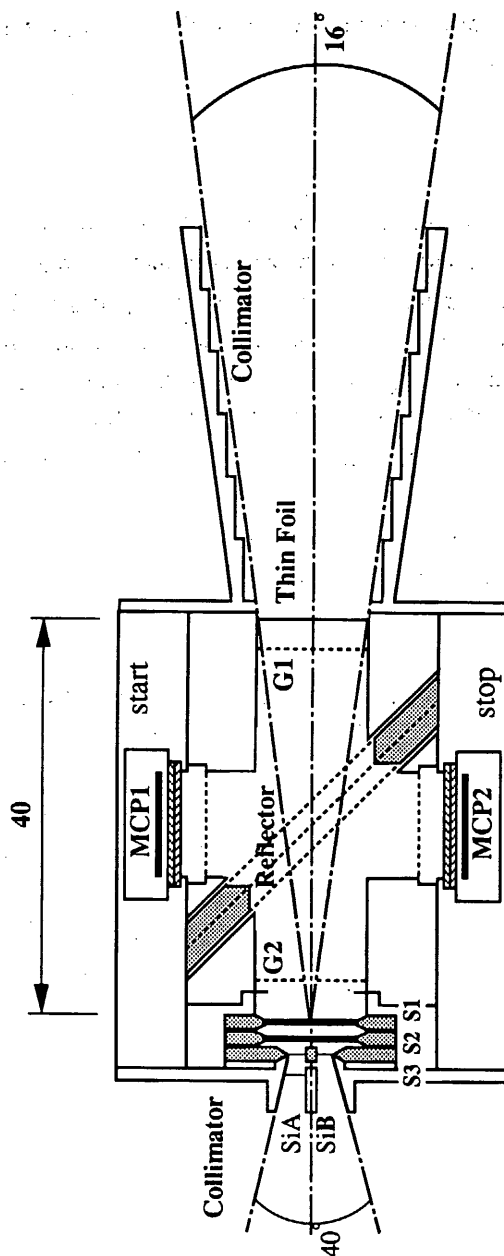


Fig.1 Schematic Drawing of Electron and Ion Composition Spectrometer(EIS)

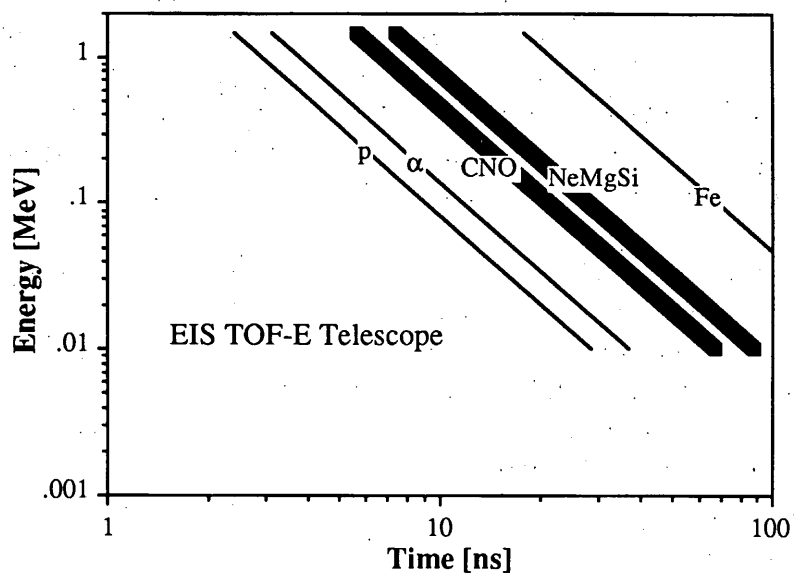


Fig.2 Theoretical Response of various Ions
for EIS TOF-E Telescope

energy and TOF timing signals for individual events.

The TOF-E telescope with the geometric factor of $0.01 \text{ cm}^2\text{sr}$ measures H, He, CNO, NeMgSi in the energy range from 40 keV/n to >400 keV/n.

2. ΔExE Telescopes

The telescope system is based on the well known principle of measuring the incoming ion and electron fluxes in two telescopes. One of them, called SiA, is protected by a thin foil in order to prevent from the sun light and low energy ions from reaching the detector while allowing the passage of electrons. The other, called SiB, which has no foil, records both ions and electrons above an energy threshold determined by the detector noise (30keV). The foil absorber in front of SiA is composed of 150 mg/cm^2 (total thickness) of polyimide coated with aluminum. Using a 30 keV threshold, this corresponds to $E > 90 \text{ keV}$ for protons (120 keV for He). The SiB detectors simultaneously count electrons and low energy ions above an threshold of 30 keV.

Schematic drawing of the ΔExE is shown in Fig.1. Each telescope consists of a thin Si detector (S3A/B) followed by common detectors (S1 and S2). S3A/B is 3mm dia., 10mm thick, S1 and S2 is each 14mm in dia., 460mm thick. The SiA and SiB telescopes look the direction from 0° to 40° against the spacecraft plane and from 0° to -40° , respectively. Apertures for each telescope are defined by an aluminum collimator located in front of S3A/B detector. This yields geometric factors for each telescope $0.047 \text{ cm}^2\text{sr}$. The collimator has a baffled structure to reduce scattering of light and electrons. Counting rate difference between the two telescopes allow protons and electrons to be distinguished.

In each telescopes, the S3 and S2 detectors are primarily operated in coincidence with energy loss ΔE measured in S3 and residual energy measured in S2. The S1 is basically employed as the anticoincidence detector in the ΔExE telescope. Fig.3 shows ΔExE tracks for various element e, H and He over a wide range of energies. The telescopes with the geometric factor of $0.047 \text{ cm}^2\text{sr}$ measure electrons from 50 to 400 keV, and H and He from 30 to >400 keV/n.

As shown in Fig. 4 and Fig. 5, electronic circuit of EIS consists of two parts. One is a analog part set in the EIS-S box and another is a digital part (EIS-E) set in the PSA-E box. Charge signals from silicon detectors are amplified by charge sensitive pre-amplifiers and shaped by shaping-amplifiers in EIS-S ΔE -E analog part. And then they are feed to ADCs in EIS-E to convert to digital signals. Time difference between start and stop signal from two MCPs is converted to analog pulse height signal by EIS-S TOF analog part and feed to ADC in EIS-E. Digital data from ADCs are used as address of two dimensional reference tables. The first table is the matrix of flight-time and energy of incoming charged particles. The signal pair of flight-time and energy falls into one position on the reference table and the corresponding counter is added by one. Another table is a matrix of ΔE and E to measure

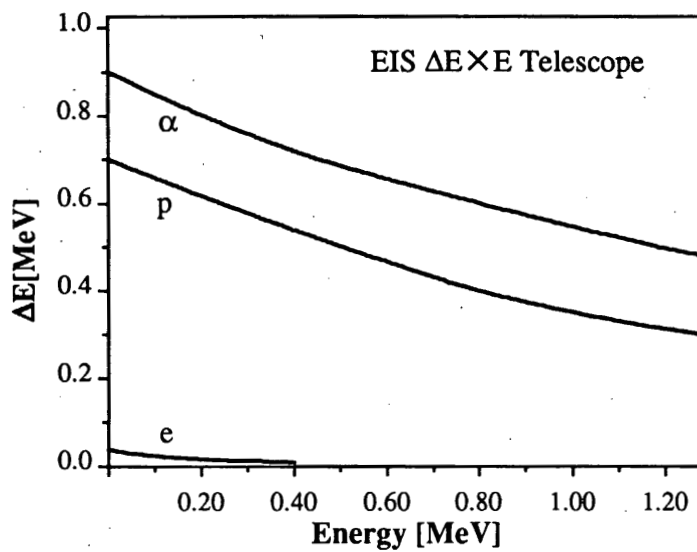


Fig.3 Theoretical Response of Electron, Proton and Helium particles for EIS $\Delta E \times E$ Telescope

light particles. Two add one tables are made like as the reference tables, but they hold data event by event to see the three dimensional spectra for both telescope. The content of counters are packed and send to SYSTEM-DHU by SI-CPU. SI-CPU also analyze the command from DHU and control all circuits.

2.1.3.4 XUV

The XUV is adjusted to detect 30.4nm and 58.4nm line intensity. To simplify the instrument system, no imaging information will be available with this scanner. It consists of a multi-layer coated mirror to focus EUV light, a filter to eliminate long wavelength light, microchannel plates (MCP) to amplify the signal, and a single plate anode to pick up the signal. A pre-amplifier will be placed at the back of the multi-layer coated mirror. Figure 2.1.3.4-1 shows the schematic configuration of the scanner.

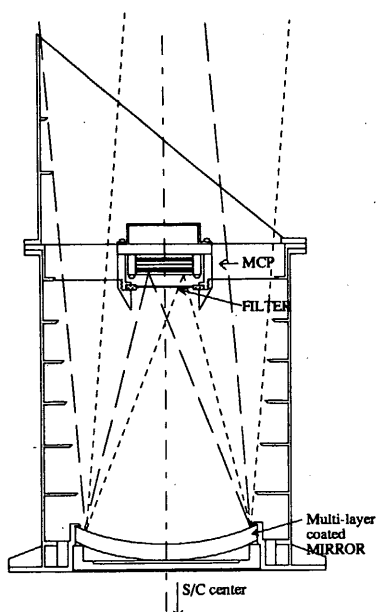


Figure 2.1.3.4-1

The frame of the scanner (tube) is made of 0.4mm thick duralumin which makes the scanner very light weight. The hood is cut obliquely because the scanner will be placed on the side wall of the spacecraft, and the sun direction is fixed to the left hand side of Figure 2.1.3.4-1. A Mo/Si multi-layer coated mirror reflects preferentially the 30.4nm EUV light and the EUV light whose wave length is longer than 50nm. Maximum reflectivity is 24% at 30.4nm and the full-width-half-maximum is about 4nm.

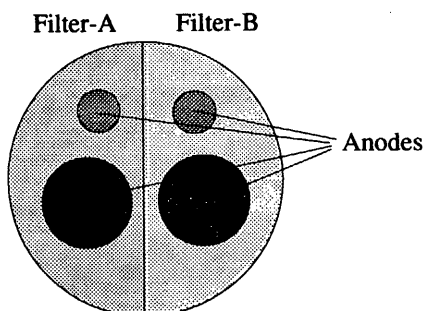


Figure 2.1.3.4-2

MCP plates with 27° bias angles are used. The first stage MCP is coated with CsI to increase the efficiency of photon detection. About 2keV (variable) high voltage is applied to the MCP.

A filter is placed between the mirror and the MCP to eliminate longer wavelength light than the EUV range which we are interested in. This filter is separated into 2 parts and one half of it (Filter-A) cut the

light whose wave length is longer than 40nm. Another part (Filter-B) pass both 30.4nm and 58.4nm EUV light.

The signal is picked up by 4 anode behind the MCP. Two of them have 1mm diameter and other two have 2mm diameter to have 1 and 2 degrees field of view, respectively. A pair of 1 and 2mm anodes placed back of the Filter-A are used to detect 30.4nm EUV light and another pair is placed back of the Filter-B to detect 30.4nm + 58.4nm EUV light (Figure 2.1.3.4-2).

The signal pick-up part is well shielded from high energy particles from space with a thick side and back wall. High energy particles which may pass through the spacecraft are blocked by the mirror and the fuel tank of the spacecraft.

2.1.4 Size, Weight, and Power Consumption

2.1.4.1 Size & Weight

Component	Size(mm x mm x mm)	Weight(kg)
PSA-E	311x230x65	2.07 +/- 0.3
ISA-S	140x130x135	1.2 +/- 0.1
ESA-S	140x130x135	1.2 +/- 0.1
EIS-S	80x155x192	0.95 +/- 0.1
XUV-S	80x80x217	0.4 +/- 0.05

2.1.4.2 Power Consumption

PSA Total

Operation Mode		+5 V (mA)	+12 V (mA)	-12 V (mA)	+29 V (mA)	+27V Bus (mA)	+19V Bus (mA)
Stand-by 1 (CPU+H32)	Max	970					
	Ave	790	34	25			
Stand-by 2 (CPU+H32+SI)	Max	1358					
	Ave.	1178	427	288			
All HV/SV ON	Max	1370					
	Ave	1185	557	308			
All Heater ON	Max						
	Ave						665 +/- 320

CPU/H32

Operation Mode		+5 V (mA)	+12 V (mA)	-12 V (mA)	+29 V (mA)	+27V Bus (mA)	+19V Bus (mA)
SI-CPU OFF	Max	640					
	Ave	440	34	25			
SI-CPU ON	Max	870					
	Ave	700	34	25			
Stand-by 1 (CPU+H32)	Max	970					
	Ave	790	34	25			

ESA

Operation Mode		+5 V (mA)	+12 V (mA)	-12 V (mA)	+29 V (mA)	+27V Bus (mA)	+19V Bus (mA)
Stand-by 1 (CPU+H32)	Max	970					
	Ave	790	34	25			
PAX ON	Max	1260					
	Ave	1080	257	158			
ESA HV/SV ON	Max	1260					
	Ave	1080	287	162			
ESA Heater ON	Max						
	Ave						211 +/- 122

ISA

Operation Mode		+5 V (mA)	+12 V (mA)	-12 V (mA)	+29 V (mA)	+27V Bus (mA)	+19V Bus (mA)
Stand-by 1 (CPU+H32)	Max	970					
	Ave	790	34	25			
PAX ON	Max	1260					
	Ave	1080	257	158			
ISA HV/SV ON	Max	1260					
	Ave	1080	287	162			
ISA Heater ON	Max						
	Ave						211 +/- 122

EIS

Operation Mode		+5 V (mA)	+12 V (mA)	-12 V (mA)	+29 V (mA)	+27V Bus (mA)	+19V Bus (mA)
EIS OFF	Max Ave	 10 +/- 2					
EIS Stand-by	Max Ave	 108+/-5	170+/-5	130+/-5			
EIS HV ON	Max Ave	 115+/-5	217+/-5	140+/-5			
EIS Heater ON	Max Ave						106

XUV

Operation Mode		+5 V (mA)	+12 V (mA)	-12 V (mA)	+29 V (mA)	+27V Bus (mA)	+19V Bus (mA)
Stand-by 1 (CPU+H32)	Max Ave	970 790	 34	 25			
PAX ON	Max Ave	1260 1080	 257	 158			
XUV HV ON	Max Ave	1260 1080	 277	 160			
XUV Heater ON	Max Ave						137 +/- 76

2.1.5 Operation

Each sensors of PSA are operated continuously except for attitude/orbital maneuver and eclipse. Operations during eclipse is depending on the power allocation for PSA. Time resolution of the PSA data is changed depending on the allocated telemetry rate. All of the HV units are controlled by PSA-E.

In the HV on/off sequences, HV outputs are changed slowly by onboard CPUs and take TBD seconds to avoid HV discharge.

One third of the allocated packets are used to transmit EIS data and two thirds of the packets are for PAX (ESA,ISA and XUV) data. Data aquisition and operation modes for each

components are described below.

ESA Operation

Spin phase synchronized data is acquired. 32 energy step x 32 (sensor elevation) sector data within a plane which contains satellite spin axis is obtained with 1/64 spin. Obtained data is sorted with pitch angle based on the onboard magnetic field detector data. The converted 2-D pitch angle data is accumulated with 1 or more spins depending on the allocated telemetry rate. Detailed ESA operation modes are TBD.

ISA Operation

Spin phase synchronized data is acquired. Same as ESA, 32 energy step x 32 (sensor elevation) sector data within a plane which contains satellite spin axis is obtained with 1/64 spin. Obtained data is accumulated with 1 or more spins depending on the allocated telemetry rate. Moment data (density, velocity, temperature) are calculated from the accumulated data. 3-D velocity distribution function data is compressed and transmitted. Transmission data rate for both moment data and compressed 3-D velocity distribution data are depending on the allocated telemetry rate. Detailed ISA operation modes are TBD.

EIS Operation

Spin phase synchronized data is acquired. Detailed EIS operation modes are TBD.

XUV Operation

Data is acquired every 1° or 2° spacecraft rotation depending on the view angle of the scanner when the scanner is pointed to the Mars ($\pm 3R_m$). In other cases, the data is acquired every 5° or 10° depending on the available telemetry rate. Data is accumulated and sent to the telemetry where the accumulation rate is changed due to the available telemetry rate. The XUV has large telemetry rate when the telemetry format is in the UVS-XUV mode. This format is available when the spacecraft is far from the Mars. Word allocation of XUV is listed in the Section 2.1.6.2.3.

2.1.6 Command and Telemetry Consumption

2.1.6.1 Command Items

2.1.6.1.1 Discrete Commands

XY	Command Name	Function	Telemetry
01	PSA_CPU_ON	PSA SI-CPU turn on	PSA1 Bit 7 = 1
02	PSA_CPU_OFF	PSA SI-CPU turn off	PSA1 Bit 7 = 0
10	PSA_HTR_ENA	PSA Heater Enable	PSA1 Bit 1 = 1
11	PSA_HTR_DIS	PSA Heater Disable	PSA1 Bit 1 = 0
12	PSA_ECC_ENA	PSA ECC Enable	PSA1 Bit 2 = 1
13	PSA_ECC_DIS	PSA ECC Disable	PSA1 Bit 2 = 0
14	PSA_WDT_ENA	PSA Watch-dog Timer Enable	PSA1 Bit 5 = 1
15	PSA_WDT_DIS	PSA Watch-dog Timer Disable	PSA1 Bit 5 = 0
16	PSA_CPU_RUN	PSA SI-CPU Run	PSA1 Bit 6 = 1
17	PSA_CPU_RST	PSA SI-CPU Reset	PSA1 Bit 6 = 0
18	PSA_ADRS_SET	PSA RAM Address Set	---
20	PSA_BUS_ACC_ENA	PSA Bus Access Enable	---
21	PSA_BUS_ACC_DIS	PSA Bus Access Disable	---
22	MOD_CHANGE	Telemeter Mode Change	---

80	EIS_ON	EIS System Control Power turn on	PSA2 Bit 0 = 1
A0	EIS_OFF	EIS System Control Power turn off	PSA2 Bit 0 = 0
82	EIS_HV_ENA_SET	EIS HV "ON" Enable	PSA2 Bit 1,2
A2	EIS_HV_DIS_SET	EIS HV "ON" Disable	PSA2 Bit 1,2
84	EIS_HV_ON_SET	EIS HV Turn On	PSA2 Bit 3,4
A4	EIS_HV_OFF_SET	EIS HV Turn Off	PSA2 Bit 3,4
8E	EIS_HV_CNT_SET	EIS HV Voltage Control	---
86	EIS_CAL_ON	EIS Cal Signal On	PSA2 Bit 7 = 1
A6	EIS_CAL_OFF	EIS Cal Signal Off	PSA2 Bit 7 = 0
88	EIS_ANTI_ENA	EIS Anti-coincidence Enable	PSA2 Bit 6 = 1
A8	EIS_ANTI_DIS	EIS Anti-coincidence Disable	PSA2 Bit 6 = 0
90	EIS_CNT_SET	EIS System Control	---
8C	EIS_DISC_SET	EIS Discrimination Level Set	---
8A	EIS_ONE_ENA	EIS One Enable	PSA2 Bit 5 = 1
AA	EIS_ONE_DIS	EIS One Disable	PSA2 Bit 5 = 0

30	PAX_ON	ESA,ISA,XUV Control Power turn on	PSA3 Bit 0 = 1
31	PAX_OFF	ESA,ISA,XUV Control Power turn off	PSA3 Bit 0 = 0
40	PAX_HV_ENA_SET	ESA,ISA,XUV HV "ON" Enable	PSA4 Bit 0,2,4,6 PSA5 Bit 0
42	PAX_HV_ON_SET	ESA,ISA,XUV HV turn on	PSA4 Bit 1,3,5,7 PSA5 Bit 1
44	PAX_HV_OFF_SET	ESA,ISA,XUV HV turn off	PSA4 Bit 0-7 PSA5 Bit 0,1
60	PAX_HV_SET	ESA,ISA,XUV HV Voltage Control	---
61	PAX_CNT_SET	ESA,ISA,XUV System Control	---
46	H32_CNT_SET	H32 Control	---
4A	H32_ST_ADRS_SET	H32 Start Address Set	---
62	ESA_CNT_SET	ESA System Control	---
63	ISA_CNT_SET	ISA System Control	---
64	XUV_FOV_SET	XUV Field of View Set	---
32	H32_ON	H32 Power On	PSA3 Bit 7 = 1
33	H32_OFF	H32 Power Off	PSA3 Bit 7 = 0

2.1.6.1.2 Block Commands

Command	B0	B1	B2	B3	B4	B5	B6	B7	
EIS HV ENA SET	Not Used						SSD	MCP	PSA1
							Select for BIT=1		Bit 1 Bit 2
EIS HV DIS SET	Not Used						SSD	MCP	PSA 1
							Select for BIT=1		Bit 1 Bit 2
EIS HV ON SET	Not Used						SSD	MCP	PSA 1
							Select for BIT=1		Bit 3 Bit 4

Command	B0	B1	B2	B3	B4	B5	B6	B7	
EIS HV OFF SET	Not Used						SSD	MCP	PSA 1
							Select for BIT=1		Bit 3 Bit 4
SSD/MCP HV Output Level Control (2bytes data)									
EIS HV CNT SET (2 bytes Command)	SSD HV Control								
	Not Used						0	1	1st
	Not Used						Control Data		2nd
	MCP HV Control								
	Not Used						1	0	1st
	MCP HV Control Data (8bit)								2nd
EIS SSD Discrimination Level Set									
EIS DIS SET	Not Used		SSD3		SSD2		SSD1		
	4Levels (0-3) for each SSD								
EIS Control									
EIS CNT SET	TBD						TBD		
	Bit 7 = 1 for + 1 Table Dump								
Select HV to be enabled in PAX board									
PAX HV ENA SET	Not Used		ESA	ESA	ISA	ISA	XUV		
			MCP	SV	MCP	SV	MCP		
			Select for BIT = 1						
Select HV to be turned on in PAX board									
PAX HV ON SET	Not Used		ESA	ESA	ISA	ISA	XUV		
			MCP	SV	MCP	SV	MCP		
			Select for BIT = 1						
Select HV to be turned off in PAX board									
PAX HV OFF SET	Not Used		ESA	ESA	ISA	ISA	XUV		
			MCP	SV	MCP	SV	MCP		
			Select for BIT = 1						
ESA, ISA, and XUV HV Output Level Control									
	XUV MCP HV								
	Not Used		0	0	0	0	1	1st	
	HV Control Data (8 bits)								2nd
	ISA SV HV Table Select								
	Not Used		0	0	0	1	0	1st	
	Not Used						Control Data		2nd

PAX HV SET (2 byte command)	ISA MCP HV							
	Not Used	0	0	1	0	0	1st	
	HV Control Data (8 bits)						2nd	
	ESA SV HV Table Select							
	Not Used	0	1	0	0	0	1st	
	Not Used				Control Data		2nd	
	ESA MCP HV							
	Not Used	1	0	0	0	0	1st	
	HV Control Data (8 bits)						2nd	
PAX Control Data								
PAX CNT SET	Control Data (16 bits)							
H32 Bus Control								
H32 CNT SET	Run/ Halt	Not Used			Run/ Reset	Bus enable/ disable		
	Bit = 1 / 0							
H32 Start Address Set (2 bytes)								
H32 ST ADRS SET	Address Data (32 bits)							
ESA Control Mode Set								
ESA CNT SET	Cal	Mode	Control Data					
	Cal : 1 = Cal on 0 = Cal off							
	Mode: 1 = PHA 0 = Position Detective							
ISA Control Mode Set								
ISA CNT SET	Cal	Mode	Control Data					
	Cal : 1 = Cal on 0 = Cal off							
	Mode: 1 = PHA 0 = Position Detective							
Select XUV FOV								
XUV FOV SET	Not Used			Control Data				

2.1.6.2 Telemetry Items

2.1.6.2.1 Status Data

PIM ADRS (Hex)	S/S NAME	Bit	ITEMS	STATUS	
				1	0
8000	PSA1 (W100)	B0	PSA ECC 2BIT ERROR	ACT	NON
		B1	PSA ECC 1BIT ERROR	ACT	NON
		B2	PSA ECC ENA/DIS	ENA	DIS
		B3	PSA HTR CNT ENA/DIS	ENA	DIS
		B4	PSA WDT ERROR	ACT	NON
		B5	PSA WDT ENA/DIS	ENA	DIS
		B6	PSA CPU RUN/RST	RUN	RST
		B7	PSA CPU ON/OFF	ON	OFF
F800	PSA2 (W101)	B0	EIS ON/OFF	ON	OFF
		B1	EIS SSD HV ENA/DIS	ENA	DIS
		B2	EIS MCP HV ENA/DIS	ENA	DIS
		B3	EIS SSD HV ON/OFF	ON	OFF
		B4	EIS MCP HV ON/OFF	ON	OFF
		B5	EIS SSD DISC	SSD DISC H	SSD DISC L
		B6	EIS SYSTEM MODE	NML MODE	ADD 1 TDMP MODE
		B7	EIS CAL ON/OFF	ON	OFF
F801	PSA3 (W102)	B0	PAX ON/OFF	ON	OFF
		B1	H32 RUN/RST	H32 RUN	H32 RST
		B2	H32 RUN/HLT	H32 RUN	H32 HALT
		B3	H32 ENA/FLT	ENA	FLOAT
		B4	H32 ECC 1BIT ERROR	HAPPEN	—
		B5	H32 ECC 2BIT ERROR	HAPPEN	—
		B6	SF ENA/DIS	ENA	DIS
		B7	SPARE		
F802	PSA4 (W103)	B0	ESA MCP HV ENA/DIS	ENA	DIS
		B1	ESA MCP HV ON/OFF	ON	OFF
		B2	ESA SV HV ENA/DIS	ENA	DIS
		B3	ESA SV HV ON/OFF	ON	OFF
		B4	ISA MCP HV ENA/DIS	ENA	DIS
		B5	ISA MCP HV ON/OFF	ON	OFF

F803	PSA5 (W104)	B6	ISA SV HV ENA/DIS	ENA	DIS
		B7	ISA SV HV ON/OFF	ON	OFF
		B0	XUV MCP HV ENA/DIS	ENA	DIS
		B1	XUV MCP HV ON/OFF	ON	OFF
		B2	ESA CAL ON/OFF	ON	OFF
		B3	ESA MODE PHA/PD	MODE PHA	MODE PD
		B4	ISA CAL ON/OFF	ON	OFF
		B5	ISA MODE PHA/PD	MODE PHA	MODE PD
		B6	SPARE		
		B7	SPARE		

2.1.6.2.2 HK Status

Word	ADRS	Symbol	ITEM	Unit	Min	Max
334	8010	PSA-S-T	PSA-E temperature	℃	-50	+70
335	8011	ESA-S-T	ESA-S temperature	℃	-50	+70
336	8012	ISA-S-T	ISA-S temperature	℃	-50	+70
337	8013	EIS-S-T	EIS-S temperature	℃	-50	+70
338	8014	XUV-S-T	XUV SENSOR temperature	℃	-50	+70
339	8015	XUV-MCP-T	XUV MCP temperature	℃	-50	+70
340	8016	EIS-5P		V	-1	+10
341	8017	EIS-12P		V	-1	+15
342	8018	EIS-12N		V	-15	1
343	8019	EIS-SSD		V	0	+250
344	801A	EIS-MCP		V	0	+5000
345	801B	ESA-HVIN		V	0	+500
346	801C	ESA-HVOUT		V	0	+5000
347	801D	ESA-MESH		V	0	-15
348	801E	ISA-HV		V	0	-5000
349	801F	XUV-HV		V	0	-5000

2.1.6.2.3 Mission Packet

PAX (Standard Mode)

Byte	Bit	Content	Comments
1	0-7	TBD	
2	0-7	TI Counter	TI Counter range : TBD
3	0-7		
4		Packet ID	TBD
5			
6		Status	TBD
7			
8	0-7	XUV Data	XUV Science Data
9	0-7		
10	0-7	ESA,ISA Data	Moment Data & Velocity Distribution
432	0-7		

PAX (UVS/XUV Mode)

Byte	Bit	Content	Comments
1	0-7	TBD	
2	0-7	TI Counter	TI Counter range : TBD
3	0-7		
4	0-7	Packet ID	TBD
5	0-7		
6	0-7	Status	TBD
7	0-7		
8	0-7	XUV Data	XUB Science Data
23	0-7		
24	0-7	ESA,ISA Data	Moment Data & Velocity Distribution
432	0-7		

EIS

Byte	Bit	Contents	Comments
1	0	System reference flag	SET on ECC 1 bit error, Emergency, command
	1	System reserve	
	2-7	TBD	
2	0-3	Sector Counter	get from SI
	4	command exe status [fail/success]	[0 / 1]
	5	Detector flga for dE [A/B]	[0 / 1]
	6	Emergency flag	Emergency (NMI, WDT etc) SET
	7	mode change flag	SET on change data taking mode
3	0-2	Packet ID	for EIS Science data
	3	ECC 1bit error flag	SET on ECC 1 bit error
	4	CAL on flag	SET on CAL
	5-7	TBD	
4	0-7	MCP-HV Voltage	SI set value
5	0-7	SSD-HV Voltage	SI set value
6	0-7	Discr. Level	SI set value
7	0-7	TI 0-7 bit	TI Counter
8	0-7	TI 8-15 bit	
9	0-7	TI 16-23 bit	
10	0-7	Integrate Spin time	for EIS Science data
11	0-7	Telemetry bit rate	now SI CPU mode (not Satellite Telemetry Rate)
12	0-7	Sci. Mode Number	for EIS observation mode
13	0-7	Command return field	When ECC 1 bit error happen, set error address
14	0-7		14-15 for Segment Address
15	0-7		16-17 for Offset Address
16	0-7		
17	0-7		
18	0-7	TBD	
19	1		
24	0-7		
25	0-7	Science Data	
26	1		
432	0-7		

2.1.7 Particular Cares Required

As noted in Section 2.1.3, all of the PSA instruments have critical elements (MCP and HV PS) which should be taken particular cares in handling and operation. The environmental and handling requirements are listed below:

- 1) Surrounding humidity : < 50 %
- 2) Sensors to be constantly purged with high-purity N₂ gas
purge through the sensor covers
- 3) Strict control of hydrocarbon contaminants near the sensor units
- 4) Clean gloves to be used

2.1.8 Appendix

1. Intensity of the scattered EUV light

The intensity of the scattered light I_p , is proportional to the column density, i.e. density integrated along the line of sight n , the intensity of the solar radiation $F(\lambda)$ with wavelength λ , and the cross section of the resonance scattering σ as;

$$I_p \propto \int_{LOS} n \cdot g = \int_{LOS} n \cdot F(\lambda) \cdot \sigma$$

The coefficient $g = F(\lambda) \sigma$ is so called g -factor and depends on the wavelength. The g -factors of He I and He II emissions at the Mars orbit is given in Table 2.1.8-1.

species	emission	Wave length(Å)	σ (cm ²)	$g(s^{-1}atom^{-1})$
He ⁺	He II	303.78	9.32×10^{-14}	7.91×10^{-6}
He	He I	584.33	1.19×10^{-13}	4.90×10^{-6}

Table 2.1.8-1

1-1 EUV intensity from the Martian atmosphere and ionosphere

Assuming a barometric density profile where the scale height is 400km, the neutral Helium density of 10⁶/cc at the Martian surface, and the Helium ion density of 70/cc at 500km altitude, we can calculate I_p . In Figure 2.1.8-1, I_p (in Rayleigh) is shown where the horizontal axis is the closest distance from the center of the Mars to the line of sight (LOS) of the scanner (in R_m: Mars radii).

As $F(\lambda)$ is a function of the distance from the sun, the g -factor decreases as one moves away from the sun. In order to calculate the expected signal, we must integrate the scattered

light along the line of sight.

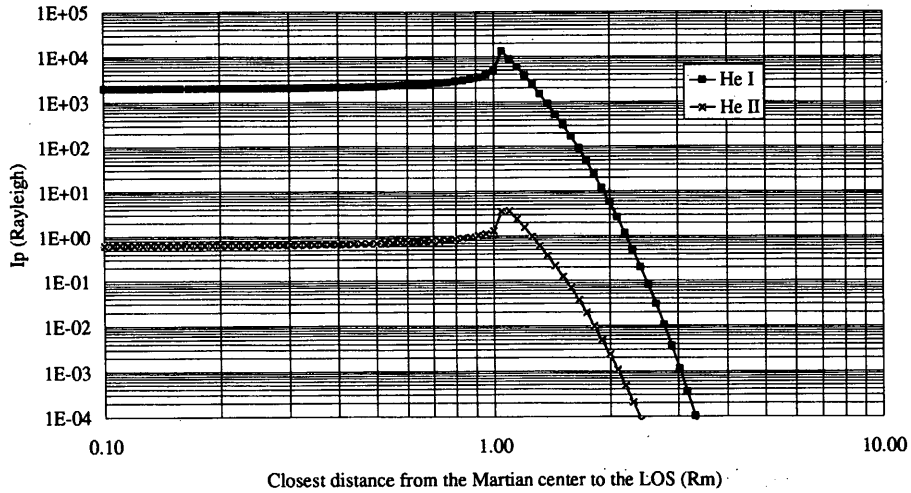


Figure 2.1.8-1

The photon count expected from the sensor, Np , is given by the following equations.

$$Np = k \cdot Ip$$

$$k = \frac{\eta \sigma \delta^2}{4}$$

where h is the efficiency of the photon detection of the scanner, s is the detection area of the scanner, d is the view angle of the EUV scanner. In these equations, k is dependent on the

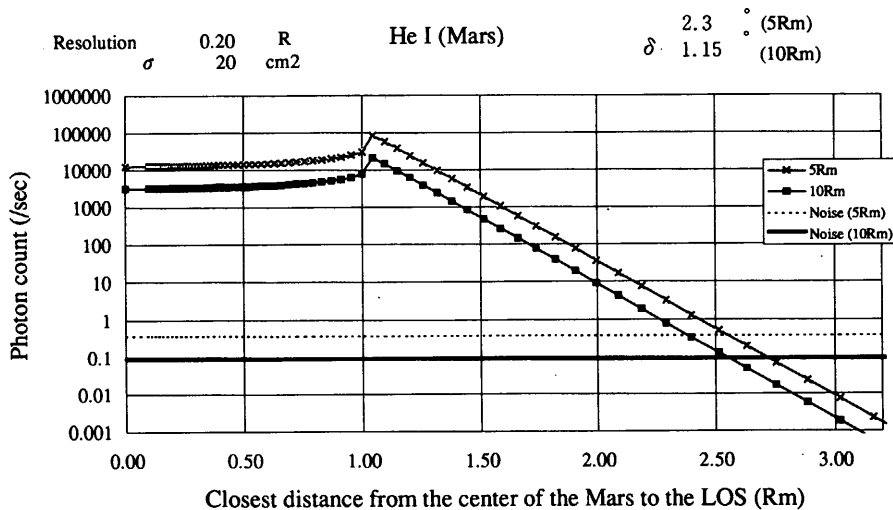


Figure 2.1.8-2

sensor design and I_p depends on the source region of the scattered EUV emissions. The k factor of the XUV is 1.4×10^{-5} and 5.5×10^{-5} when the view angle is 1° and 2° , respectively. With these numbers we can calculate the photon count of He I (Figure 2.1.8-2) and He II emissions (Figure 2.1.8-3) from the Martian atmosphere and ionosphere. The spatial resolution is fixed to $0.2R_m$ (Mars radii), so the spacecraft position is $10R_m$ and $5R_m$ from the center of the Mars with view angle of 1° and 2° , respectively.

Noise count is calculated assuming that MCP noise count rate is $2 \text{ count/cm}^2/\text{sec}$. For He I emission, the photon count exceeds noise count up to $2.5R_m$ from the center of the Mars in both view angle of 1° and 2° cases.

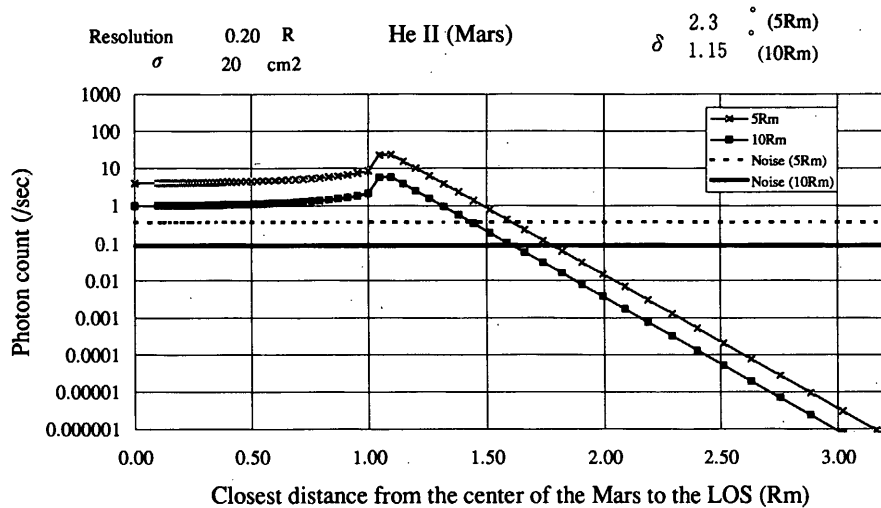


Figure 2.1.8-3

As the number density of Helium ion is less than that of the neutral Helium, the range where the photon count of He II emission exceed the noise count is smaller than that of He I emission, i.e., up to $1.5R_m$.

1-2 EUV intensity from the magnetosphere of the earth

We have an opportunity to observe the Earth's plasmasphere and magnetotail from the parking orbit around the Earth. It is expected that He II emission exceed the noise count of the order of 2 in the plasmasphere (calculation is not shown here).

For the magnetotail, let us assume the He^+ density to be 1% of the plasma density in the magnetotail. In the case when we observe the magnetotail region from the dawn or dusk side, a typical He^+ density in the tail region is 0.01 cm^{-3} and the column length is about $20R_e$. With these values, the photon count will be 0.03 photons/sec . When Planet-B is at the midnight sector and the observation is along the magnetotail, the column length will be much longer,

more than 200Re. In this case we expect $Np = 0.3$ photons/sec. Noise count level is expected to be of the order of 0.05 in these cases. Thus, we can conclude that we will have an opportunity to detect He II emissions in the Earth's magnetotail when the observation is done along the magnetotail.

2.2 Plasma Wave Analyzer (PWA)

PWS Principal Investigator and Co-Investigators

Principal Investigator	T. Ono	Tohoku University
PWS-P (Plasma) Co-Investigators		
	H. Oya	Tohoku University
	A. Morioka	Tohoku University
	K. Marubashi	CRL
	H. Miyaoka	NIPR
	T. Obara	ISAS
	M. Iizima	Tohoku University
	T. Nakagawa	Tohoku Institute of Technology
	H. Misawa	STE Laboratory, Nagoya University
	K. Kobayashi	Toyama Prefectural University

PWS-A (Altimeter) Co-Investigators

H. Oya	Tohoku University
T. Okada	ISAS

PWS Manufacturer Meisei Electric Co., Ltd.

LFA Principal Investigator and Co-Investigators

Principal Investigator	H. Matsumoto	RASC, Kyoto University
Consultant	I. Kimura	Kyoto University
Co-Investigators	T. Okada	Toyama Prefectural University
	I. Nagano	Kanazawa University
	K. Hashimoto	Tokyo Denki University
	S. Yagitani	Kanazawa University
	K. Tsuruda	ISAS
	H. Hayakawa	ISAS
	A. Matsuoka	ISAS
	M. Tsutsui	Kyoto Sangyo University
	S. Watanabe	CRL
	Y. Usui	Toyama Prefectural University
	Y. Omura	RASC, Kyoto University
	H. Usui	RASC, Kyoto University
	H. Ueda	Chiba University

LFA Manufacturer Meisei Electric Co., Ltd.

WANT

M. Hinada	ISAS
Y. Morita	ISAS

WANT Manufacturer Hitachi, Ltd., Meisei Electric Co., Ltd.

2.2.1 Observation Objectives

2.2.1.1 PWS (Plasma Wave and Sounder Experiment)

Investigation of both the microscopic plasma processes and its relation to the macroscopic distribution and dynamics of Martian plasmasphere and ionosphere are essential to clarify the interaction process between the solar wind and the non-magnetized planet Mars. The Plasma Wave and Sounder Experiment (PWS) has the role to measure the microscopic plasma wave phenomena by the high sensitive wave detector in the frequency range from 20 kHz to 7 MHz, and the macroscopic plasma structure by the plasma sounder. The scientific objectives of the PWS are summarized below.

1. Evaluate the contribution of the equivalent collision and equivalent viscosity terms to the formation of the boundary layers which should be generated as the result of the wave-particle interaction processes in and near the Martian plasmasphere.
2. Study the role of plasma waves in the mass-loading process where the solar wind strips off the atmosphere of Mars.
3. Study the acceleration and thermalization process of the Martian ionospheric plasma through the electromagnetic disturbances which are caused by the solar wind.
4. Detect the planetary radio waves which will be generated near the planetopause.
5. Determine the solar wind parameters from the plasma oscillation and the electron acoustic waves in the solar wind.
6. Observe the vertical plasma density profile to study the global structure and its dynamics of the Martian ionosphere.
7. Measure the global plasma motion in the Martian plasmasphere through the Doppler effect of the artificially stimulated plasma resonance by plasma sounder.
8. Detect the irregularities of the ionospheric plasma through the radio scattering feature obtained from the sounder echo characteristics.
9. Measure the spacecraft altitude from the solid surface of the planet to study the Martian topography and surface composition, by means of the accurate detection of the echo time of the transmitted RF pulses.

2.2.1.2 LFA (Low Frequency wave Analyzer)

The Low Frequency wave Analyzer (LFA) takes the role of measuring plasma waves in the frequency range from DC to 30 kHz, and of measuring the spacecraft potential relative to the ambient plasma in order to meet the scientific goals of the PLANET-B spacecraft.

The scientific objectives of the LFA are to study the wave phenomena related with the plasma dynamics in the different regions of the Martian ionosphere and magnetosphere such as the mass-loading and particle acceleration via wave-particle interactions. Primary scientific objectives of LFA are summarized as follows:

1. Generation and propagation mechanisms of plasma waves in the up- and down-stream regions of the bow shock, at the planetopause on the dayside, on the nightside ionosphere as well as in the solar wind.
2. Nonlinear waves in the high-Beta plasma.
3. Ionospheric propagation of waves originated in the Martian atmosphere such as lightning discharge.
4. Diagnostics of the plasma parameters by the VLF plasma waves and the structure of the Martian ionosphere and magnetosphere.
5. Wave effects in the mass-loading process.
6. Structure and dynamics of the plasma by the DC electric field measurement and the spacecraft potential.
7. Wave effects on the mass-, momentum-, and energy-transfer between the solar wind and Martian ionospheric/magnetospheric plasma through the wave-particle interaction.
8. Comparison of wave phenomena between the Mars and the Earth.

2.2.2 Instrument Specification

2.2.2.1 PWA-E

The instruments related to the plasma wave observation, i.e.,

- 1) PWS (Plasma Wave and Sounder Experiment),
- 2) LFA (Low Frequency Wave Analyzer),
- 3) WANT (Wire Antennas), and
- 4) WANT PRE (Pre-amplifiers for Wire Antennas)

are combined into one system, named as PWA (Plasma Wave Analyzes), for the purpose to perform the organized operation using the common onboard CPU (SI-CPU) and to reduce the

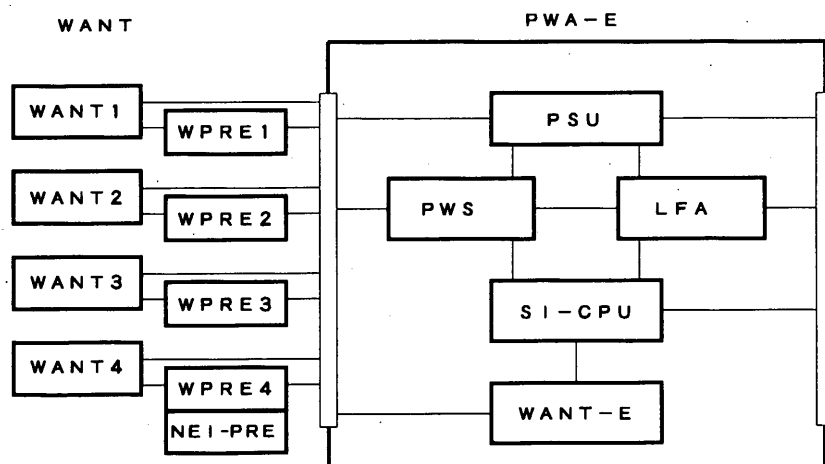


Figure 2.2-1 PWA Configuration.

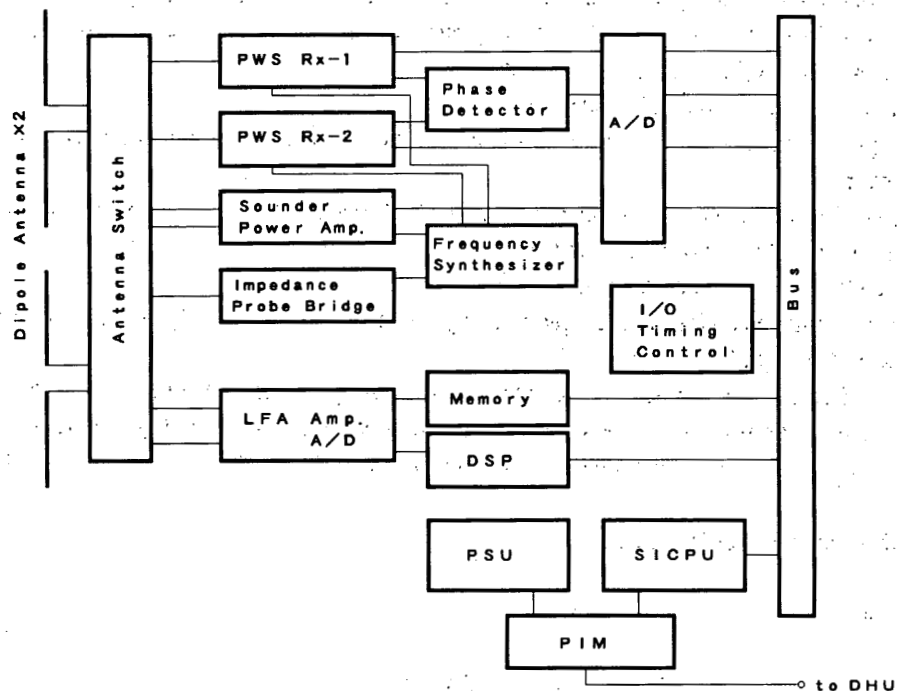


Figure 2.2-2 Block diagram of PWA system.

weight budget. The construction and block diagram of PWA-E subsystem is shown in Figure 2.2-1 and Figure 2.2-2. The onboard software for SI-CPU of PWA are designed to control the antenna deployment, data processing, communication with central DHU (Data Handling Unit) and operation of the observation.

2.2.2.2 PWS

The PWS has three observational modes; 1) Natural Plasma Wave (NPW) mode to observe the natural plasma waves in the frequency range from 20 kHz to 7 MHz, 2) Stimulated Plasma Wave (SPW) mode to sound the vertical profile of the Martian ionosphere, to stimulate the local plasma resonances, and to measure the altitude of the spacecraft from the solid surface of the planet, by means of the transmission of the high power RF pulses, 3) Number Density of Electron by Impedance Probe (NEI) mode to measure the in-situ electron density profile along the spacecraft trajectory using the impedance probe.

The function of the PWS and block diagram of the front end system from the preamplifiers to data processor are illustrated in Figure 2.2-2 and Table 2.2-1. Four wire antenna systems (WANT) with 50 m tip to tip length which compose cross dipole antennas are used to detect the electric field of plasma waves, to transmit the RF pulses for SPW operation, and to measure the probe impedance for NEI operation.

Table 2.2-1 Function of PWS System.

PWS	NPW	DS	....	2sec	20kHz- 7MHz
		PL	....	2sec	20kHz- 7MHz
	SPW	NORM	....	32sec	20kHz- 7MHz
		H-SW	....	8sec	8MHz - 10MHz
		ALT	....	250msec	9MHz
	NEI		....	2sec	20kHz- 7MHz

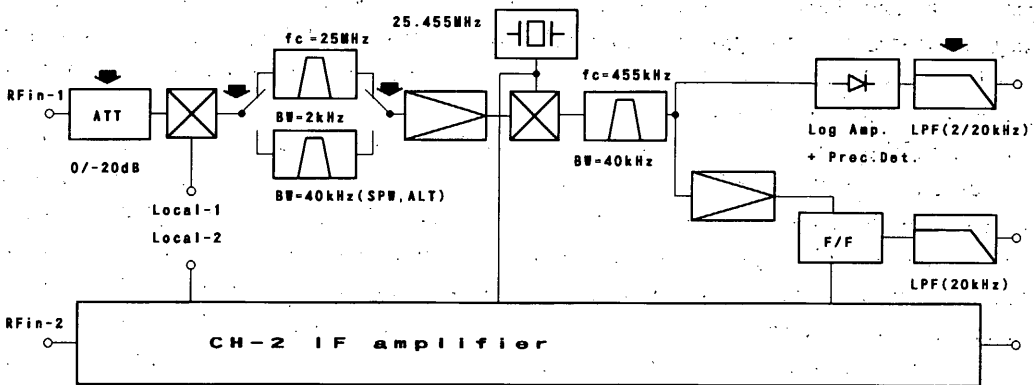


Figure 2.2-3 Block diagram of IF amplifier and phase detector.

1) NPW mode

The NPW mode has two observational functions, i.e., the measurement of the dynamic spectrum of two components of the electric field, E_x and E_y (DS mode), and the measurement of the polarization-frequency spectrum of Right-hand and Left-hand components of the received waves (PL mode). The NPW consists of two sets of swept frequency spectrum analyzers which are composed of double super heterodyne receivers as shown in Figure 2.2-3. The receiving frequency is swept stepwise from 20 kHz to 7 MHz with 256 steps in every 2 seconds on board.

The time resolution of the NPW data on the ground depends on the operational mode and the data transmission rate of the spacecraft, from 2 sec to 512 sec. The dynamic range of the receiver is 80 dB which is achieved by using the AC logarithmic amplifier in the second intermediate frequency (IF) stage. The local signals for the heterodyne receiver are generated by the digital frequency synthesizer which provides stable frequency signals.

The separation of the received electric field into R-hand and L-hand components is performed by separation circuit of polarized signal at the 1st IF stage with the isolation of more than 30 dB.

2) SPW mode

The SPW mode has three operational mode, i.e., vertical sounding of the plasma density profile and stimulation of the plasma waves (SPW Normal mode), measurement of the total content of the Martian ionosphere, and altitude measurement of the spacecraft (SPW H-sweep mode and ALT mode).

In the SPW mode, the power amplifier is operated to transmit RF pulses into Martian plasma.

The block diagram of the SPW system is illustrated in Figure 2.2-4. The source signals for the power amplifier are fed from the swept frequency generator (digital frequency synthesizer) whose frequency is swept from 20 kHz to 7 MHz during 32 sec for the Normal mode, from 8MHz to 10 MHz during 2sec for the H-sweep mode and 9 MHz during 250 msec for ALT mode. The signal from the swept frequency generator is amplified to 600 Watt power level through three stages of the amplifier, i.e., the pre-driver, the driver, and the main amplifier stages. Through these stages, the original continuous RF signals are modulated in a pulse form with the pulse width of 100 μ sec for Normal and H-sweep mode and 300 μ sec for the ALT mode. The repetition of the pulses is 125 msec.

In the SPW operation, one set of the 50 m dipole antenna is used for the transmission of RF pulses and other 50 m antenna is used for the reception of the reaction of the transmitted pulses including the echoes from the topside ionosphere and solid surface. The NPW subsystem is used as a receiver where gain and bandwidth are adjusted to be suitable for the reception of the echoes of the pulses, and plasma waves generated as a reaction of the transmitted RF pulses. The bandwidth of the receiver is set to be 20 kHz so as to be suitable pulse reception. The receiver is protected from high power transmission during 500 μ sec. The timing relation between the pulse transmission and protection period is given in Figure 2.2-5. This signal is distributed to the other subsystems as the guard pulse which is used to protect the subsystems or make a marker on their data when subsystems suffer the disturbance at the time of the high power transmission. The received analog data after the transmission of RF pulse are converted to the digital value and converted to the compressed data by the onboard cpu.

The data transmission rate for Normal and H-sweep mode is 64 Byte/sec, and that for Alt mode is 62 or 128 Bytes/sec which is selected by the command.

3) NEI mode

The NEI mode provides the electron density using a swept frequency impedance probe which has been developed by many Japanese sounding rocket and previously launched satellites.

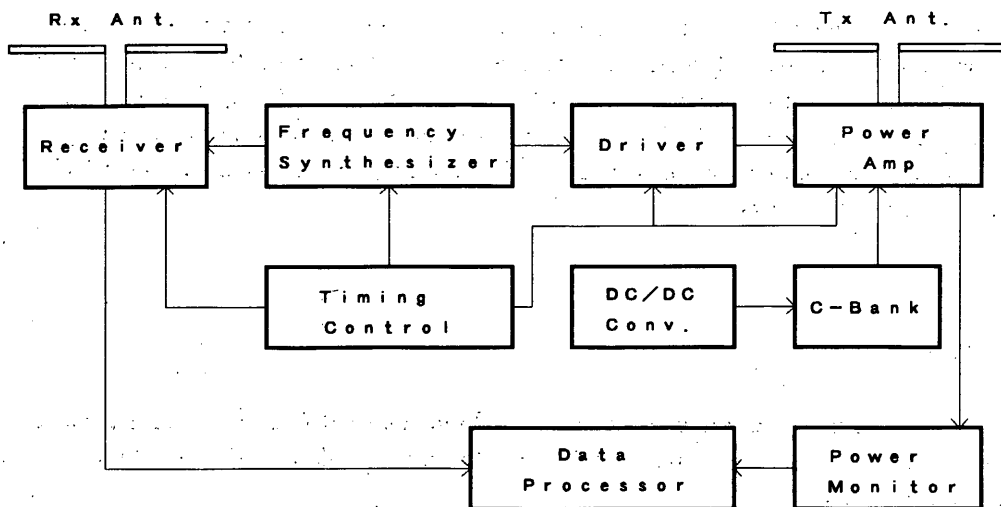


Figure 2.2-4 Block diagram of SPW.

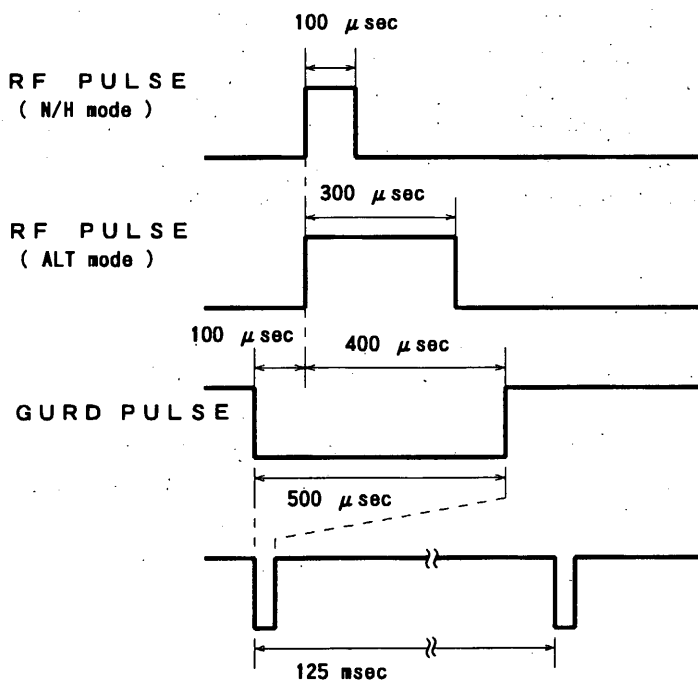


Figure 2.2-5 SPW Gurd Pulse.

From the measured impedance value of the probe, the plasma parameters are obtained; especially from the upper-hybrid resonance frequency, electron density is obtained within an accuracy of 3 %. One of the four long wire antennas is used as the probe, and the signal whose frequency is swept from 20 kHz to 7 MHz is fed to the probe. The preamplifier detects the signal modulated by the effect of the surrounding plasma. The output level from the preamplifier, then, gives the effective capacitance value as a function of the supplied frequency of the probe. Ranges of capacitance value are 1 pF to 1000 pF. The subsystems for generation of the swept frequency signal, IF amplifier and the data processing unit are provided as the common facilities with the NPW and SPW system.

2.2.2.3 LFA

The LFA consists of four different components: (1) the onboard frequency analyzer (OFA), (2) the memory-mode waveform capture (WFC-M), (3) direct-mode waveform capture, and (4) the single probe (SPB).

1) OFA

The OFA provides power spectral information of plasma waves over the frequency range from 10 Hz to 30 kHz. The resolutions in time and frequency of the spectral analysis are selected by command. The highest resolution is 0.5 sec in time and 512 points in the frequency range up to 30 kHz.

One of the electric field components from the dipole antenna system of WANT-Ex and WANT-Ey is selected and fed to the OFA receiver input circuit. The OFA receiver has a dynamic range of 70 dB, and its gain is stepped up by 20 dB to amplify weak signal. The signals from the sensors are sampled with a sampling frequency of 90 kHz, coded into 16-bit string data and then analyzed by a digital signal processor (DSP). The main function of the DSP is the Fast Fourier Transform analysis of the waveforms, the filtering, etc.

2) WFC-M

The WFC-M captures simultaneous waveforms of two electric field components from the sensors of WANT-Ex and WANT-Ey, over the frequency range from 10 Hz to 1 kHz. The signal waveforms from the dipole antennas are sampled with a sampling frequency 2.56 kHz for each channel, coded into 14-bit string data and then compressed into 8-bit string data. The waveforms are used for a detailed analysis of the observed wave characteristics such as the determination of the wave normal direction and polarization. The WFC-M receiver has a dynamic range of 70 dB, and the gain of the receiver can be stepped up by 20 or 40 dB to amplify weak signals. The capacity of the memory is 4 megabytes (4MB), banked into 16 sections each having 256 kilobytes. By using the 4MB memory, waveforms of two electric fields can be recorded for the observation period of 13.5 min.

3) WFC-D

The WFC-D is used as a double probe or a single probe mode. In the double probe mode,

WFC-D measures the waveform of the electric field from the sensor WANT-Ey over the frequency range from DC to 40 Hz. The signals from the sensors are sampled with a sampling frequency of 128 Hz and coded into 14-bit string data. The waveform is used for measuring the DC electric field and for a detailed analysis of the observed wave characteristics such as spectrum with high frequency resolution. The WFC-D (double probe) receiver has a dynamic range of 70 dB, and the gain of the receiver can be stepped up by 20dB to amplify weak signals. In the single probe mode, the WFC-D measures the spacecraft potential relative to the ambient plasma in the range from -10 V to +10 V, by feeding a bias current to the elements of WANT-Ey(+) and WANT-Ey(-). The magnitude of the proper bias current is set by command.

A summary table of the instruments and system diagram are given in Table 2.2-2 and Figure 2.2-6, respectively.

Table 2.2-2 Summary of LFA Specification.

	Frequency range	Frequency Resolution	Dynamic Range	Remarks
OFA	10 Hz ~ 30 kHz	Variable : 60 ~ 500 Hz Sampling freq. : 90 kHz	70 dB 20 dB step 16 bit-string	With a DSP program, resolutions in time and freq. can be changed
WFC-M	10 Hz ~ 1 kHz	Sampling freq. : 2.56 kHz/ch	70 dB 20/40 dB step 14 bit-string	14 bit-string data is compressed into 8 bit-string data 4MB Memory → 13.5 min Rec.
WFC-D DPB	DC ~ 40 Hz	Sampling Freq. : 128 Hz	70 dB 20dB step 14 bit-string	One of the mode DPB or SPB is selected by command
WFC-D SPB	DC ~ 40 Hz	Sampling Freq. : 128 Hz	-10 V ~ +10 V 14 bit-string	

The vacuum lubrication technique will another example of significant improvements. This is required as the driving mechanism takes its task as long as 18 months later after the launch. To reduce associated risks, the potentiometer is replaced by optical sensing device (photo diode) to detect the deployment length of the wire and the gear assembly is designed to be composed of self-lubrication materials instead of the vacuum grease.

Moreover, the limited capacity of the launching rocket results in system design with an extremely strict weight budgetary limit. To make the system efficient, the driving and interface circuits of the four WANT systems are unified in a single unit installed in the PWA, in sharp contrast to the ones of the previous satellites having individual circuits. To cut the weight, the output capacity of the step motor is lowered although producing the same level of the driving torque through the high reduction rate of the gear assembly. Further weight reduction has been achieved by introduction of light-weight materials leading to the entire system weight of 630g (1.5 kg for the EXOS-D and GEOTAIL).

2) System Configuration

The PLANET-B orbiter, having nominal spin rate of 7.5 rpm (tentative) is equipped with four wire antenna systems (WANT) to detect plasma waves in the electrical field. Four modules of the WANT packages are installed at 90-degree interval around the spinning axis of the satellite and to be deployed in orbit to obtain their operational configuration of 25 m in length. The dimensions of the core spacecraft is approximately 1.6 m (W) x 1.6 m (D) x 0.58 m (H) . Figure 2.2-7 depicts a schematic diagram of the spacecraft in its operational configuration. It is equipped with six modules to be deployed in orbit: four sets of WANTs; a mast (MST) of 5 m in length to reduce magnetic interference from the satellite against scientific instruments; a thermal protection assembly (TPA-S).

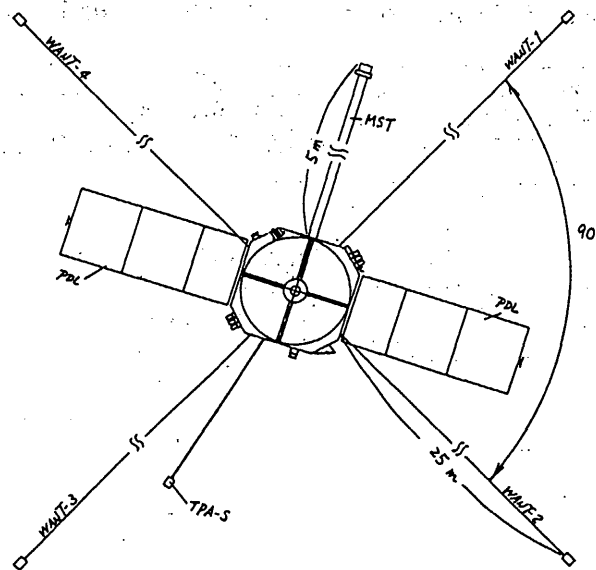


Figure 2.2-7 Entire system's configuration in its operational mode.

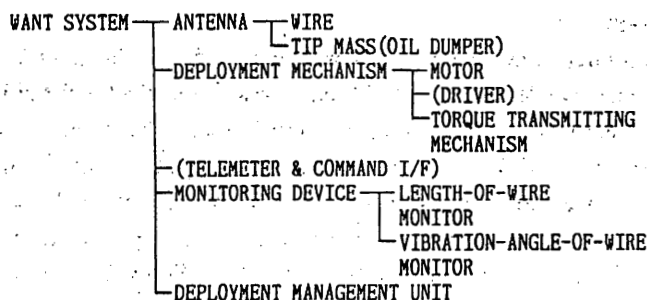
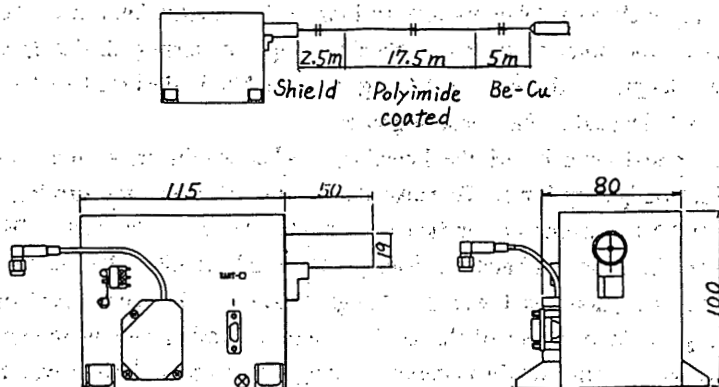


Figure 2.2-8 Schematic diagram of the wire antenna package.

Table 2.2-3 Characteristics the PLANE-B WANT system.

total weight	630g
dimensions of case	80×115×100mm
power consumption	3.34W(at deployment), 0.1W(at observation)
total wire length	25m
wire's diameter and mass density	
from tip to 5m	φ 0.38mm, 0.8g/m(naked)
from 5m to 22.5m	φ 0.62mm, 1.1g/m(covered by Polyimide sheet)
from 22.5m to 25m	φ 1.13mm, 3.7g/m(laminated by Copper alloy shield and Polyimide sheet)
speed of wire deployment	2.5cm/sec
tip mass	18.5g

The attitude and orbit of the satellite are to be controlled through the Reaction Control System (RCS) of the monopropellant engines. To hold the high gain communication link to the earth, the orbiter is to execute attitude maneuver approximately one degree per day throughout the mission lifetime, which induces the vibration of the wires as well as the satellite attitude perturbation. Coning motion of the satellite is strictly required to be maintained within 0.7 deg in angle for the same purpose.

The WANT system composed of: Be-Cu wire line with a tiny tip mass for generating a moderate tension; driving mechanism consisting of a DC step motor, driver circuit and gear assembly; telemetry and command interface; monitoring devices of deployed length and deflection angle; and deployment management software. The driving and interface circuits as well as management software are installed in the plasma wave analyzer (PWA) of the onboard scientific instruments. The schematic diagram of the WANT package is displayed in Figure 2.2-8.

Each wire can be divided into 3 parts: naked tip portion of bundled Be-Cu core lines with diameter of 0.38 mm each; the middle part covered by polyimide sheet for electrical insulation from the plasma; and the root part also shielded by the copper-mesh for suppression of the electric interference from the core satellite. A tip oil damper of 18.5 g to suppress the vibration of the wire also provide the WANT wire with moderate tension. The characteristics of the WANT system is summarized in Table 2.2-3. All the WANT wires can be deployed either independently or simultaneously at the constant speed of 2.5 cm/s. The centrifugal tension acting on the wire and its appendage is trimmed by a step motor.

3) Extension Sequence

Although the nominal procedure is aimed at the simultaneous extension of the wires, each wire of WANTS can be deployed either independently or simultaneously by command "SELECT".

After the "DRIVE-ON" command is released, the deployment procedure is controlled by the autonomous deployment management software, which detects any contingency of deployment based on information through the length monitoring device without any ground based assistance and, if necessary, execute emergency deployment suspension of the associated wires to preserve dynamical balance of the entire spacecraft. In a suspended case, a recovery operation is to be commanded from the ground. The fault tree analysis and the associated emergency operation manual are to be revised.

As extension of wires together with succeeding deployment of the other appendages leads to a reduction in satellite's spin rate, spin-up procedures are required prior to extension mode executed to maintain the operational spin rate. The amount of the spin-up is to be determined.

4) Numerical Analysis

The primary interest of the numerical analysis here is to have some appreciation as to satellite coning motion as well as wires oscillation as affected by:

- (1) normal extension of the WANT wires;
- (2) asymmetrical extension (due to some malfunction);
- (3) initial nutation of the satellite;
- (4) attitude maneuver.

The spin rate of the satellite will play a key role on the entire system's dynamical behavior. First of all, the initial spin rate of the satellite is required to be over 15 rpm as the asymmetrical extension of the wires leads to as much as 0.6 deg. of the satellite coning angle, slightly below the allotted one (0.7 deg). It should be noted that the autonomous extension management software is designed to maintain the deference of the extended length of the wires within 5 m. For this spin rate, the induced in-plane oscillation angle of the wires due to the normal deployment is reduced to as small as 2.5 deg (limit 4 deg). Another key factor to the wires deployment is the initial nutational angle of the satellite. To hold the high gain communication link, it must be 0.5 deg at most although it is considered practical. Finally, the attention should be directed to the effect of the daily attitude maneuver, which is executed through pair of the axial thrusters of 2.3 N in magnitude. It is revealed, through the analysis, that the impulsive time duration of the thruster firing has significant influence on the wires vibration and should be as small as 50 msec to maintain the attitude perturbation within the specified tolerance limit.

5) Configuration of Dipole Antenna

A couple of wire dipole antennas is orthogonal to each other extended in a plane perpendicular to the spacecraft spin axis. Each dipole antenna has a length of 50 m tip-to-tip. The configuration of the dipole antennas is shown in Figure 2.2-9. A preamplifier is placed in the close vicinity of the antenna deploying mechanism which is mounted inside the side panel of the spacecraft.

Figure 2.2-10 shows an outline drawing of the WANT element. The element is 25 m in length. The surface of the element except the part of 5 m from the tip of the wire is coated with a thin Polyimide film for electrical insulation from the ambient plasma. The foot part of 2 m from the antenna deploying mechanism is shielded by a copper-mesh sleeve which is connected to the 2nd-common of the preamplifier through a resistance of 2 Mohms to suppress the effect of the electrical interference from the components onboard the spacecraft.

6) Preamplifiers and their Peripheral Circuits

Figure 2.2-11 is a diagram of the PWA preamplifier and its peripheral circuit for the WANT system. The electric potential induced on the WANT element is fed to the PWS and LFA (WFC-M, OFA) preamplifier (consisting of an FET source follower with input impedance of 100 Mohm and 0dB gain) through a 220 pF decoupling capacitor. The signal with the frequency more than 20 kHz is transferred to the PWS circuit. The lower limit of the passing frequency of the preamplifier is 8 Hz. The output impedance of the preamplifier is about several tens-ohms. The WFC-D preamplifier (an operational amp.) is connected to the WANT through a voltage-divider circuit (500 Mohm and 1 Gohm). The bias current for the WFC-D is fed through a resistor 20 megaohm to each WANT element by turning on the switch (SW-1) and the DC calibration signal is fed by turning on the switch (SW-2).

In order to calibrate the gain and phase characteristics of the overall WFC-M, OFA, and WFC-D (DPB) receiver system including the preamplifier, a calibration signal is prepared. The calibration signal is a composite signal of the four square waves with same amplitude and with different basic frequencies to cover the receiver band from 1 Hz to 30 kHz. The fundamental frequencies of these square waves are 10 Hz, 100 Hz, 10 kHz and 10 kHz. It is fed to each

of the WANT antenna elements by turning on the switch(SW-3) through a resistance of 2 kohm.

The calibration signal level is changed to 0 dB, -20 dB, and -40 dB by a telemetry command. The DC calibration signal sweeps in the range from -8 V to +8 V with 1 V resolution.

The shunt circuits are added to reduce the PWS sounder experiment effect. For driving the shunt circuit, the guard pulse is supplied from the PWS apparatus.

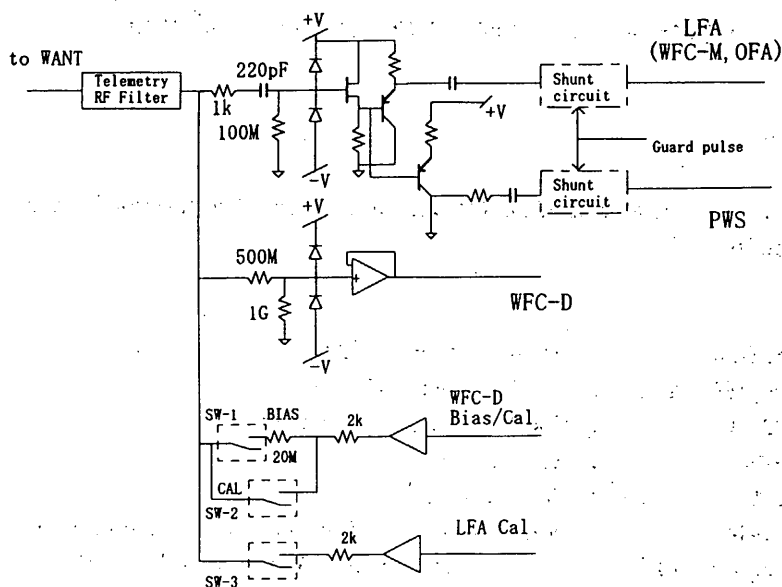


Figure 2.2-9 Block diagram of the preamplifier and its peripheral circuit.

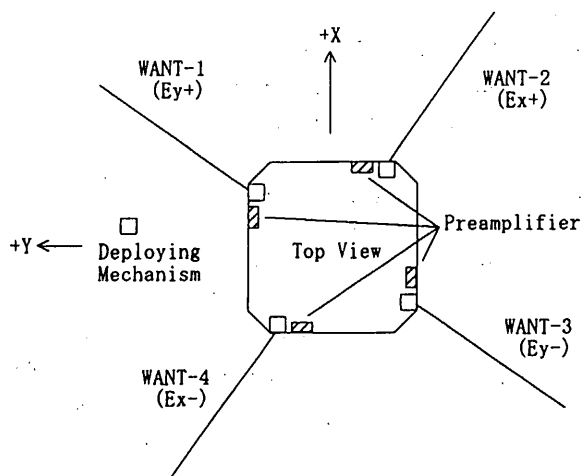


Figure 2.2-10 Configuration of dipole antenna.

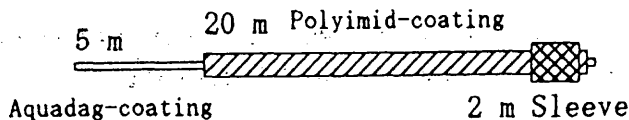


Figure 2.2-11 Outline draw of the WANT element.

2.2.2.5 Software

Figure 2.2-12 shows a flow chart of the PWA main program. The function of each block of the flow chat is as follows:

INITIAL	: Initialize the PWA-CPU
get_PWA_data	: Get data from PWS and LFA
COM1	: Check HK status and command
PWS	: Routine of PWS
LFA	: Routine of LFA
COM2	: Edit packets of PWA to send Data Handling System (DHS)
wait_for_INT6	: Waite for interrupt (ch 6) in every 125 msec.

Figure 2.2-13 and 2.2-14 show a flow chart of the PWS and LFA program as given in Figure 2.2-12. The function of each block of the flow chart is as follows:

get_PWS_status	: Read status from I/O port
get_FIFO_data	: Read A/D data from FIFO
frame_PWS	: Make frames of PWS data
obs_mode	: Check the mode of observation
Dump mode	: Judge if WFC-M is Dump mode or not
Rec_mode	: Judge if WFC-M is Record mode or not
load_4M_memory	: Read data from 4M memory
frame_WFC-M	: Make frames of WFC-M data
cmp_WFC-M	: Compress WFC-M data before writing in 4M memory
store_WFC-M	: Store the compressed data in 4M memory
cmp_WFC-D	: Compress WFC-D data before editing frame
frame_WFC-D	: Make frames of WFC-D data
frame_OFA	: Make frames of OFA data

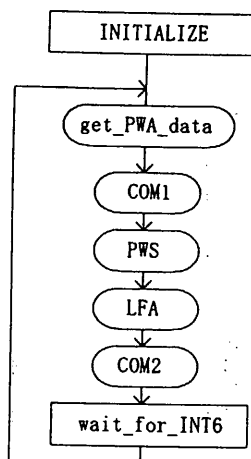


Figure 2.2-12 Flow chart of PWA main program

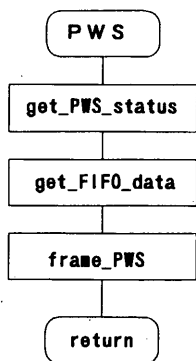


Figure 2.2-13 Flow chart of PWS program

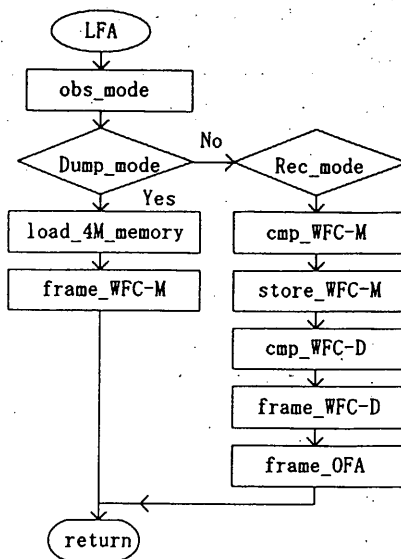


Figure 2.2-14 Flow chart of LFA program

2.2.3 Instrument Configuration

The PWA consists of the PWA-E package, 4 WANT packages and 4 WANT-Preamplifier packages, as has been shown in Figure 2.2-1. The PWA-E consists of the electronics of the PWS and the LFA, Subsystem CPU (SI-CPU), Power Supplying Unit (PSU), and electronics of WANT driving system. The SI-CPU and PSU are shared between PWS and LFA. Overview of the PWA-E is shown in Figure 2.2-15. Each WANT-Pre package has a preamplifier which is shared between the PWS and the LFA, and driving circuit. The WANT-Pre-4 has an additional preamplifier of the NEI which is used in the NEI mode operation.

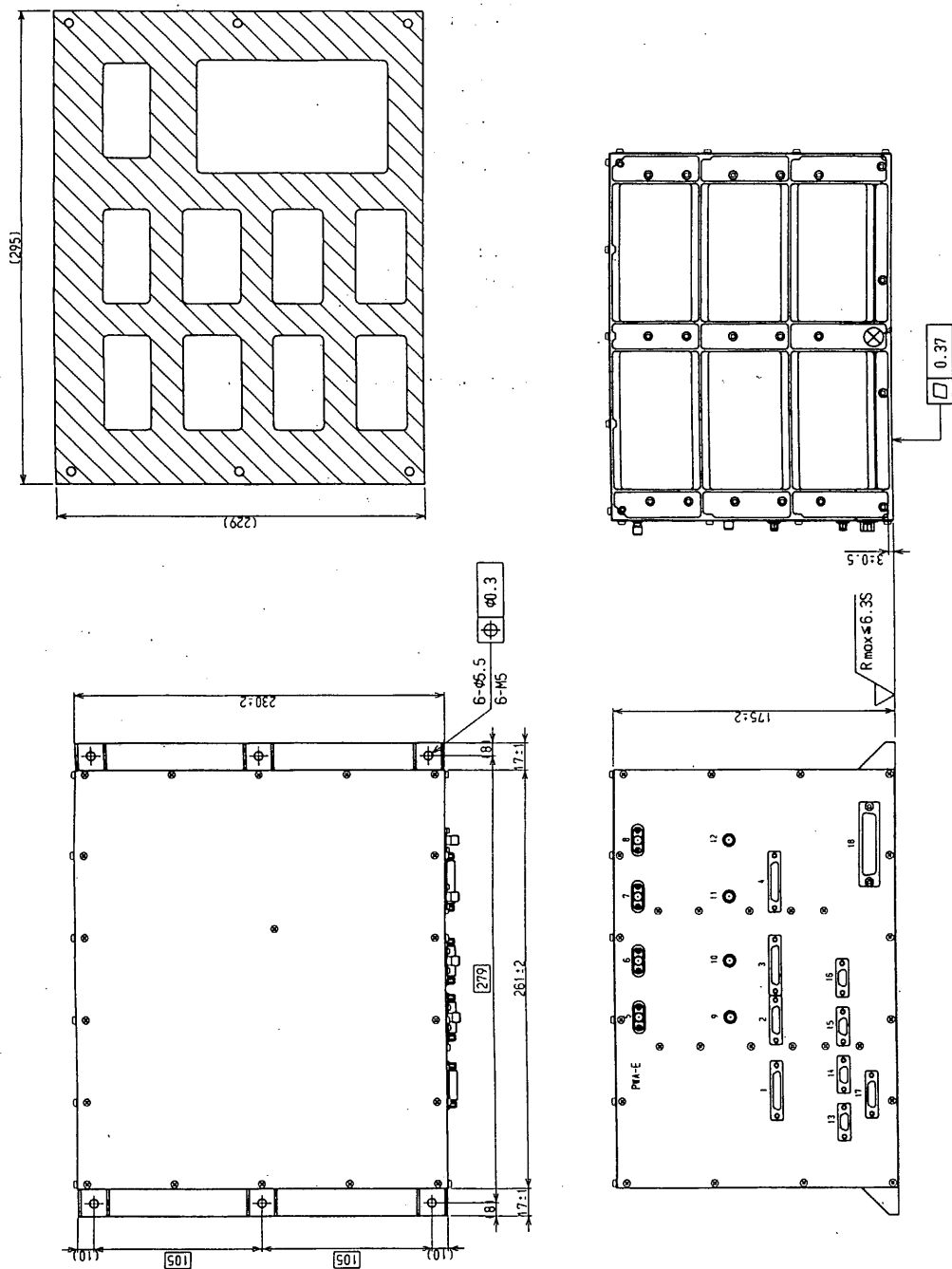


Figure 2.2-15 Configuration of PWA-E

2.2.4 Size, Weight, and Power Consumption

2.2.4.1 Size and Weight

	Size (mm)	Weight (kg)
PWA-E	279x230x175	5.5
WANT 1-4	80x115x100	0.63x4= 2.52
WANT Preamp 1-4	100x63x35	0.16x4= 0.64

2.2.4.2 Power Consumption

Operational Mode	+5V (mA)	+12V (mA)	-12V (mA)	+29V (mA)	BUS +27V (mA)
LFA ON	153 ± 20	218 ± 50	218 ± 50	±	±
CPU	500 ± 50	±	±	±	±
PWS NEI/NPW	202 ± 20	353 ± 20	217 ± 10	±	±
PWS SPW	202 ± 20	353 ± 20	217 ± 10	250 ± 50	±
PWS ALT	232 ± 20	443 ± 20	217 ± 10	250 ± 50	±
SPW HEATER ON	±	±	±	250 ± 50	±
WANT DRV ON	80 ± 10	40 ± 10	20 ± 10	±	480 ± 40
WANT-PRE ON	-	25 ± 5	25 ± 5	-	-
NEI PRE ON	-	30 ± 10	10 ± 10	-	-

2.2.5 Operation

The PWS has 6 observational functions as has been listed in Table 2.2-1. These observational functions are operated individually or through the combination mode controlled by the organized command. In the combined mode, the sequence time of each function and the repetition time of the combination are directed by block commands. The operational mode of PWS are listed in Table 2.2-4.

The LFA has 4 observational functions as has been listed in Table 2.2-2. The OFA mode and WFC-M can be operated simultaneously. One of the mode of WFC-D(DPB) or WFC-D (spb) is selected by command. The data of WFC-M are usually transmitted to the ground by Dump mode of the telemetry.

The content of telemetry data of the PWA depends on both the observation mode and allocation of packet number between PWS and LFA. The number (1~ 37) in Table 2.2-5

indicates the cases defined by the mode of observation, telemetry bit rate, and packet allocation between PWS and LFA. For example, the case 1 shows that the observation is made in the Periapsis mode, the bit rate is 64 kbps, and the PWS uses two-thirds of packets allocated to PWA while LFA uses one-third.

Table 2.2-4 PWS Operational Mode

Mode	Operation	Mode	Operation
1	NPW(DS)	11	SPW(NOR)+NPW(PL)
2	NPW(PL)	12	SPW(H-S)+NPW(DS)
3	NPW(DS)+NPW(PL)	13	SPW(H-S)+NPW(PL)
4	NPW(DS)+NEI	14	SPW(NOR)+NEI
5	NPW(PL)+NEI	15	SPW(H-S)+NEI
6	NEI	16	SPW(ALT)+NEI
7	SPW(NOR)	17	SPW(NOR)+SPW(H-S)
8	SPW(H-S)	18	SPW(NOR)+SPW(ALT)
9	SPW(ALT)	19	SPW(H-S)+SPW(ALT)
10	SPW(NOR)+NPW(DS)	20	SPW(ALT)+NPW(DS)

Table 2.2-5 Telemetry Format and Bit Rate

Obs. mode	Bit rate PWS : LFA	64 kbps	32 kbps	16 kbps	8 kbps	4kbps	2kbps	512 bps
Periapsis mode	2 : 1	1	3	5	---	---	---	---
	1 : 2	2	4	6	---	---	---	---
Standard mode	2 : 1	7	9	11	13	15	17	19
	1 : 2	8	10	12	14	16	18	20
WFC-M Dump mode	1 : 2	---	21	22	23	24	25	---
MIC, MDC, UVS/XUV	2 : 1	26	28	30	32	34	36	---
Dump mode	1 : 2	27	29	31	33	35	37	---

2.2.6 Commands and Telemetry

2.2.6.1 Command Items

1) Discrete Command

PWA Common

X	Y	command name	function
0	1	PWA_CPU_ON	PWA CPU ON
0	2	PWA_CPU_OFF	PWA CPU OFF
1	0	PWA_HTR_ENA	PWA HEATER ENABLE
1	1	PWA_HTR_DIS	PWA HEATER DISABLE
1	2	PWA_ECC_ENA	PWA ECC ENABLE
1	3	PWA_ECC_DIS	PWA ECC DISABLE
1	4	PWA_WDT_ENA	PWA WDT ENABLE
1	5	PWA_WDT_DIS	PWA WDT DISABLE
1	6	PWA_CPU_RUN	PWA CPU RUN
1	7	PWA_CPU_RST	PWA CPU RESET
1	8	PWA_ADRS_SET	PWA ADDRESS SET
2	0	PWA_BUS_ACC_ENA	PWA BUS ACCESS ENABLE
2	1	PWA_BUS_ACC_DIS	PWA BUS ACCESS DISABLE
2	2	PWA_MOD_CHNG	PWA MODE CHANGE
7	0	WANT_PRE_ON	WANT PRE-AMP POWER ON
7	2	WANT_PRE_OFF	WANT PRE-AMP POWER OFF

PWS Command

X	Y	command name	function
8	0	PWS_ON	PWS POWER ON
8	2	PWS_OFF	PWS POWER OFF
8	4	PWS_DC/DC_ON	DC/DC CONVERTER ON
8	6	PWS_DC/DC_OFF	DC/DC CONVERTER OFF
8	8	PWS_PWR_AMP_ON	POWER AMP ON
8	A	PWS_PWR_AMP_OFF	POWER AMP OFF
9	0	PWS_CAL_ON_SET	PWS CAL ON PARAMETER SET
9	1	PWS_CAL_OFF_SET	PWS CAL OFF PARAMETER SET
9	2	PWS_ANT_SET	PWS ANTENNA PARAMETER SET
9	4	PWS_MODE_SET	PWS OBS MODE SET
9	6	PWS_LOCAL_SET	PWS LOCAL-OSC PARAMETER SET
9	8	PWS_RX_SET	PWS RECEIVER PARAMETER SET
9	A	PWS_PWR_ON_SET	POWER AMP PARAMETER ON SET
9	B	PWS_PWR_OFF_SET	POWER AMP PARAMETER OFF SET
9	E	PWS_OBS_TIME_SET	PWS OBS TIME SET
A	0	PWS_TX_STRT_PC_SET	SPW START PC SET
A	2	PWS_TX_STOP_PC_SET	SPW STOP PC SET
A	4	PWS_PGM_PARA_SET	PWS PROGRAM PARAMETER SET

LFA Command

X	Y	command name	function
3	0	LFA_ON_SET	LFA ON MODE SET
3	2	LFA_OFF_SET	LFA OFF MODE SET
3	4	LFA_BIAS_SET	WFCD BIAS PARAMETER SET
3	6	LFA_BANK_SET	WFCD MEMORY BANK SET
3	8	LFA_GAIN_SET	LFA GAIN AND OFA ANTENNA SET
3	A	LFA_DSP_SET	LFA DSP SET
3	C	LFA_CAL_ATN_SET	LFA CAL ATTENUATION SET
4	0	LFA_WFCM_ST_TIM_SET	LFA WFCM START TIME SET
4	2	LFA_WFCM_RD_BNK_SET	LFA WFCM START TIME SET
4	4	LFA_WFCM_CMPR_SET	LFA WFCM CMPR SET

WANT Command

X	Y	command name	function
C	0	WANT_ON_SET	WANT STBY, ANT, MONI, LIM, SEL1~4 ON SET
C	2	WANT_OFF_SET	WANT STBY, ANT, MONI, LIM, SEL1~4 OFF SET
C	4	WANT_DRV_ON	WANT 1 ~ 4 DRIVE ON
C	6	WANT_DRV_OFF	WANT 1 ~ 4 DRIVE/STAND-BY OFF

2) PWS Block Command

command name	B 0	B 1	B 2	B 3	B 4	B 5	B 6	B 7
PWS CAL ON SET	CAL MODE	CAL A/M	GND	LEVE	PHAS	SPW	NEI	ALT
	1	CAL	AUTO	ON	ON	ON	ON	ON
	0	—	—	—	—	—	—	—

command name	B 0	B 1	B 2	B 3	B 4	B 5	B 6	B 7
PWS CAL OFF SET	CAL MODE	CAL A/M	GND	LEVE	PHAS	SPW	NEI	ALT
	1	MES	MAN	OFF	OFF	OFF	OFF	OFF
	0	—	—	—	—	—	—	—

command name	B 0	B 1	B 2	B 3	B 4	B 5	B 6	B 7
PWS ANT SET	—	—	—	—	—	—	—	ANT
	1							REV
	0							NOR

command name	B 0	B 1	B 2	B 3	B 4	B 5	B 6	B 7
PWS MODE SET	MSB							LSB
	1	CODE OF OBSERVATION MODE						
	0							

command name		B 0	B 1	B 2	B 3	B 4	B 5	B 6	B 7	
PWS LOCAL SET					NPW	NEI	SPW NOR	SPW H-S	SPW ALT	
1 ST BYTE	1				FIX	FIX	FIX	FIX	FIX	
	0				-	-	-	-	-	
		B 0	B 1	B 2	B 3	B 4	B 5	B 6	B 7	
		MSB								LSB
		FIX-FREQUENCY ADDRESS								
2 ND BYTE	1									
	0									

command name		B 0	B 1	B 2	B 3	B 4	B 5	B 6	B 7
PWS RX SET		B0 B1 GAIN		—	—	—	NEI	NPW	SPW NOR
	1	1 1 HIGH					FIX	FIX	FIX
	0	1 0 MID					SWP	SWP	SWP
		0 1 LOW							

command name		B 0	B 1	B 2	B 3	B 4	B 5	B 6	B 7
POWER AMP ON. SET		—	CENT	LOAD	PAMP PWR	CB4	CB3	CB2	CB1
	1		ON	ON	HIGH	ON	ON	ON	ON
	0		—	—	—	—	—	—	—

command name		B 0	B 1	B 2	B 3	B 4	B 5	B 6	B 7
POWER AMP OFF SET		—	CENT	LOAD	PAMP PWR	CB4	CB3	CB2	CB1
	1		OFF	OFF	LOW	OFF	OFF	OFF	OFF
	0		—	—	—	—	—	—	—

command name	B 0	B 1	B 2	B 3	B 4	B 5	B 6	B 7
PWS OBS TIME SET	MSB							LSB
	1	OBSERVATION SEQUENCE CODE						
	0							

command name		B 0	B 1	B 2	B 3	B 4	B 5	B 6	B 7
PWS TX START PC		MSBLSB							
	1	TX START PC COUNT							
	0								

command name		B 0	B 1	B 2	B 3	B 4	B 5	B 6	B 7
PWS TX STOP PC		MSBLSB							
	1	TX STOP PC COUNT							
	0								

command name		B 0	B 1	B 2	B 3	B 4	B 5	B 6	B 7
PWS PGM PARA SET		MSB							LSB
1 ST BYTE	1	CODE OF PRORAM PARAMETE							
	0								
2 ND BYTE		B 0	B 1	B 2	B 3	B 4	B 5	B 6	B 7
		MSB							LSB
	1	ADDRESS OF PARAMETER							
	0								

3) LFA Block Command

command name		B 0	B 1	B 2	B 3	B 4	B 5	B 6	B 7
LFA ON SET		LFA	CAL	DCAL	BIAS	CLK	—	—	—
	1	ON	ON	ON	ON	PWS			
	0	—	—	—	—	—			

command name		B 0	B 1	B 2	B 3	B 4	B 5	B 6	B 7
LFA ON SET		LFA	CAL	DCAL	BIAS	CLK	—	—	—
	1	OFF	OFF	OFF	OFF	LFA			
	0	—	—	—	—	—			

command name		B 0	B 1	B 2	B 3	B 4	B 5	B 6	B 7
WFCD BIAS SET		SIGN	MSB						LSB
	1	+							
	0	-							

command name		B 0	B 1	B 2	B 3	B 4	B 5	B 6	B 7
WFCD BIAS SET		—	—	—	—	MSB		LSB	
	1								
	0								

command name		B 0	B 1	B 2	B 3	B 4	B 5	B 6	B 7
LFA GAIN ANT SET		—	—	WFCD	OFA	WFCM		WFCD	OFA
	1			SPB	EX	1 0 : HIGH		HIGH	HIGH
						0 1 : MID			
	0			DPB	EY	0 0 : LOW		LOW	LOW

command name		B 0	B 1	B 2	B 3	B 4	B 5	B 6	B 7
LFA DSP SET		FIFO	ADC	DSP INT	WDT	RUN	HLD	RST	DSP CLK
LFA DSP ADC FIFO SET	1	RST	CAL	INT	ENA	RUN	HLD	RST	OFF
	0	—	—	—	DIS	—	—	—	—

3) WANT Block Command

command name	B 0	B 1	B 2	B 3	B 4	B 5	B 6	B 7
WANT ON SET	STBY	ANT	MONI	LIM	SEL1	SEL2	SEL3	SEL4
1	ON	EXT	ON	DIS	ON	ON	ON	ON
0	—	—	—	—	—	—	—	—

command name	B 0	B 1	B 2	B 3	B 4	B 5	B 6	B 7
WANT OFF SET	STBY	ANT	MONI	LIM	SEL1	SEL2	SEL3	SEL4
1	OFF	RET	OFF	ENA	OFF	OFF	OFF	OFF
0	—	—	—	—	—	—	—	—

2.2.6.2 Telemetry Items

Packet Format

The transmission form of PWA mission data depends on both telemetry bit rate and the packet transmission format which is defined for observation modes of Planet-B as shown in Table 2.2.6.

Table 2.2.-6. Allocations of PWS mission packet depending on types of edition format of the telemetry.

Format No.	Observation Mode	Total Packets	Allocation
Format 3	Extension (WANT)	24	2+8m, 6+8m, 4+8m
Format 16	Observation P	16	2+4m
Format 17	Observation S	16	2+4m
Format 19	UVS/XUV	8	4+16m, 13+16m
Format 20	MIC	8	4+16m, 13+16m
Format 21	WFC-M	36	1+16m, 7+16m, 4+8m 3+16m, 10+16m, 5+8m
Format 22	MDC	8	4+16m, 13+16m

PWA Status Items

ADDRESS 8000 (PWA1)

ITEMS	BIT	STATUS	
		I/O	FUNCTION
PWA_CPU_ON/OFF	0	1	PWA SI-CPU ON
		0	PWA SI-CPU OFF
PWA_CPU_RUN/RST	1	1	PWA SI-CPU RUN
		0	PWA SI-CPU RESET
PWA_WDT_ENA/DIS	2	1	PWA WDT ENABLE
		0	PWA WDT DISABLE
PWA_WDT_ERROR	3	1	PWA WDT ERROR HAPPEN
		0	-
PWA_HTR_ENA/DIS	4	1	PWA HEATER CONTROL ENABLE
		0	PWA HEATER CONTROL DISABLE
PWA_ECC_ENA/DIS	5	1	PWA ECC ENABLE
		0	PWA ECC DISABLE
PWA_ECC_1BIT_ERROR	6	1	PWA ECC 1BIT ERROR HAPPEN
		0	-
PWA_ECC_2BIT_ERROR	7	1	PWA ECC 2BIT ERROR HAPPEN
		0	-

ADDRESS F800 (PWA2)

ITEMS	BIT	STATUS		
		I/O	FUNCTION	
LFA_ON/OFF	0	1	LFA ON	
		0	LFA OFF	
LFA_CAL_ON/OFF	1	1	LFA CAL ON	
		0	LFA CAL OFF	
WFCD_BIAS_ON/OFF	2	1	WFCD BIAS ON/OFF	
		0	WFCD BIAS ON/OFF	
OFA_GAIN_H/L	3	1	OFA GAIN HIGH	
		0	OFA GAIN LOW	
WFCD_GAIN_G/L	4	1	WFCD GAIN HIGH	
		0	WFCD GAIN LOW	
WFCM_GAIN_H/M/L_B1	5	—	B5	B6
		—	1	0
WFCM_GAIN_H/M/L_B2	6	—	0	1
		—	0	0
OFA_ANT_EX/EY	7	1	OFA ANTENNA EX	
		0	OFA ANTENNA EY	

ADDRESS F801 (PWA3)

ITEMS	BIT	STATUS	
		1/0	FUNCTION
LFA_DSP_ON/OFF	0	1	LFA DSP ON
		0	LFA DSP OFF
DSP_RUN/HLD/RST_ B1	1	—	B1 B2
		—	1 0 LFA DSP RUN
DSP_RUN/HLD/RST_ B2	2	—	0 1 LFA DSP HOLD
		—	0 0 LFA DSP RESET
LFA_DSP_WDT_ ENA/DIS	3	1	LFA DSP WDT ENABLE
		0	LFA DSP WDT DISABLE
LFA_WDT_ERR/NOR	4	1	LFA WDT ERROR
		0	LFA WDT NORMAL
LFA_FIFO_FL/NOR	5	1	LFA FIFO FULL
		0	LFA FIFO NOT FULL
LFA_FIFO_EM/NOR	6	1	LFA FIFO EMPTY
		0	LFA FIFO NOT EMPTY
LFA_FIFO_HF/NOR	7	1	LFA FIFO HALF FULL
		0	LFA FIFO NOT HALF FULL

ADDRESS F802 (PWA4)

ITEMS	BIT	STATUS	
		1/0	FUNCTION
PWS_CAL_ON_SET	0	1	PWS CAL ON SET
		0	-
PWS_ANT_SET	1	1	PWS ANTENNA SET
		0	-
PWS_MODE_SET	2	1	PWS MODE SET
		0	-
PWS_LOCAL_SET	3	1	PWS LOCAL SET
		0	-
PWS_RX_SET	4	1	PWS RX SET
		0	-
PWS_PWR_ON_SET	5	1	PWS POWER AMP ON SET
		0	-
PWS_PGM_PARA_SET	6	1	PWS DATA SET
		0	-
OBS_TIME_SET	7	1	PWS OBSERVE TIME SET
		0	-

ADDRESS F803 (PWA5)

ITEMS	BIT	STATUS	
		1/0	FUNCTION
PWS_ON/OFF	0	1	PWS ON
		0	PWS OFF
PWS_DC/DC_ON/OFF	1	1	PWS DC/DC ON
		0	PWS DC/DC OFF
POWER_AMP_ON/OFF	2	1	POWER AMP ON
		0	POWER AMP OFF
CAL/MES	3	1	PWS CAL
		0	PWS MEASURE
CAL_AUTO/MAN	4	1	PWS CAL AUTO
		0	PWS CAL MANUAL
GND_CAL_ON/OFF	5	1	GND CAL ON
		0	GND CAL OFF
LEVEL_CAL_ON/OFF	6	1	PWS LEVEL CAL ON
		0	PWS LEVEL CAL OFF
PHASE_CAL_ON/OFF	7	1	PWS PHASE CAL ON
		0	PWS PHASE CAL OFF

ADDRESS F804 (PWA6)

ITEMS	BIT	STATUS		
		1/0	FUNCTION	
SPW_CAL_ON/OFF	0	1	SPW CAL ON	
		0	SPW CAL OFF	
NEI_CAL_ON/OFF	1	1	NEI CAL ON	
		0	NEI CAL OFF	
ALT_CAL_ON/OFF	2	1	ALT CAL ON	
		0	ALT CAL OFF	
RX_GAIN_CONT	3	—	B3	B4
		—	1	1
	4	—	1	0
		—	0	1
NPW_FIX/SWEEP	5	1	PWS NPW FIX	
		0	PWS NPW SWEEP	
SPW_FIX/SWEEP	6	1	SPW FIX	
		0	SPW SWEEP	
NEI_FIX/SWEEP	7	1	NEI FIX	
		0	NEI SWEEP	

ADDRESS F805 (PWA7)

ITEMS	BIT	STATUS	
		1/0	FUNCTION
POWER_CONT_H/L	0	1	POWER CONTROL HIGH
		0	POWER CONTROL LOW
WANT_SET_NOR/REV	1	1	WANT SET NORMAL
		0	WANT SET REVERSE
C-BANK1_ON/OFF	2	1	C-BANK1 ON
		0	C-BANK1 OFF
C-BANK2_ON/OFF	3	1	C-BANK2 ON
		0	C-BANK2 OFF
C-BANK3_ON/OFF	4	1	C-BANK3 ON
		0	C-BANK3 OFF
C-BANK4_ON/OFF	5	1	C-BANK4 ON
		0	C-BANK4 OFF
LOAD_ON/OFF	6	1	POWER AMP LOAD ON
		0	POWER AMP LOAD OFF
CENTER_ON/OFF	7	1	POWER AMP CENTER ON
		0	POWER AMP CENTER OFF

ADDRESS F806 (PWA8)

ITEMS	BIT	STATUS	
		1/0	FUNCTION
NEI_ON/OFF	0	1	NEI ON
		0	NEI OFF
NPW_DS_ON/OFF	1	1	NPW-DS ON
		0	NPW-DS OFF
NPW_PL_ON/OFF	2	1	NPW-PL ON
		0	NPW-PL OFF
SPW_NOR_ON/OFF	3	1	SPW-NOR ON
		0	SPW-NOR OFF
SPW_H-S_ON/OFF	4	1	SPW-H-S ON
		0	SPW-H-S OFF
SPW_ALT_ON/OFF	5	1	SPW-ALT ON
		0	SPW-ALT OFF
SPW_FIX/SWEEP	6	1	SPW FIX
		0	SPW SWEEP
NPW_FIX/SWEEP	7	1	NPW FIX
		0	NPW SWEEP

ADDRESS F807 (PWA9)

ITEMS	BIT	STATUS	
		1/0	FUNCTION
NEI_FIX/SWEEP	0	1	NEI FIX
		0	NEI SWEEP
—	1	1	
		0	
—	2	1	
		0	
—	3	1	
		0	
PWS_CAL_ON_SET	4	1	PWS CAL ON SET
		0	—
PWS_PWR_OFF_SET	5	1	PWS POWER AMP OFF SET
		0	—
PWS_TX_STRT_PC_SET	6	1	PWS TX START PC SET
		0	—
PWS_TX_STOP_PC_SET	7	1	PWS TX STOP PC SET
		0	—

ADDRESS F808 (PWA10)

ITEMS	BIT	STATUS	
		1/0	FUNCTION
WANT_STBY	0	1	STANDBY ON
		0	STANDBY OFF
WANT_EXT/RET	1	1	EXTENSION
		0	RETRACTION
WANT_MONI	2	1	MONITOR ON
		0	MONITOR OFF
WANT_LIMIT	3	1	HARD LIMITER ENABLE
		0	HARD LIMITER DISABLE
WANT-1_SELECT	4	1	WANT-1 SELECT ON
		0	WANT-1 SELECT OFF
WANT-2_SELECT	5	1	WANT-2 SELECT ON
		0	WANT-2 SELECT OFF
WANT-3_SELECT	6	1	WANT-3 SELECT ON
		0	WANT-3 SELECT OFF
WANT-4_SELECT	7	1	WANT-4 SELECT ON
		0	WANT-4 SELECT OFF

ADDRESS F809 (PWA11)

ITEMS	BIT	STATUS	
		1/0	FUNCTION
WANT-1_EXT_FULL	0	1	WANT-1 FULL EXTENSION
		0	WANT-1 NOT FULL EXTENSION
WANT-1_RET_FULL	1	1	WANT-1 FULL RETRACTION
		0	WANT-1 NOT FULL RETRACTION
WANT-2_EXT_FULL	2	1	WANT-2 FULL EXTENSION
		0	WANT-2 NOT FULL EXTENSION
WANT-2_RET_FULL	3	1	WANT-2 FULL RETRACTION
		0	WANT-2 NOT FULL RETRACTION
WANT-3_EXT_FULL	4	1	WANT-3 FULL EXTENSION
		0	WANT-3 NOT FULL EXTENSION
WANT-3_RET_FULL	5	1	WANT-3 FULL RETRACTION
		0	WANT-3 NOT FULL RETRACTION
WANT-4_EXT_FULL	6	1	WANT-4 FULL EXTENSION
		0	WANT-4 NOT FULL EXTENSION
WANT-4_RET_FULL	7	1	WANT-4 FULL RETRACTION
		0	WANT-4 NOT FULL RETRACTION

ADDRESS F80A (PWA12)

ITEMS	BIT	STATUS	
		1/0	FUNCTION
WANT_DRV	0	1	WANT DRIVE ON
		0	WANT DRIVE OFF
WFCD_CAL_ON/OFF	1	1	WFCD CAL ON
		0	WFCD CAL OFF
LFA_ADC_CLK_ LFA/PWS	2	1	LFA ADC CLOCK LFA
		0	LFA ADC CLOCK PWS
WFCD_SPB/DPB	3	1	WFCD SINGLE PROBE
		0	WFCD DOUBLE PROBE
WFCD_BANK_SET_ MSB	4	1	WFCD BANK SET MSB BIT
		0	
WFCD_BANK_SET_ B2	5	1	WFCD BANK SET B2 BIT
		0	
WFCD_BANK_SET_ B3	6	1	WFCD BANK SET B3 BIT
		0	
WFCD_BANK_SET_ LSB	7	1	WFCD BANK SET LSB BIT
		0	

House Keeping Items

F.No	ITEM	ABBRE.	T/V	RANGE
8010	LFA-E-T	LFA-T	T	- 5 0 °C ~ + 8 0 °C
8011	PWS-RX-T	RX-T	T	- 5 0 °C ~ + 8 0 °C
8012	PWS-PAMP-T	PAMP-T	T	- 5 0 °C ~ + 8 0 °C
8013	_____	_____	—	_____
8014	WANT-PRE-1-T	WPRE1-T	T	- 5 0 °C ~ + 8 0 °C
8015	WANT-PRE-2-T	WPRE2-T	T	- 5 0 °C ~ + 8 0 °C
8016	WANT-PRE-3-T	WPRE3-T	T	- 5 0 °C ~ + 8 0 °C
8017	WANT-PRE-4-T	WPRE4-T	T	- 5 0 °C ~ + 8 0 °C
8018	WANT-1-T	WANT1-T	T	- 5 0 °C ~ + 8 0 °C
8019	WANT-2-T	WANT2-T	T	- 5 0 °C ~ + 8 0 °C
801A	WANT-3-T	WANT3-T	T	- 5 0 °C ~ + 8 0 °C
801B	WANT-4-T	WANT4-T	T	- 5 0 °C ~ + 8 0 °C
801C	PWA+5V	PWA+5V	V	0 V ~ + 8 V
801D	PWA+12V	PWA+12V	V	0 V ~ + 1 5 V
801E	PWA-12V	PWA-12V	V	0 V ~ - 1 5 V
801F	PWA+29V	PWA+29V	V	0 V ~ + 3 5 V

2.2.7 EMI Requirements to Other Subsystems of the PLANET-B Spacecraft

It is expected that a variety of natural waves exist in the Martian ionosphere and magnetosphere. The main subject of the LFA is to investigate the wave phenomena and their relation with the electromagnetic dynamics of the Martian ionosphere and magnetosphere. The intensity of the natural waves, however, ranges from very weak level to moderately intense level. Therefore, interference noise generated in various subsystems onboard the spacecraft may bring a fatal damage to the plasma wave investigation. The WANT elements have been designed to be kept away from the possible noise source, and the PWA receiver circuit will be shielded electrostatically as much as possible.

In order to reduce the effects of the noise interference, it is required to suppress the noise current on the power lines below the specified level and to devise not to radiate electromagnetic noise from the harness cables. After the consensus on the reduction of the noise generation in the PLANET-B spacecraft has been approved by the project, we require all the instruments onboard the spacecraft keep the following "The electromagnetic compatibility specifications":

Electromagnetic compatibility

PLANET-B CE01/03 : Power line noise

following the GEOTAIL EMC criterion of GEOTAIL CE01/03

PLANET-B RE02 : EM radiation

PSU (power supply unit) : regulation of ripple and noise levels.

2.3 MGF/PET/MST/UVS (MPM)

MPM consists of 4 components; Magnetic Field Experiment (MGF), Probe for Electron temperature (PET), Ultraviolet Imaging Spectrometer (UVS), and Extendible Mast (MST).

Magnetic Field Experiment (MGF)

Principal Investigator : Tatsundo Yamamoto ISAS
Co-Investigator : Ayako Matsuoka ISAS
Ryoichi Fujii STE Laboratory, Nagoya University
Susumu Kokubun STE Laboratory, Nagoya University
Masaru Kono University of Tokyo
Fumio Tohyama Tokai University
Yutaka Tonegawa Tokai University
Mario H. Acuña NASA/GSFC
Manufacturer : Meisei Electric Co., Ltd.

Probe for Electron Temperature (PET)

Principal Investigator : Koichiro Oyama ISAS
Co-Investigator : Takumi Abe Aoyama Gakuin University
Katsuhisa Marubashi CRL
Tadanori Takahashi Tohoku University
Hiroyuki Shinagawa STE Laboratory, Nagoya University
Andrew F. Nagy Atmos. Ocean & Space Sci.,
University of Michigan
Kristian Schlegel Max-Planck Institute for Aeronomy
Jhoon Kim Korea Aerospace Research Institute
Manufacturer : Meisei Electric Co., Ltd.
Meiwa System Co.

Ultraviolet Imaging Spectrometer (UVS)

Principal Investigator : Hiroshi Fukunishi Tohoku University
Co-Investigator : Shoichi Okano Tohoku University
Makoto Taguchi Tohoku University
Katsuhisa Suzuki Yokohama National University
Manufacturer : Toshiba Co.
Hamamatsu Photonics K.K.

Extendible Mast (MST)

M.C.Natori and K.Higuchi ISAS
Manufacturer : Japan Aircraft Manufacturing Co., Ltd.

2.3.1 Observation Objectives

2.3.1.1 Magnetic Field Measurement (MGF)

The primary scientific missions of PLANET-B aim at the understanding of the Martian upper atmosphere environment and its interaction with the solar wind. The magnetic field team will contribute to the mission by measuring magnetic field variations in the frequency range below 10 Hz, using a fluxgate magnetometer. The major scientific objectives for MGF experiment are as follows:

Intrinsic / Residual Magnetic Field

The magnitude of the Martian intrinsic magnetic field is still unknown. The determination of the magnetic moment is one of the most important objectives in the PLANET-B mission. It would absolutely relate to the fundamental features in the interaction between the solar wind - the Martian ionosphere. It also gives us important information on the Mars internal structures. Residual magnetic field is an interesting issue. Magnetic field variations along the spacecraft orbit near the periapsis could give us some information on magnetic environment in the past, in conjunction with corresponding surface images from the MIC instrument.

Magnetic Field in the Ionosphere

Penetration of solar wind magnetic field into the Martian upper atmosphere is one of the major objectives in the PLANET-B mission. Because of the highly collisional media of the Martian ionosphere, magnetic field diffusion could take an essential role in the interaction processes between the solar wind and the Martian ionosphere. The shielding effect due to induced magnetic field is also important in global pressure balance. Field-aligned current that connects ionospheric current would contribute to the energy transfer from the solar wind into the Martian ionosphere.

Magnetic Field in the Solar Wind

During the high-altitude traverse in the dayside region, measurements of the solar wind magnetic field is very important. Close to the Martian ionosphere, the direct interaction with Martian upper atmosphere could be significant and the role of magnetic field of solar wind origin will be investigated, that relates to the mass loading effect. Towards higher altitude, the bow shock configuration will be obtained, which gives us some information on the Martian intrinsic magnetic field. The comparison of its shape and location, in conjunction with the upstream wave activities, to those in the Earth's environment is also important, because of relatively larger gyro-radius of charged particles.

Magnetic Field in the Tail Region

Magnetic field behind Mars takes a configuration of the tail due to trapping or draping effect. Relationship to the acceleration mechanism for charged particles are investigated.

2.3.1.2 Probe for Electron Temperature (PET)

Measurements of the electron temperature in the Martian ionosphere have several purposes. One of the main aims is to draw a thermal structure of Martian ionosphere by continuous observation of electron temperature as we did in Earth ionosphere. We know that continuous observation is essential to find out the secrets hidden in the nature.

Apart from this aim, though it is related deeply to these topics, comparison between theoretical calculation and observation is important to understand physics behind. It should be noted that even in the Earth ionosphere, electron temperature calculated by theory is much lower than that observed especially in the high altitude. The same is true in the Venus ionosphere. It is worth to check this in the Martian ionosphere.

Another item to be pursued is to study the special phenomenon such as similar to ionospheric hole in the Venus ionosphere. The formation mechanism of the hole is still controversial. Recently Cole [*J. Geophys. Res.*, 99, 14951-14958, 1994] insists that flux rope is not produced at the ionopause and convected to their place of observation, thus against the Kelvin-Helmholtz instability of the ionopause for their formation. Thus the formation mechanism of the hole where magnetic energy and plasma pressure balances is still not clear. Measurement of electron temperature surely contribute to discuss this problem in the hole.

The probe can tell whether plasma have high energy tail or not whether electrons are maxwellian or not.

There are several other things that can be studied, but electron temperature probe will present excellent data which have never been obtained in the Martian ionosphere, even if the orbiter such as Mars 96 flies in front of us.

2.3.1.3 Ultraviolet Imaging Spectrometer (UVS)

The ultraviolet imaging spectrometer with a D/H absorption cell photometer (code name, UVS) covers the FUV and MUV region from 115 to 310 nm. The major scientific objectives are :

- to study the interaction processes between the Martian upper atmosphere and the solar wind from observations of hydrogen and oxygen corona around Mars,

- to study the escape processes and the evolution of the Martian atmosphere from D/H ratio observations,

- to study the dynamical processes in the Martian ionosphere and thermosphere from observations of dayglow emissions such as CO Cameron band (180–200 nm), CO₂⁺ doublet and OI 297.2 nm emission lines,

- to discover auroral phenomena in the nightside disk, and

- to study the dynamical and mass transport processes in the Martian lower atmosphere from observations of dust storms, polar caps and ozone distributions in the dayside disk.

2.3.2 Instrument Specifications

2.3.2.1 Magnetic Field Measurement (MGF)

The subsystem for magnetic field measurements (MGF) consists of three-axis fluxgate magnetometer sensor, cables and electronics. The functional block diagram of the system is shown in Figure 2.3.2.1. The MGF subsystem is composed of two components; MGF-S and MGF-E. The latter component is installed in MPM-E, and shared with PET-E.

Triad fluxgate sensor, which utilizes a ring core geometry, is installed at the end of a 5-m deployable mast. The sensor-electronics system is designed to be similar to those used in successful AKEBONO and GEOTAIL missions. Special effort is made to reduce the total weight of the system, mainly by introducing the HIC technology to

the analog electronics component. The analog part of MGF instrument is of standard design and consists of amplifier, filter, phase sensitive detector, integrator and voltage-current converter.

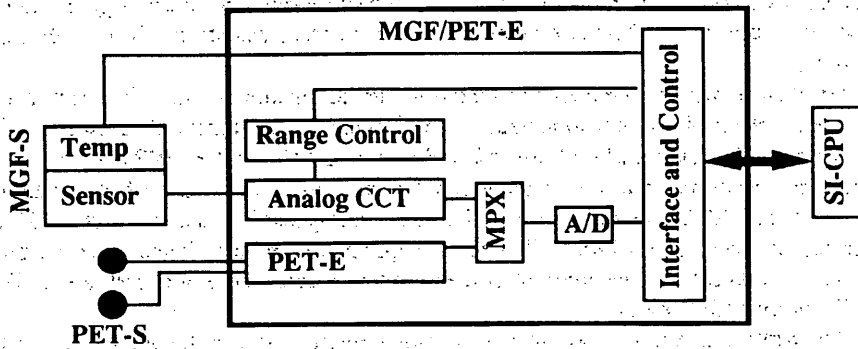


Figure 2.3.2.1. Functional Block Diagram of MGF.

The sampling for the magnetic field data is synchronized with the spacecraft spin, and its rate is 256 vectors every spin (about 32 vectors / second). Sampled data are edited according to the spacecraft edition mode and bit rate, and sent to the Data Handling Unit of the spacecraft through PIM for telemetry. Specifications of the MGF instrument are summarized in Table 2.3.2.1.

Table 2.3.2.1. Specifications of the MGF instrument

Sensor	Ring core geometry, three-components (X, Y, Z)
Drive frequency	14.8 kHz $\pm$ 0.5 kHz
Dynamic ranges	± 16 nT; ± 256 nT; ± 1024 nT; ± 65536 nT
Quantization steps (14 bit resolution)	0.002 nT; 0.031 nT; 0.125 nT; 8 nT
Sampling rates	256 vectors / spin

2.3.2.2 Probe for Electron Temperature (PET)

The probe current is expressed in terms of the probe voltage V with respect to the plasma potential in the electron retarding regime. That is

$$I = i_E \cdot \exp(eV / kT_E) - i_I \quad (1)$$

where $i_E = S_E \cdot N_E \cdot \sqrt{\kappa T_E / 2 \pi m}$ and $i_I = S_I \cdot N_I \cdot e V_S$.

In the above equation, S_E , N_E and T_E are the electron collecting area, electron density and electron temperature respectively. κ , m , e are Boltzmann's constant, electron mass and electron charge. i_I is independent of the probe voltage in the satellite measurements since the satellite velocity V_S is much higher than the ion thermal velocity V_{th} . S_I is the ion collecting area.

When a small sinusoidal wave of the amplitude, a , is superposed onto the sweep voltage, the V - I characteristic curve shifts as shown in Figure 2.3.2.2a and the shifted V - I relationship is written as

$$I = i_E \cdot I_0(ea / kT_E) \cdot \exp(eV / kT_E) - i_I \quad (2)$$

where $I_0(X)$ is the modified Bessel function of the zeroth order with argument X . The floating potential at which probe current is zero, is expressed as

$$V_{fa1} = kT_E / e \cdot \ln [i_I / i_E \cdot I_0(ea / kT_E)] \quad (3)$$

On the other hand, the floating potential without sinusoidal wave is written as

$$V_f = kT_E / e \cdot \ln [i_I / i_E] \quad (4)$$

The shift of the floating potential from the original potential is obtained by subtracting Eq.(4) from Eq.(3)

$$V_{fa1} - V_f = -kT_E / e \cdot \ln [I_0(ea / kT_E)] \quad (5)$$

When a sinusoidal wave of the amplitude, $2a$, is applied to the electrode, the floating potential shift can be written as

$$V_{fa2} - V_f = -kT_E / e \cdot \ln [I_0(2ea / kT_E)] \quad (6)$$

The electron temperature is obtained from the individual floating potential shifts when the sinusoidal wave of the amplitude a and $2a$ are successively applied. The first electron temperature T_{E1} and the second electron temperature T_{E2} are calculated from the equations (5) and (6). If we take the ratio of the two floating potential shifts which are expressed by the equations(5) and (6), the ratio can be written as

$$r = \ln [I_0(2ea / kT_E)] / \ln [I_0(ea / kT_E)] \quad (7)$$

The equation (7) gives the 3rd electron temperature T_{E3} , since e , k and e are known and r can be calculated from the potential shifts. When the electrons in the plasma are maxwellian, three electron temperatures T_{E1} , T_{E2} , and T_{E3} should be the same. If all these electron temperatures differ from one other, it can be inferred that electrons in the plasma have high energy tail or consists of two groups of different temperatures:

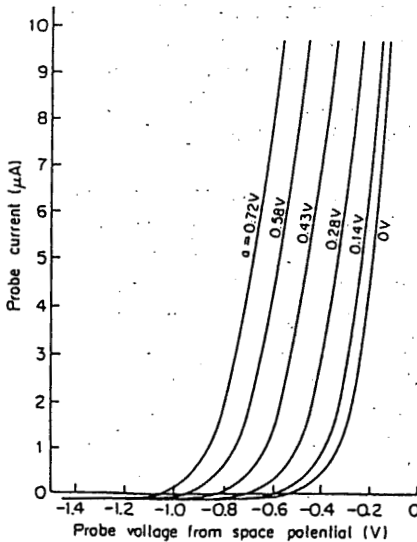


Figure 2.3.2.a. Principle of the Electron temperature measurement; shift of the floating potential caused by the application of sinusoidal signal at the floating potential of the probe.

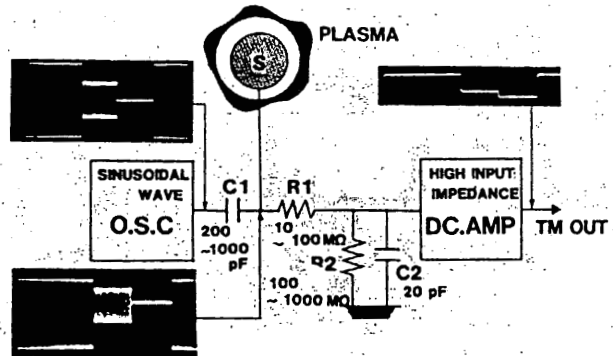


Figure 2.3.2.b. Basic electronic circuit of Electron temperature probe.

Based on this principle, we designed our experiment, the basic circuit of which is shown in Figure 2.3.2.2b. Sinusoidal waves of amplitudes a and $2a$ are applied to an electrode through a small capacitor and the dc component is measured by a resistor. The values of these resistances are determined by the electron density of the ambient plasma. The different applied and observed wave forms at three main points of the electron temperature probe are also shown. In the figure a sinusoidal wave, whose amplitude changes successively from 500 mV, 250 mV, to 0 mV respectively is applied to the electrode (denoted as S). The electrode is always at a floating potential but shifts due to the non-linearity of the sheath resistance and thus results in the sensor electrode includes contributions from the floating potential shifts as well as the original sinusoidal wave which is slightly distorted by the nonlinearity of the sheath resistance. The signal is then allowed to pass through a low pass filter which consists of a high resistance and a capacitor and is finally amplified. This instrument has been flown in Japan, Canada, India, U.S.A. and Sweden and the results obtained confirmed its high performance [Oyama, *Adv. Space Res.*, **11**, (10)109-(10)158, 1991]. Electronics of the PET is accommodated in one box with Magnetometer, and UV imager in order to economize the weight of the instruments. Electric power for PET will be supplied through Magnetometer and power is switched on/off simultaneously with magnetometer. The idea behind this is that only T_e data can not discuss such as the formation mechanism of the hole.

2.3.2.3 Ultraviolet Imaging Spectrometer (UVS)

Principle

The ultraviolet imaging spectrometer is composed of a grating spectrometer (code name, UVS-G) and a D/H absorption cell photometer (code name, UVS-P). The UVS-G is a flat-field type spectrometer operating in the ultraviolet region between 115 nm and 310 nm with a spectral resolution of 2–3 nm. The optics of UVS-G consists of an off-axis parabolic mirror, a slit, a concave grating and a small folding mirror. The detector covering the FUV region from 115 to 200 nm is a wedge strip anode (WSA) with a micro-channel plate (MCP), while the detector covering the MUV region from 200 to 310 nm is a linear image sensor (LIS).

The UVS-P is a photometer capable of separately detecting hydrogen (H) and deuterium (D) Lyman α emissions, using the absorption cell technique. Note that the center wavelengths of H and D Lyman α emissions, 121.566 nm and 121.533 nm respectively, are too close to be resolved by a small spectrometer like UVS-G. The H and D absorption cells contain hydrogen and deuterium molecule gases, respectively, and filaments are equipped inside the cell. When the filament in the cell is turned on, the hydrogen or deuterium molecules thermally dissociate into atoms which absorb H or D Lyman α incident into the field-of-view of the photometer. The absorption cell can be regarded as a very narrow band rejection filter with a center wavelength equal to the rest wavelength of Lyman α and a HWHM of 0.001–0.002 nm. By switching the filament turned on in the H cell and that in the D cell alternately, both intensities of H Lyman α and D Lyman α emissions can be measured separately.

Although the instantaneous field-of-views of UVS-G and UVS-P contain no spatial information, the mapping of emissions can be accomplished by using the spin and orbital motion of spacecraft as shown in Figure 2.3.2.3a.

The UVS instrument consists of UVS-G and UVS-P sensors and UVS-E electronic unit. UVS-E is installed in MPM-E. A block diagram of UVS is shown in Fig-

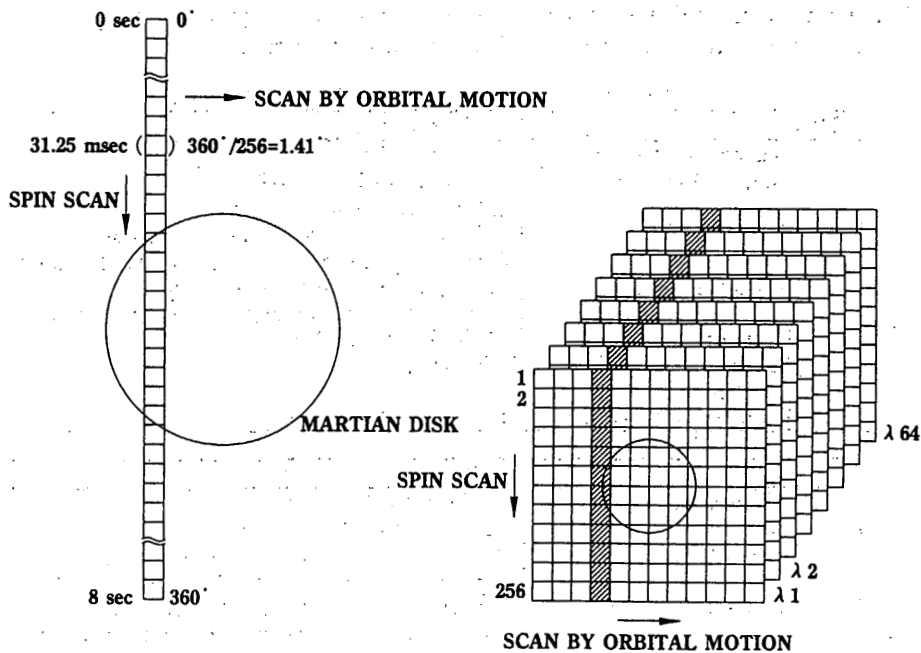


Figure 2.3.2.3a. Imaging method of UVS using the spin and orbital motion of spacecraft.

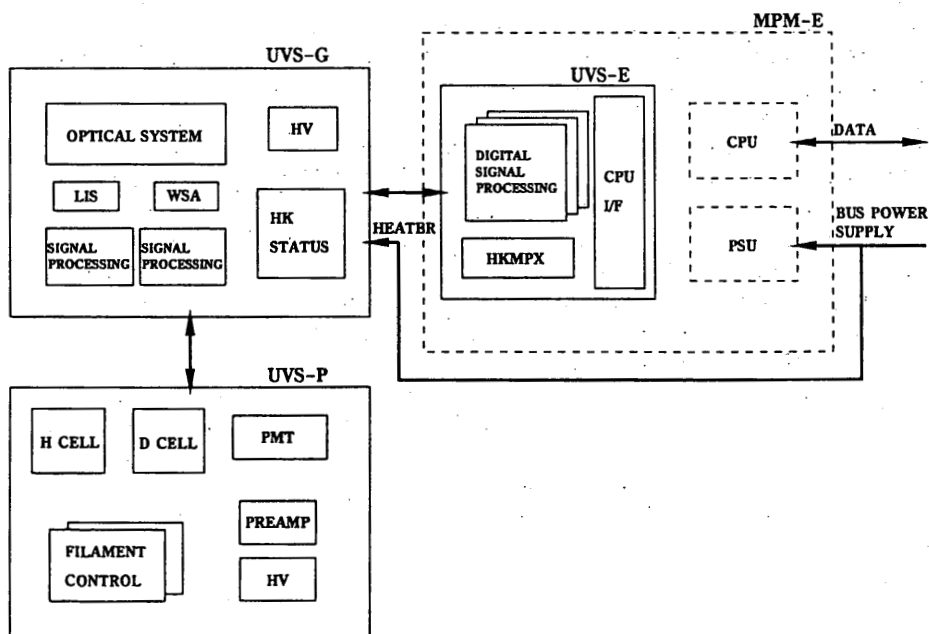


Figure 2.3.2.3b. A block diagram of the UVS instrument.

ure 2.3.2.3b. The specifications of UVS are listed in Table 2.3.2.3. All the units were designed to be as small and light as possible with minimal degradation of optical performance in order to suit the weight and power budget requirements.

Table 2.3.2.3. Specifications of UVS instrument

UVS-G	Characteristic
Wavelength Region	115 nm – 310 nm
Spectral Resolution	2.7 nm @ 115 nm – 200 nm 3.4 nm @ 200 nm – 310 nm
Field-of-View	1.43° (in a plane including the spin axis) 0.09° (in a plane perpendicular to the spin axis)
Spatial Resolution	1.43° (in a plane including the spin axis) 1.41° (in a plane perpendicular to the spin axis)
Detector	MCP+WSA and LIS
Maximum Count Rate of WSA	2.2×10^4 cps
Dynamic Range of LIS	$10^5 - 10^9$ Photon/s/Pixel

UVS-P	Characteristic
Wavelength	121.566 nm (H Lyman α) 121.533 nm (D Lyman α)
Field-of-View	3.0° (in a plane including the spin axis) 0.5° (in a plane perpendicular to the spin axis)
Spatial Resolution	3.0° (in a plane including the spin axis) 1.41° (in a plane perpendicular to the spin axis)
Detector	Side-on type solar blind photomultiplier
Sensitivity	0.25 cps/R

UVS-G

Ultraviolet emissions incident into the aperture of UVS-G are collected by an objective mirror which is an off-axis parabolic mirror with a 50 mm diameter and a 100 mm focal length. This mirror is made of beryllium and plated with nickel for satisfying requirements in weight budget and optical performance. A mount for this mirror is also made of beryllium. An entrance slit with 0.15 mm $\times$ 2.50 mm rectangular aperture limits the instantaneous field-of-view of the instrument to 0.09° (in a plane perpendicular to the spin axis) $\times$ 1.43° (in a plane including the spin axis). The incident ultraviolet emissions are dispersed by a concave grating with a 50 mm diameter ruled area and focused on two ultraviolet detectors. Efforts should be paid to keep the optical surfaces of the mirror, the grating and the windows of the detectors clean, because the contamination on the optical surfaces severely degrades transmission of vacuum ultraviolet light. The first order spectrum between 115 nm and 200 nm is detected by a wedge strip anode (WSA) with a micro-channel plate (MCP), and the second order spectrum between 200 and 310 nm is detected by a linear image sensor (LIS) which has a linear array of photodiodes. Note that the spectral resolution of UVS-G (2–3 nm) is determined by dispersion of the grating, though the detectors have much higher spatial resolution. The second order spectrum is folded by a mirror placed in front of LIS to avoid mechanical interference between the detectors. A bright object sensor (BOS) detects the Martian bright disk at 45° (or 1 sec if the spin period is 8 sec) prior to incident of strong ultraviolet emission into MCP, and transmits a signal to UVS-E. The signal can shut down the high-voltage supplied to MCP to avoid permanent damage of the photodetector due to exposure of a very bright object. A baffle and field stops are to suppress stray light when the field-of-view of UVS-G is near the bright disk. A cap is attached

at the end of the baffle to keep the optics dustless and dry until launch. The phase clock (PCLK) divides a spin period into 256 time intervals for timing of data sampling. Thus, the spatial resolution of this instrument is $1.41^\circ \times 1.43^\circ$. The baffle field-of-view is 10° . None of the antennae or masts of the spacecraft should inside of this cone angle.

UVS-P

UVS-P consists of two absorption cells, an interference filter and a photomultiplier tube. Each absorption cell has 25 mm (D) $\times$ 102 mm (L) cylindrical shape and MgF_2 windows are attached at both ends of the cell. Light from hydrogen corona is collected by a MgF_2 lens which is one of the windows of the first absorption cell. An interference filter is used to select hydrogen and deuterium Lyman α emissions from the background continuum. Pure hydrogen or deuterium gas is filled in the cell at pressure of 1–3 Torr. The hydrogen or deuterium molecules are thermally dissociated into atoms by tuning on some of four tungsten filaments fixed at inner wall of the cell. Then, atomic hydrogen or deuterium absorbs Lyman α emission from the same isotope. A side-on type solar-blind photomultiplier tube is placed at the focus of the lens and detects H and/or D Lyman α emission. Tuning-on sequence and temperature of filaments are controlled by software. A baffle suppresses stray light when the field-of-view of UVS-P is near the bright disk of Mars. A cap is attached at the end of the baffle to keep the optics dustless and dry until launch. The instantaneous field-of-view of UVS-P is $0.5^\circ \times 3.0^\circ$ and the spatial resolution is $1.4^\circ \times 3.0^\circ$. The baffle field-of-view is 20° . None of the antennae or masts of the spacecraft should inside of this cone angle.

2.3.2.4 Extendible Mast (MST)

Extendible mast system (MST) installed on PLANET-B spacecraft is a subsystem to keep a sensor for magnetic field measurements (MGF-S) in sufficient distance from the spacecraft because the magnetic field to be measured is very weak compared with the magnetization of the spacecraft.

The MST system has to be transported from the ground to space in a packed configuration. The sensor is installed at the tip of the mast. Extendible mast will be extended through a command, and will keep the sensor in a proper position.

The mast to be applied to PLANET-B is "HINGELESS MAST" that is classified in a group of coilable lattice type, and is developed through the cooperation of ISAS and a contract company. The MST system is composed of two components, one MST-M and MST-E. The latter component is installed in MPM-E.

MST-M

MST-M is composed of four main units, which are a canister, a drive unit, a HINGELESS MAST, and a top plate (see Figure 2.3.2.4a). The canister is made of composite material (Graphite/Epoxy) due to the requirement of weight reduction. The drive unit powered by a DC-motor is installed in a bottom section of the canister, and has a function of mast extension in orbit and retraction at ground testing. It holds the mast in a stowed configuration, and extends the mast by releasing a center strap. The HINGELESS MAST consists of continuous longerons, integrated radial spacers, diagonal wires, and a center strap. Radial spacers play a role of hinges through the elastic deformation. It reduces the weight of hinges very much, and can also realize the high structural accuracy. Deployment force of the mast is generated by the stored elastic energy in longerons and spacers. Some details of the HINGELESS MAST are shown in Figure 2.3.2.4b. The top plate is installed on the top of the mast to satisfy mechanical and thermal interfaces for the sensor. The plate is made of non-magnetic materials;

aluminum honeycomb sandwich structure. Materials of MST-M are shown in Table 2.3.2.4a. Mechanical and thermal properties of MST-M are shown in Table 2.3.2.4b.

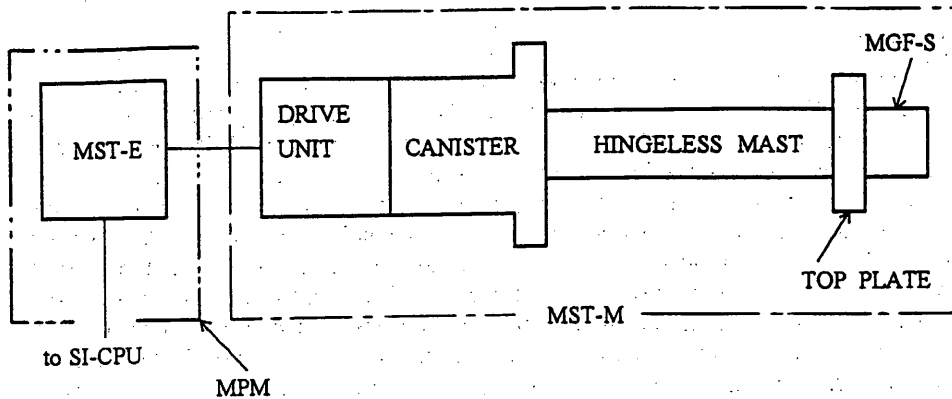


Figure 2.3.2.4a. Components of MST

Table 2.3.2.4a. Materials of MST-M

Item		Material
Hingeless Mast	Longeron	S2-Glass / Epoxy
	Radial Spacer	Polyimide
	Diagonal Wire	Titanium
Top Plate		Aluminum Alloy, Honeycomb Sandwich
Canister		Graphite / Epoxy
Center Strap		Phosphor Bronze

Table 2.3.2.4b. Mechanical and Thermal Properties of MST-M

Item		Stowed	Deployed
Weight		2.34 ± 0.25 kg	
Dimension		$357 \times \phi 270$	$5334 \times \phi 270$
Center of Gravity		see Fig. 2.3.3:1f	←
Moment of Inertia	Ix	422 kg cm ²	1.40×10^5 kg cm ²
	Iy	442 kg cm ²	1.40×10^5 kg cm ²
	Iz	250 kg cm ²	250 kg cm ²
MST Diameter		—	$\phi 150$ mm
Stiffness	Bending	—	1.4×10^8 kg mm ²
	Shearing	—	67 kg
	Torsional	—	1.1×10^6 kg mm ²
Buckling	Bending	—	321 kg mm
	Torsional	—	35 kg mm
Pointing Accuracy [Repeatability & Stability]		—	less than $\pm 1.0^\circ$
Heat Generation		Max. 12.0 Watts	
Heat Mass		2.57×10^3 J/K	
Time of Extension (REF.)		Approx. 7 ~ 15 min.	

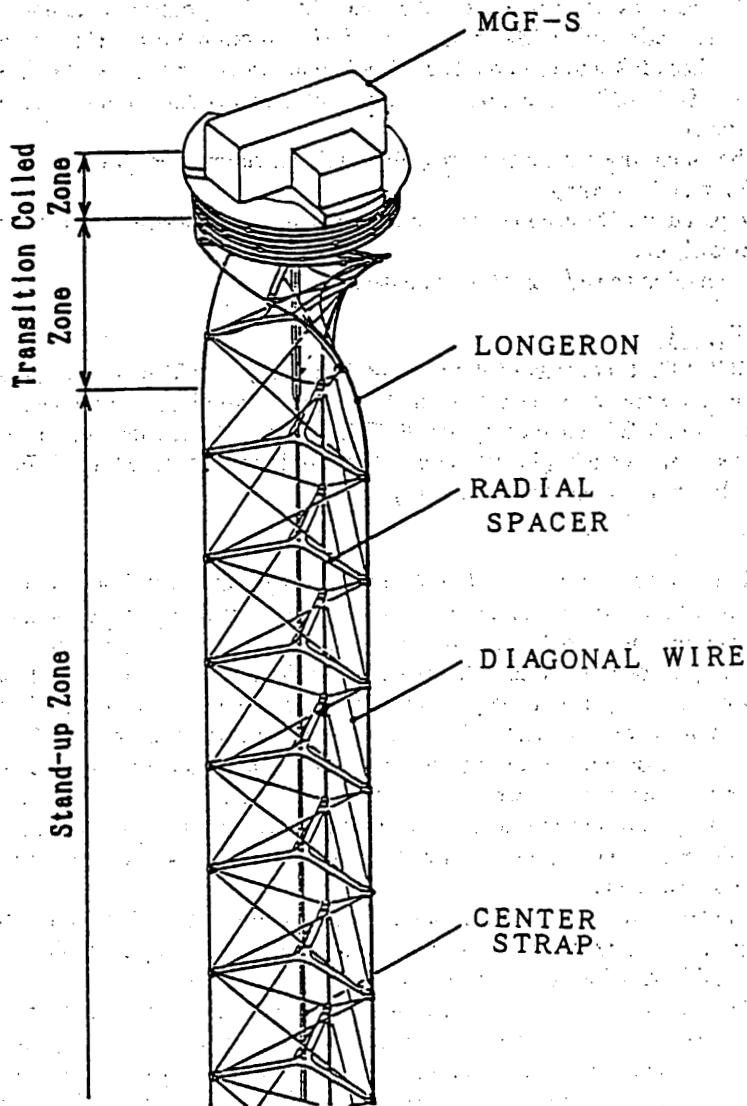


Figure 2.3.2.4b. Details of the HINGELESS MAST

2.3.2.5 MPM-E

MPM-E is composed of 5 units; MGF/PET-E, UVS-E, MST-E, SI-CPU, and PSU. MGF/PET-E, UVS-E, and MST-E govern corresponding peripherals with command control, status monitor, housekeeping monitor, and acquisition of mission data. SI-CPU has a role of an interface between each unit and DHU through PIM, along with mission data edition if necessary.

SI-CPU

SI-CPU consists of two parts; PIM and CPU. The program loading/verification for CPU is made with DMA mode from DHU through PIM. The command and telemetry (both HK and mission data) interface are made with DPRAM between PIM and CPU. 8-bit A/D conversion for analog HK items is done automatically without CPU-control.

The major jobs for the onboard program that is running on CPU are;

- 1) Command decoding,
- 2) Preparation of bi-level housekeeping items, including instrument status check and control, and
- 3) Acquisition and edition of mission data.

MGF/PET-E

MGF/PET-E consists of 4 parts; MGF-E, PET-E, A/D converter, and SI-CPU interface. A/D converter with 4-channel multiplexer digitizes 3-component magnetic field data from MGF-E and composite PET data from PET-E, with a sample rate that is 256 times of spacecraft spin frequency. Digitized data are stored in a FIFO memory and SI-CPU reads stored data once every spin.

UVS-E

High-voltage supply for MCP is set up by DC (Discrete Commands) and also signals from BOS. MCP operates in the photon counting mode. A photon incident into MCP generates current pulses in either anode of WSA. Since the pulse heights, H_1 and H_2 , are proportional to the distance from the position where a photon enters MCP to either edge of WSA, the relative position X of the incident photon on WSA is calculated from the relation of $X = H_1 / (H_1 + H_2)$. The position is calculated on a RAM with 6-bit resolution and stored in one of two dual-port RAMs, while the other is ready to be read by SI-CPU. A flag indicates which DPRAM is ready to be read. The high-voltage level of MCP, the gain of the amplifier, the gain of the BOS amplifier and the discriminator level of the BOS signal are set up by BC (Block Commands). These parameters are stored in the HK data.

Charges induced by incident photons in each element of LIS are sequentially read out, amplified, digitized and stored in a FIFO memory. Timing of reading-out is triggered by a PCLK pulse from AOCE.

The photomultiplier tube in UVS-P also operates in the photon counting mode. Current pulses from the photomultiplier tube are amplified and shaped, and then real current pulses corresponding to photons are discriminated from noise pulses which have relatively low pulse heights. Arrival of the pulses is counted by a non-reset counter, of which count is latched at every PCLK pulse and read by SI-CPU. The numbers of turned-on filaments, the filament temperature, the high-voltage level applied to the photomultiplier tube, the gain of the amplifier and the discriminator level are set up by BC and can be monitored in the HK.

All the scientific data are allocated to the memory space of SI-CPU. HK status, HK data, I/O flags, DC and BC are also allocated to the I/O space. An interrupt pulse is generated at start of each spin referring the IP pulse from AOCE. This pulse is sent off to INT7 of SI-CPU. A data ready signal of TCLK2 interrupts SI-CPU and then SI-CPU reads the data. The HK status and HK data are renewed for every 1/16 of the spin period.

MST-E

MST-E is composed of a print board and software in SI-CPU. The print board is supported by 9 small blocks and screws in MPM-E box. The set of small blocks isolates MST-E board from other print boards, and that protects from vibration and shock disturbance by its stress relief. MST-E has three connectors; one is used for interface of SI-CPU, and the others are used for MST-M.

2.3.3 Instrument Configuration

The subsystem MPM consists of 6 units; MPM-E, MGF-S, PET-S, UVS-G, UVS-P, and MST-M. The outlines of each unit are given in Figure 2.3.3.1. The sensor of the MGF instrument (MGF-S) is installed at the end of the deployable mast (MST-M). The two sensors of the PET instrument (PET-S) are put at the end of the two solar paddles, respectively. MPM-E is composed of 5 units; MGF/PET-E, UVS-E, MST-E, SI-CPU, and PSU. The functional configuration of the total MPM-E subsystem is given in Figure 2.3.3.2. The conceptual diagram of the MPM system is shown in Figure 2.3.3.3.

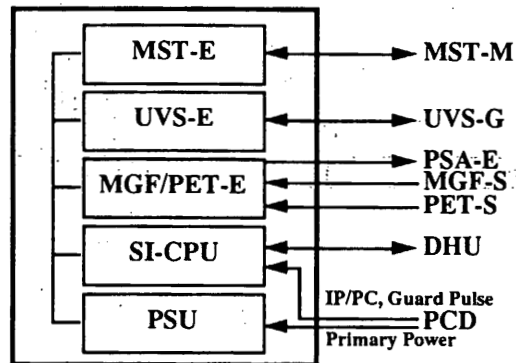


Figure 2.3.3.2. Functional Diagram of MPM-E

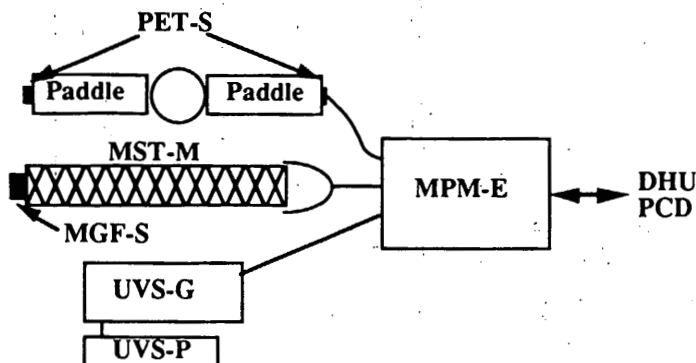


Figure 2.3.3.3. Conceptual Diagram of MPM

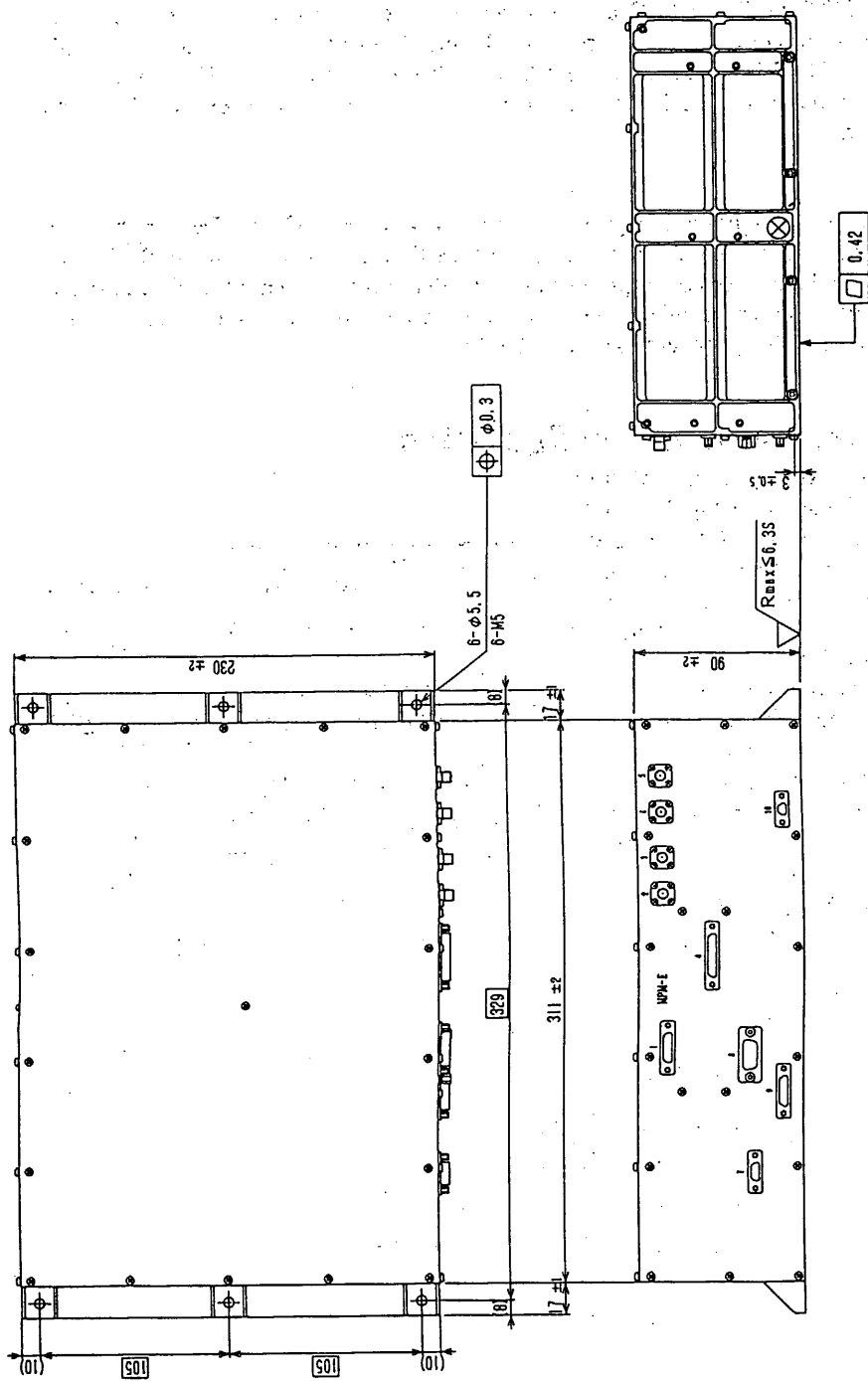


Figure 2.3.3.1a. Outline of MPM-E

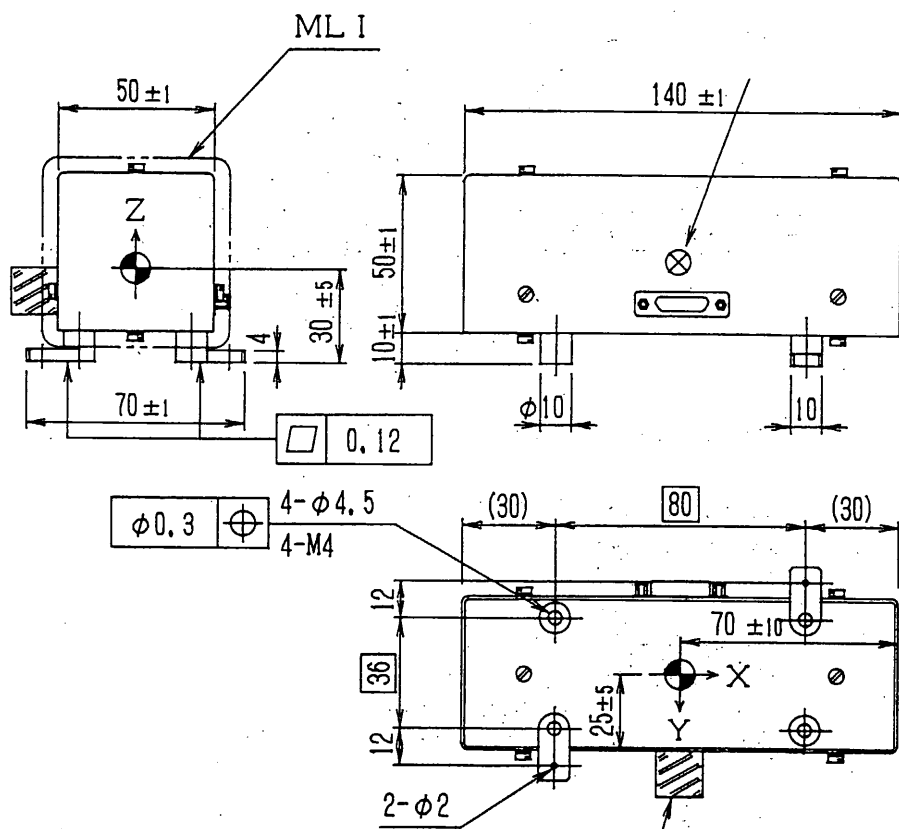


Figure 2.3.3.1b. Outline of MGF-S

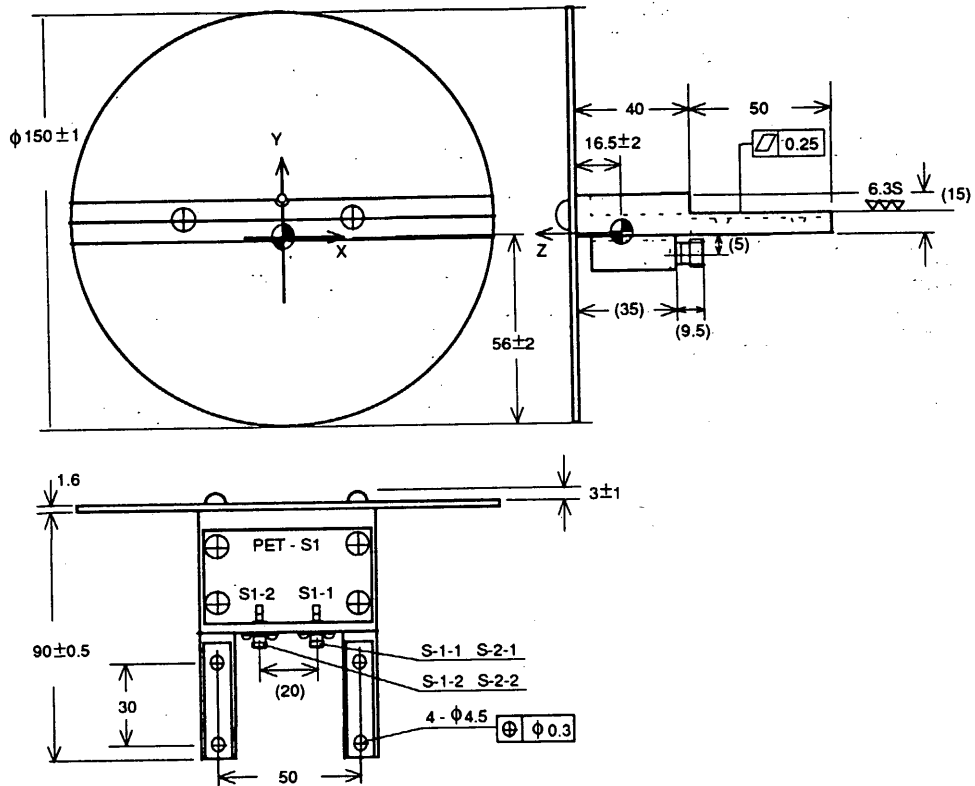


Figure 2.3.3.1c. Outline of PET-S

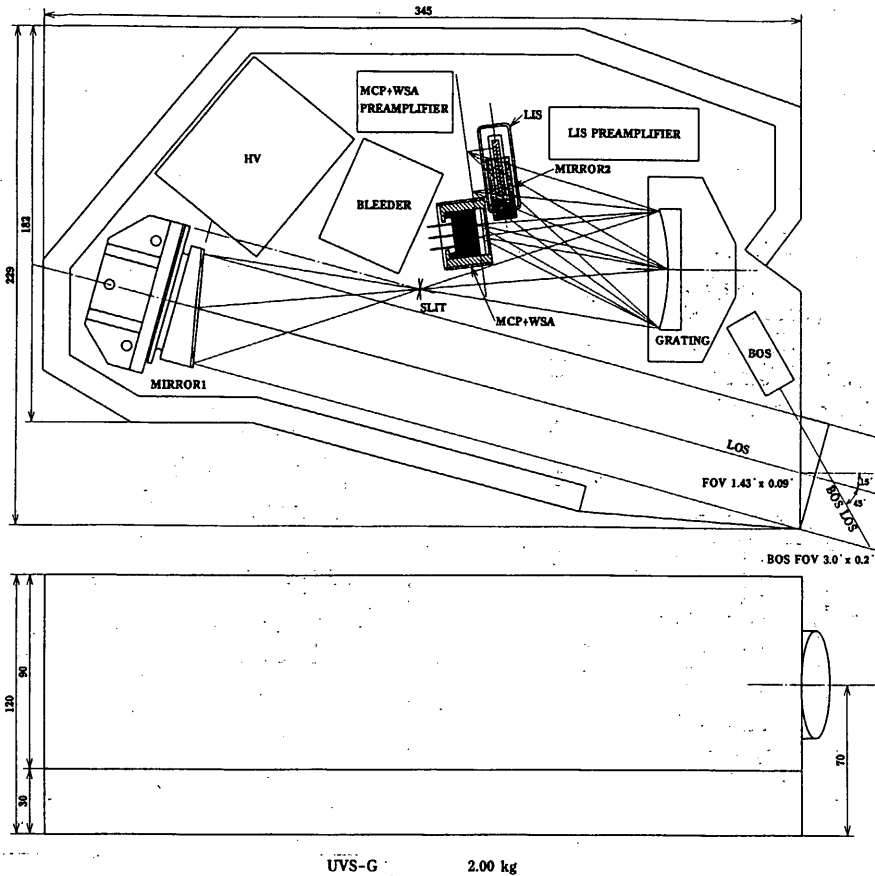


Figure 2.3.3.1d. Outline of UVS-G

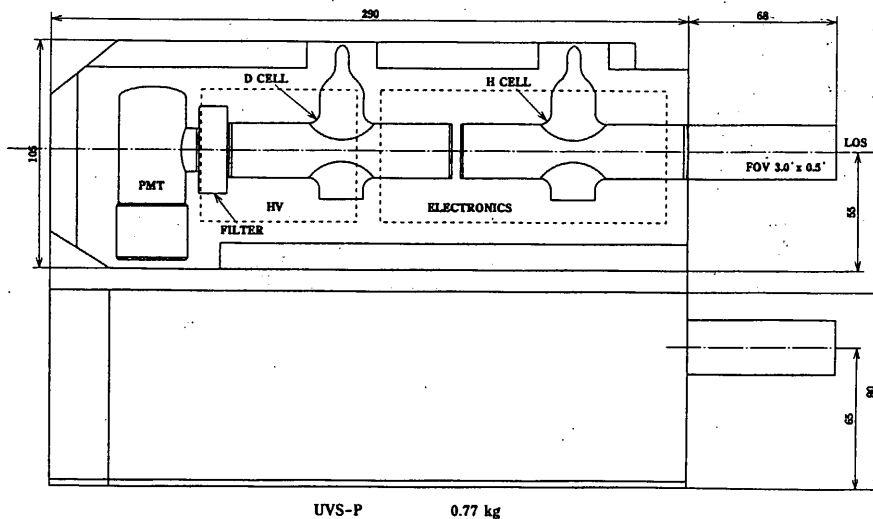


Figure 2.3.3.1e. Outline of UVS-P

2.3.4 Size, Weight, and Power Consumption

2.3.4.1 Size and Weight

The size and weight of MPM sub-components are listed in Table 2.3.4.1.

Table 2.3.4.1 Size and Weight of MPM sub-components

Unit	Size (mm)	Weight (kg)
MGF-S	140×50×50	575±50 (Including Cable)
PET-S	φ150	0.088±0.01 × 2
MST-M	357×φ270 (Stowed) 533×φ270 (Deployed)	2.34±0.25
UVS-G	345×229×120	2.00±
UVS-P	290×105×90	0.77±
MPM-E	311×230×90	2.80±0.3

2.3.4.2 Power Consumption

Power consumption of each unit in MPM is listed in Table 2.3.4.2.

Table 2.3.4.2a. Power Consumption of SI-CPU

Operation Mode	Max/Average	+5V (mA)	+12V (mA)	-12V (mA)	+29V (mA)	BUS (27V) (mA)	BUS (19V) (mA)
CPU ON	Max	360±	33±	25±	0±	0±	0±

Table 2.3.4.2b. Power Consumption of MGF/PET

Operation Mode	Max/Average	+5V (mA)	+12V (mA)	-12V (mA)	+29V (mA)	BUS (27V) (mA)	BUS (19V) (mA)
MGF/PET OFF	Max	5±1	5±1	5±1	0±	0±	0±
MGF/PET ON	Max	30±5	108±10	88±10	0±	0±	0±

Table 2.3.4.2c. Power Consumption of MST

Operation Mode	Max/Average	+5V (mA)	+12V (mA)	-12V (mA)	+29V (mA)	BUS (27V) (mA)	BUS (19V) (mA)
MST STBY OFF	Max	5±	8±	8±	0±	0±	0±
MST STBY ON	Max	90±5	20±	20±	0±	0±	0±
MST DRV ON	Max	100±	20±	20±	0±	382±	0±
MST HTR ON	Max	6±	8±	8±	0±	100±	0±

Table 2.3.4.2d. Power Consumption of UVS

Operation Mode	Max/Average	+5V (mA)	+12V (mA)	-12V (mA)	+29V (mA)	BUS (27V) (mA)	BUS (19V) (mA)
UVS OFF	Max	10±	5±	3±	0±	0±	0±
UVS ON	Max	387±39	177±18	190±19	0±	0±	0±
UV OBS	Max	387±39	199±20	210±20	0±	0±	0±
PM OBS	Max	387±39	201±20	204±20	266±27	0±	0±
UV/PM OBS	Max	387±39	212±21	215±22	266±27	0±	0±
UVS HTR ON	Max	0±	0±	0±	0±	TBD±	TBD±

Table 2.3.4.2e. Total Power Consumption of MPM

Operation Mode	Max/Average	+5V (mA)	+12V (mA)	-12V (mA)	+29V (mA)	BUS (27V) (mA)	BUS (19V) (mA)
STAND-BY (CPU-ON)	Max	380±	51±	44±	0±	0±	0±
MGF/PET ON	Max	405±	154±	127±	0±	0±	0±
MGF/PET ON MST DRV ON	Max	500±	166±	139±	0±	382±	0±
MGF/PET ON UVS ON	Max	782±	326±	311±	0±	0±	0±
MGF/PET ON UVS-UV OBS	Max	782±	348±	322±	0±	0±	0±
MGF/PET ON UVS-PM OBS	Max	782±	350±	325±	266±	0±	0±
MGF/PET ON UVS-UV/PM OBS	Max	782±	361±	341±	266±	0±	0±
MST HTR ON (CPU-OFF)	Max	115±	18±	16±	0±	100±	0±
UVS HTR ON (CPU-OFF)	Max	TBD±	TBD±	TBD±	TBD±	TBD±	TBD±

2.3.5 Operation

2.3.5.1 MGF and PET

MGF and PET operate basically with one mode in the PLANET-B mission. They are kept in the operational mode after the Mars insertion, except for the spacecraft emergency. The onboard sampling rate is fixed as 256 data every spin. Sampled data are edited by SI-CPU for allocated telemetry rate. In the extremely low telemetry bit rate, onboard despin will be made for MGF data.

PET can give meaningful data only in the ionosphere. Therefore most of the time PET data will be taken in a periapsis mode (Telemetry format-16, which is operated at the rate of 64k-16k bit/sec). This means that electron temperature is measured roughly every 2 seconds. Minimum telemetry requirement for the PET will be 512 bps (Format-17) which samples electron temperature every 64 seconds. In other modes, VF data are sent for telemetry from PET.

The range change for MGF is made manually or automatically. In the nominal operation it is under CPU control. The function of sensor polarity change is available for inflight determination of sensor offset. Command signal necessary for the PET is only POWER ON/OFF. But it might be better to add one more command to change the gain of the differential amplifier in case that amplitude of the signal is over the possible input range.

2.3.5.2 UVS

UVS operates with three modes in the PLANET-B experiments; Standard Observation Mode, Periapsis Mode and UVS-XUV Mode. The number of mission packets occupied by the UVS data and the available telemetry bit rate are different in these modes. Scientific data taken by the UVS are arranged in mission packets as 9 edition modes and 8 edition sub-modes as shown in Tables 2.3.5.2a and 2.3.5.2b. The edition modes determine the operation of the two photodetectors of UVS-G and provide

the edition format of data taken by them, while the edition sub-modes fix the turning-on sequence of the absorption cell filaments in the UVS-P experiment. The UVS data are stacked as synchronized with the spin phase. The time for stacking is changed depending on the telemetry bit rate from 8 sec (1 spin period) to 2048 sec (256 spin period). Each mission packet (432 bytes) for UVS data contains science data of 416 bytes, a 14-byte header which includes all information necessary for analysis of the science data, and 2-byte residual.

Standard Observation Mode

The WSA detector of UVS-G measures emissions from hydrogen corona, oxygen corona and oxygen aurora at 13 wavelengths selected between 115–200 nm. LIS and UVS-P are off.

Periapsis Mode (I)

The WSA detector of UVS-G measures emissions from hydrogen corona, oxygen corona and oxygen aurora at 13 wavelengths selected between 115–200 nm with a spatial resolution of 256' (1.41°) for 1 spin period. LIS is off. UVS-P measures H or D Lyman α profile by utilizing Doppler shift due to the orbital motion of the spacecraft or by changing filament temperature.

Periapsis Mode (II)

The WSA detector of UVS-G measures dayglow emissions from the Martian limb at 52 wavelengths selected between 115–200 nm with a spatial resolution of 256' (1.41°) for 1 spin period. LIS and UVS-P are off.

Periapsis Mode (III)

The LIS detector of UVS-G measures emissions from the bright disk at 52 wavelengths selected between 200–310 nm with a spatial resolution of 256' (1.41°) for 1 spin period. WSA and UVS-P are off.

UVS-XUV Mode (I)

The WSA detector of UVS-G measures emissions from hydrogen corona, oxygen corona and oxygen aurora at 13 wavelengths selected between 115–200 nm with a spatial resolution of 256' (1.41°) for 1 spin period. LIS is off. UVS-P measures H or D Lyman α profile by utilizing Doppler shift due to the spacecraft orbital motion or by changing filament temperature.

UVS-XUV Mode (II)

The WSA detector of UVS-G measures dayglow emissions from the limb at 52 wavelengths selected between 115–200 nm with a spatial resolution of 256' (1.41°) for 1 spin period. UVS-P measures H or D Lyman α profile by utilizing Doppler shift due to the spacecraft orbital motion or by changing filament temperature.

UVS-XUV Mode (III)

The LIS detector of UVS-G measures emissions from the bright disk at 52 wavelengths selected between 200–310 nm detected with a spatial resolution of 256' (1.41°) for 1 spin period. WSA and UVS-P are off.

UVS-XUV Mode (IV)

All detectors are operated simultaneously. The WSA detector of UVS-G measures emissions from hydrogen corona, oxygen corona, oxygen aurora and dayglow emissions from the limb at 52 wavelengths between 115–200 nm while the LIS detector

measures emissions from the bright disk at 52 wavelengths between 200–310 nm with a spatial resolution of 64 (5.63°) for 1 spin period. A spectrum taken in this mode is also used for calibration of UVS-G. UVS-P measures H or D Lyman α emissions or both H and D Lyman α emissions to retrieve a D/H ratio.

UVS-XUV Mode (V)

All detectors are operated simultaneously. The WSA detector of UVS-G measures emissions from hydrogen corona, oxygen corona, oxygen aurora and dayglow emissions from the limb at 52 wavelengths between 115–200 nm while the LIS detector measures emissions from the bright disk at 52 wavelengths between 200–310 nm with a spatial resolution of 256 (1.41°) for 1 spin period. A spectrum taken in this mode is also used for calibration of UVS-G. UVS-P measures H or D Lyman α emissions or both H and D Lyman α emissions to retrieve a D/H ratio.

Table 2.3.5.2a. UVS Edition Mode

Edition Mode	Objects	Detector			Data points		Packet Rate (pct/spin) (Number of spins for data stacking)							
		MCP	LIS	PM	Spec	Spin	0.5	1	2	4	8	16	32	64
Standard Mode	H / O Corona O Aurora	ON	OFF	OFF	13	256	1/16 (256)	1/8 (128)	1/4 (64)	1/2 (32)	1 (16)	2 (8)	4 (4)	8 (2)
Periapsis Mode (I)	H / O Corona O Aurora	ON	OFF	1,2, 3,4	13	256	N/A	N/A	N/A	N/A	N/A	N/A	4 (4)	8 (2)
Periapsis Mode (II)	Dayglow	ON	OFF	OFF	52	256	N/A	N/A	N/A	N/A	N/A	N/A	4 (16)	8 (8)
Periapsis Mode (III)	O ₃ , Dust	OFF	ON	OFF	52	256	N/A	N/A	N/A	N/A	N/A	N/A	4 (16)	8 (8)
UVS-XUV Mode (I)	H / O Corona O Aurora	ON	OFF	1,2, 3,4	13	256	N/A	N/A	2 (8)	4 (4)	8 (2)	16 (1)	32 (1)	64 (1)
UVS-XUV Mode (II)	Dayglow	ON	OFF	1,2, 3,4	52	256	N/A	N/A	2 (32)	4 (16)	8 (8)	16 (4)	32 (2)	64 (1)
UVS-XUV Mode (III)	O ₃ , Dust	OFF	ON	OFF	52	256	N/A	N/A	2 (32)	4 (16)	8 (8)	16 (4)	32 (2)	64 (1)
UVS-XUV Mode (IV)	H / O Corona, O ₃ O Aurora, Dayglow Dust, Calibration	ON	ON	5,6 7,8	104	64	N/A	N/A	2 (16)	4 (8)	8 (4)	16 (2)	32 (1)	64 (1)
UVS-XUV Mode (V)	H / O Corona, O ₃ O Aurora, Dayglow Dust, Calibration	ON	ON	5,6 7,8	104	256	N/A	N/A	2 (64)	4 (32)	8 (16)	16 (8)	32 (4)	64 (2)

Table 2.3.5.2b. UVS Edition Sub-mode

No	Edition Sub-Mode	Objects	Data	Spin	Fil-Temp	Method of Measurement
1	H Ly α Doppler Scan	H Temp.	1	4	Fixed	H Ly α Profile using Doppler Shift due to orbital motion of satellite
2	D Ly α Doppler Scan	D Temp	1	4	Fixed	D Ly α Profile using Doppler Shift due to orbital motion of satellite
3	H Ly α Modulation	H Temp	1	4	4 PTS+OFF	H Ly α Profile by changing Filament Temperature
4	D Ly α Modulation	D Temp	1	4	4 PTS+OFF	D Ly α Profile by changing Filament Temperature
5	H Ly α Fixed Temp	H Corona	1	16	Fixed+OFF	H Ly α Distribution by comparing intensities when filament ON and OFF
6	D Ly α Fixed Temp	D Corona	1	16	Fixed+OFF	D Ly α Distribution by comparing intensities when filament ON and OFF
7	D/H Ratio (I)	D/H Ratio	2	16	Fixed	H Ly α and D Ly α Intensities
8	D/H Ratio (II)	D/H Ratio	3	16	Fixed	H Ly α and D Ly α Intensities, and contamination

2.3.5.3 MST

The operation of the mast deployment shall be carried out after the Mars insertion of the spacecraft. It shall be kept in stowed configuration during the Earth-parking phase and the trans-Mars cruising phase. Because of the long-time (about 14 months) stowed configuration in the vacuum condition, a special care is taken for the mechanical system.

The mast has three functions; driving, monitoring, and keeping temperature. These functions are as follows:

Driving

Mast Extension : The strap spool is driven by the motor, and strap is released from the spool. The mast is extended by itself with elastic energy stored in it at coiled configuration.

Mast Retraction : The strap spool is driven in reverse by the motor to wind up the strap, and the mast is retracted.

Stop : The mast is able to be stopped at any time during both extension and retraction by turning off the motor power.

Monitoring

Extension Length : Micro-SW-1 counts revolution of the strap spool. Extension length is given by calculating these data.

Strap Tension : Micro-SW-2 detects the motion of pulley, and generates a signal when strap tension is inactive.

Full Retraction : Micro-SW-3 detects the motion of holding hook installed in the unit, and generates a signal when mast is fully retracted.

Over Load : Motor current is checked by the current monitor circuit. Motor current is cut as soon as over current is detected.

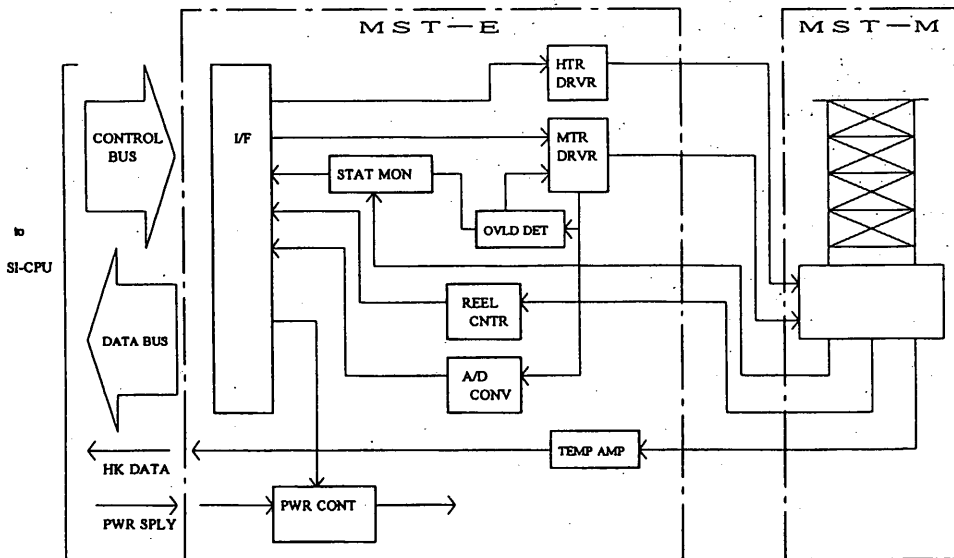


Figure 2.3.5.3 Function Block Diagram of MST

The function block diagram is shown in Figure 2.3.5.3. Command signals, mast length data, and temperature control signal are processed in SI-CPU board. The mast length data are taken from micro-SW that is operated by strap spool. MST-E receives command signals from SI-CPU. They are STBY ON/OFF, EXT/RET, DRV ON/OFF, HTR ON/OFF.

The deployment of the mast will be made fully automatically under the SI-CPU control. When the SI-CPU notices the fully-deployed condition or the overload status, it automatically stops the deploy sequence. In the case of spacecraft attitude emergency, DHU shall send the "DRV-OFF" command to MPM.

2.3.6 Command and Telemetry Items

2.3.6.1 Command Items

Discrete command items are listed in Table 2.3.6.1. The details of block command items are described in Table 2.3.6.2.

Table 2.3.6.1 Discrete Command Items (PIM-ID = 09)

XY	COMMAND	FUNCTION	TELEMETRY
00	NOP	-	-
01	MPM_CPU_ON	MPM SI-CPU ON	MPM1 B7 = 1
02	MPM_CPU_OFF	MPM SI-CPU OFF	MPM1 B7 = 0
04	MPM_MCRP_OUT	MPM MCRP Out	-
05	MPM_REQ_ACK	MPM-PIM Request Acknowledge	-
06	MPM_TI_CNT_SET	MPM TI Counter Set	-
07	MPM_TI_CNT_RESTART	MPM TI Counter Restart	-
08	MPM_A_BUS_GUARD	MPM-PIM A-Bus Guard	-
09	MPM_B_BUS_GUARD	MPM-PIM B-Bus Guard	-
0A	MPM_A_BUS_G_CANCEL	MPM-PIM A-Bus Guard Cancel	-
0B	MPM_B_BUS_G_CANCEL	MPM-PIM B-Bus Guard Cancel	-
10	MPM_HTR_ENA	MPM Heater Control Enable	MPM1 B3 = 1
11	MPM_HTR_DIS	MPM Heater Control Disable	MPM1 B3 = 0
12	MPM_ECC_ENA	MPM SI-CPU ECC Enable	MPM1 B2 = 1
13	MPM_ECC_DIS	MPM SI-CPU ECC Disable	MPM1 B2 = 0
14	MPM_WDT_ENA	MPM SI-CPU WDT Enable	MPM1 B5 = 1
15	MPM_WDT_DIS	MPM SI-CPU WDT Disable	MPM1 B5 = 0
16	MPM_CPU_RUN	MPM SI-CPU Run	MPM1 B6 = 1
17	MPM_CPU_RESET	MPM SI-CPU Reset	MPM1 B6 = 0
18	MPM_ADRS_SET	MPM Address Set	-
20	MPM_BUS_ACCESS_ENA	MPM SI-CPU DMA Enable	-
21	MPM_BUS_ACCESS_DIS	MPM SI-CPU DMA Disable	-
22	MPM_MODE_CHANGE	MPM Mode Change Set	-
30	MGF/PET_ON	MGF/PET-E PS ON	MPM2 B0 = 1
31	MGF/PET_OFF	MGF/PET-E PS ON	MPM2 B0 = 0
32	MGF_SENSE_NOR	MGF Sense Normal	MPM2 B1 = 0
33	MGF_SENSE_REV	MGF Sense Reverse	MPM2 B1 = 1
34	MGF_RNG_AUTO	MGF Range Control by CPU	MPM2 B2 = 0

Table 2.3.6.1 (Continued) Discrete Command Items (PIM-ID = 09)

36	PET_CAL_ON	PET Calibration ON	MPM2 B3 = 1
37	PET_CAL_OFF	PET Calibration OFF	MPM2 B3 = 0
38	MGF_RNG_SET	MGF Range Set	MPM2 B2 = 1
39	MGF/PET_MODE_SET	MGF/PET Observation Mode Set	-
40	UVS_ON	UVS-E PS ON	MPM3 B0 = 1
41	UVS_OFF	UVS-E PS OFF	MPM3 B0 = 0
42	UVS_OBS_MODE_SET	UVS Observation Mode Set	MPM4 B0-7 = *
50	UV_HV_ENA	UVS-G MCP HV Enable	MPM2 B4 = 1
51	UV_HV_ON	UVS-G MCP HV ON	MPM2 B5 = 1
52	UV_HV_OFF	UVS-G MCP HV OFF and Disable	MPM2 B4,5 = 0
54	UV_DATA_SET	UVS-G Data Set	MPM3 B3,4 = *
55	UV_CAL_DATA_SET	UVS-G Calibration Data Set	-
56	UV_MCP_GAIN_SET	UVS-G MCP Gain Set	MPM3 B3,4 = *
57	UV_MCP_DISC_SET	UVS-G Discriminator Set	-
58	UV_MCP_AMP_GAIN_SET	UVS-G MCP Amplifier Gain Set	-
59	UV_LIS_AMP_GAIN_SET	UVS-G LIS Amplifier Gain Set	-
60	PM_HV_ENA	UVS-P Photomultiplier HV Enable	MPM2 B6 = 1
61	PM_HV_ON	UVS-P Photomultiplier HV ON	MPM2 B7 = 1
62	PM_HV_OFF	UVS-P Photomultiplier HV OFF Disable	MPM2 B6,7 = 0
63	PM_H_FIL_ON	UVS-P H-Cell Filament ON	MPM3 B1 = 1
64	PM_H_FIL_OFF	UVS-P H-Cell Filament OFF	MPM3 B1 = 0
65	PM_D_FIL_ON	UVS-P D-Cell Filament ON	MPM3 B2 = 1
66	PM_D_FIL_OFF	UVS-P D-Cell Filament OFF	MPM3 B2 = 0
67	PM_DATA_SET	UVS-P Photomultiplier Data Set	MPM3 B5,6 = *
68	PM_H_FIL_DATA_SET	UVS-P H-Cell Filament Data Set	-
69	PM_D_FIL_DATA_SET	UVS-P D-Cell Filament Data Set	-
6A	PM_GAIN_SET	UVS-P Photomultiplier Gain Set	MPM3 B5,6 = *
6B	PM_DISC_SET	UVS-P Photomultiplier Discriminator Set	-
6C	PM_AMP_GAIN_SET	UVS-P Photomultiplier Amplifier Gain Set	-
6D	PM_BOS_GAIN_SET	UVS-P BOS Gain Set	-
6E	PM_H_FIL_TEMP_SET	UVS-P H-Cell Filament Temperature Set	-
6F	PM_H_FIL_SEL_SET	UVS-P H-Cell Filament Selection Set	-
70	PM_D_FIL_TEMP_SET	UVS-P D-Cell Filament Temperature Set	-
71	PM_D_FIL_SEL_SET	UVS-P D-Cell Filament Selection Set	-
80	MST_STBY_ON	MST-E PS ON	MPM5 B0 = 1
81	MST_STBY_OFF	MST-E PS OFF	MPM5 B0 = 0
82	MST_EXT_MODE	MST Extension Mode	MPM5 B1 = 1
83	MST_RET_MODE	MST Retract Mode	MPM5 B2 = 1
84	MST_DRV_ON	MST Drive ON	MPM5 B3 = 1
85	MST_DRV_OFF	MST Drive OFF	MPM5 B3 = 0
86	MST_HTR_CONT_ON	MST Heater Control Enable	MPM5 B4 = 1
87	MST_HTR_CONT_OFF	MST Heater Control Disable	MPM5 B4 = 0

Table 2.3.6.2a. MGF Range Set

ITEM (XY:38)		B0	B1	B2	B3	B4	B5	B6	B7
MGF	1	-	X	Y	Z	-	-	Range Data	
RNG SET	0	-	-	-	-	-	-		

Table 2.3.6.2b. MGF/PET Observation Mode Set

ITEM (XY:39)		B0	B1	B2	B3	B4	B5	B6	B7
MGF/PET	1	REV	BC	Range Data		MGF/PET Observation Mode			
MODE SET	0	NOR	AUTO						

Table 2.3.6.2c. UVS Observation Mode Set

ITEM (XY:42)		B0	B1	B2	B3	B4	B5	B6	B7
UVS OBS	1	UVS Observation Mode							
MODE SET	0								

Table 2.3.6.2d. UVS-G Data Set

ITEM (XY:54)		B0	B1	B2	B3	B4	B5	B6	B7
UV	1	MCP GAIN		MCP DISC		MCP AMP GAIN		LIS AMP GAIN	
DATA SET	0								

Table 2.3.6.2e. UVS-G Calibration Data Set

ITEM (XY:55)		B0	B1	B2	B3	B4	B5	B6	B7
UV CAL	1	UVS-G Calibration Data							
DATA SET	0								

Table 2.3.6.2f. UVS-G MCP Gain Set

ITEM (XY:56)		B0	B1	B2	B3	B4	B5	B6	B7
UV MCP	1	-	-	-	-	-	-	MCP GAIN	
GAIN SET	0	-	-	-	-	-	-		

Table 2.3.6.2g. UVS-G MCP Discriminator Set

ITEM (XY:57)		B0	B1	B2	B3	B4	B5	B6	B7
UV MCP	1	-	-	-	-	-	-	MCP DISC	
DISC SET	0	-	-	-	-	-	-		

Table 2.3.6.2h. UVS-G MCP Amplifier Gain Set

ITEM (XY:58)		B0	B1	B2	B3	B4	B5	B6	B7
UV MCP AMP	1	-	-	-	-	-	-	MCP AMP GAIN	
GAIN SET	0	-	-	-	-	-	-		

Table 2.3.6.2i. UVS-G LIS Amplifier Gain Set

ITEM (XY:59)		B0	B1	B2	B3	B4	B5	B6	B7
UV LIS AMP	1	-	-	-	-	-	-	LIS AMP GAIN	
GAIN SET	0	-	-	-	-	-	-		

Table 2.3.6.2j. UVS-P Photomultiplier Data Set

ITEM (XY:67)		B0	B1	B2	B3	B4	B5	B6	B7
PM	1	PM GAIN		PM DISC		PM AMP GAIN		BOS GAIN	
DATA SET	0								

Table 2.3.6.2k. UVS-P H-Cell Filament Data Set

ITEM (XY:68)		B0	B1	B2	B3	B4	B5	B6	B7
PM H FIL	1	-	-	H-CELL FIL TEMP		H-CELL FIL SEL			
DATA SET	0	-	-						

Table 2.3.6.2*l*. UVS-P D-Cell Filament Data Set

ITEM (XY:69)		B0	B1	B2	B3	B4	B5	B6	B7
PM D FIL	1	-	-	D-CELL FIL		D-CELL FIL SEL			
DATA SET	0	-	-	TEMP					

Table 2.3.6.2*m*. UVS-P Photomultiplier Gain Set

ITEM (XY:6A)		B0	B1	B2	B3	B4	B5	B6	B7
PM	1	-	-	-	-	-	-	PM GAIN	
GAIN SET	0	-	-	-	-	-	-		

Table 2.3.6.2*n*. UVS-P Discriminator Set

ITEM (XY:6B)		B0	B1	B2	B3	B4	B5	B6	B7
PM	1	-	-	-	-	-	-	PM DISC	
DISC SET	0	-	-	-	-	-	-		

Table 2.3.6.2*o*. UVS-P Photomultiplier gain Set

ITEM (XY:6C)		B0	B1	B2	B3	B4	B5	B6	B7
PM AMP	1	-	-	-	-	-	-	PM AMP	
GAIN SET	0	-	-	-	-	-	-	GAIN	

Table 2.3.6.2*p*. UVS-P BOS Gain Set

ITEM (XY:6D)		B0	B1	B2	B3	B4	B5	B6	B7
PM BOS	1	-	-	-	-	-	-	PM BOS	
GAIN SET	0	-	-	-	-	-	-	GAIN	

Table 2.3.6.2*q*. UVS-P H-Cell Filament Temperature Set

ITEM (XY:6E)		B0	B1	B2	B3	B4	B5	B6	B7
PM H FIL	1	-	-	-	-	-	-	H-CELL	
TEMP SET	0	-	-	-	-	-	-	FIL TEMP	

Table 2.3.6.2*r*. UVS-P H-Cell Filament Selection Set

ITEM (XY:6F)		B0	B1	B2	B3	B4	B5	B6	B7
PM H FIL	1	-	-	-	-	-	-	H-CELL	
SEL SET	0	-	-	-	-	-	-	FIL SEL	

Table 2.3.6.2*s*. UVS-P D-Cell Filament Temperature Set

ITEM (XY:70)		B0	B1	B2	B3	B4	B5	B6	B7
PM D FIL	1	-	-	-	-	-	-	D-CELL	
TEMP SET	0	-	-	-	-	-	-	FIL TEMP	

Table 2.3.6.2*t*. UVS-P D-Cell Filament Selection Set

ITEM (XY:71)		B0	B1	B2	B3	B4	B5	B6	B7
PM D FIL	1	-	-	-	-	-	-	D-CELL	
SEL SET	0	-	-	-	-	-	-	FIL SEL	

2.3.6.2 Telemetry Items

Housekeeping Items

MPM bi-level housekeeping items are listed in Table 2.3.6.3. Analog housekeeping items for MPM aim at monitoring temperature of sensors, HV levels, and outputs of PSU. They are listed in Table 2.3.6.4.

Mission Data Format

T.B.D.

Table 2.3.6.3. MPM Bi-Level Housekeeping Items

S/S Name	Bit	Item	1	0
MPM1 (8000H)	B0	MPM ECC 2 BIT ERROR	ACT	NON
	B1	MPM ECC 1 BIT ERROR	ACT	NON
	B2	MPM ECC ENA/DIS	ENA	DIS
	B3	MPM HTR ENA/DIS	ENA	DIS
	B4	MPM WDT ERR	ACT	NON
	B5	MPM WDT ENA/DIS	ENA	DIS
	B6	MPM CPU RUN/RST	RUN	RST
	B7	MPM CPU ON/OFF	ON	OFF
MPM2 (F800H)	B0	MGF/PET ON/OFF	ON	OFF
	B1	MGF SENSE REV/NOR	REV	NOR
	B2	MGF RNG BC/AUTO	BC	AUTO
	B3	PET CAL ON/OFF	ON	OFF
	B4	UV HV ENA/DIS	ENA	DIS
	B5	UV HV ON/OFF	ON	OFF
	B6	PM HV ENA/DIS	ENA	DIS
	B7	PM HV ON/OFF	ON	OFF
MPM3 (F801H)	B0	UVS ON/OFF	ON	OFF
	B1	PM H FIL ON/OFF	ON	OFF
	B2	PM D FIL ON/OFF	ON	OFF
	B3	UV MCP GAIN1	↑	↓
	B4	UV MCP GAIN2	↑	↓
	B5	PM GAIN1	↑	↓
	B6	PM GAIN2	↑	↓
	B7	SPARE	-	-
MPM4 (F802H)	B0	UVS OBS MODE ID0	↑	↑
	B1	UVS OBS MODE ID1	↑	↑
	B2	UVS OBS MODE ID2	↑	↑
	B3	UVS OBS MODE ID3	↑	↑
	B4	UVS OBS MODE ID4	↑	↑
	B5	UVS OBS MODE ID5	↑	↑
	B6	UVS OBS MODE ID6	↑	↑
	B7	UVS OBS MODE ID7	↓	↓
MPM5 (F803H)	B0	MST STBY ON/OFF	ON	OFF
	B1	MST EXT MODE	EXT	-
	B2	MST RET MODE	RET	-
	B3	MST DRV ON/OFF	ON	OFF
	B4	MST HTR CONT ON/OFF	ON	OFF
	B5	MST RET	FULL	-
	B6	MST STRAP TNT ON/OFF	ON	OFF
	B7	MST OVLD	OVLD	-

Table 2.3.6.4. MPM Analog Housekeeping Items

S/S Name	Symbol	Item	Unit	MIN	MAX
MPMA1 (8010H)	MGF-E-T	MGF-E Temperature	°C	-60	+80
MPMA2 (8011H)	MGF-S-T	MGF-S Temperature	°C	-60	+80
MPMA3 (8012H)	PET-VF	PET-VF	V	TBD	TBD
MPMA4 (8013H)	MST-T	MST Motor Temperature	°C	-50	+80
MPMA5 (8014H)	UVS-G-T	UVS-G Temperature	°C	-50	+80
MPMA6 (8015H)	PM-H-T	H-Cell Temperature	°C	-50	+80
MPMA7 (8016H)	PM-D-T	D-Cell Temperature	°C	-50	+80
MPMA8 (8017H)	PM-T	UVS-P Temperature	°C	-50	+80
MPMA9 (8018H)	UV-MCP-HV	UVS-G MCP HV	V	0	TBD
MPMA10 (8019H)	PM-HV	UVS-P Photomultiplier HV	V	TBD	TBD
MPMA11 (801AH)	PM-H-FIL	H-Cell Filament Voltage	V	TBD	TBD
MPMA12 (801BH)	PM-D-FIL	D-Cell Filament Voltage	V	TBD	TBD
MPMA13 (801CH)	MPM +5V	MPM-PSU +5V	V	0	TBD
MPMA14 (801DH)	MPM +12V	MPM-PSU +12V	V	0	TBD
MPMA15 (801EH)	MPM -12V	MPM-PSU -12V	V	TBD	0
MPMA16 (801FH)	MPM +29V	MPM-PSU +29V	V	0	TBD

2.3.7 Particular Cares Required

Expected magnetic field intensity in the Mars environment is quite small (a few tens of nT), therefore, the MGF investigators have requested of other subsystems to take the following action in their design, that is to suppress stray magnetic field from each unit. The specifications and the design standard for magnetic field interference are given in Section 12.2 of this issue.

The UVS instrument has critical elements which should be taken particular cares in handling. The environmental and handling requirements are listed below.

- Surrounding humidity: < 50 %
- Purge of optics with high-purity N₂ gas until launch
- Removal of the caps at the end of the baffles of UVS-G and UVS-P as late as possible prior to launch
- Clean gloves used

2.3.8 Appendix : MGF Science Team

Principal Investigator :	Tatsundo Yamamoto	ISAS
Co-Investigator :	Ayako Matsuoka	ISAS
	Ryoichi Fujii	STE Laboratory, Nagoya University
	Susumu Kokubun	STE Laboratory, Nagoya University
	Kiyofumi Yumoto	STE Laboratory, Nagoya University
	Kazuo Shiokawa	STE Laboratory, Nagoya University
	Toshio Terasawa	University of Tokyo
	Takeshi Iijima	University of Tokyo
	Kanji Hayashi	University of Tokyo
	Masaru Kono	University of Tokyo
	Tomoko Nakagawa	Tohoku Institute of Technology
	Fumio Tohyama	Tokai University
	Yutaka Tonegawa	Tokai University
	Kiyoshi Maezawa	Nagoya University
	Tohru Araki	Kyoto University
	Toshihiko Iyemori	Kyoto University
	Toyohisa Kamei	Kyoto University
	Masahiko Takeda	Kyoto University
	Yoshimori Honkura	Tokyo Institute of Technology
	Tsugunobu Nagai	Tokyo Institute of Technology
	Masaki Matsushima	Tokyo Institute of Technology
	Ousuke Saka	Kyushu University
	Mario H. Acuña	NASA/GSFC

2.4 Mars Imaging Camera (MIC)

Principal Investigator :	Tadashi Mukai	Kobe University
Co-Investigator :	Tatsuaki Hashimoto	ISAS
	Akiko M. Nakamura	ISAS
	Susumu Sasaki	ISAS
	Jun'ichiro Kawaguchi	ISAS
	Jun'ichi Haruyama	ISAS
	Sho Sasaki	University of Tokyo
	Motomaro Shirao	The Planetary Geological Society of Japan
	Naoyuki Fujii	Nagoya University
	Kyosuke Iwasaki	Kyoto Gakuin University
	Tokuhide Akabane	Kyoto University
Manufacturer :	NEC Corporation	

2.4.1 Observation Objectives

The Mars Imaging Camera (MIC) aims to observe the global structure on the surface of Mars, the seasonal variation of meteorological phenomena of Mars and the shape and the surface structure of Phobos / Deimos as well as the predicted dust rings around Mars.

The scientific objectives of MIC are briefly summarized as

(1) geological objectives of Mars:

- The study of a wavelength dependence of the scattering properties of surface area, e.g. the bright areas (Arabia, Tharsis) and the dark areas (Syrtis Major, Aurora Sinus).
- The study of color variation in the rim of the polar caps.

(2) meteorological objectives of Mars:

- The study of transient meteorological phenomena, i.e. dynamics of clouds and dust storms, occurrence of haze and fog.
- The study of seasonal meteorological phenomena, i.e. growth and contraction of the polar caps.

(3) scientific objectives concerning Phobos / Deimos:

- The study of the shape and the surface structure of Phobos / Deimos, e.g. origin of the grooves on Phobos, a size/spatial distribution of craters on the surface of both satellites
- The search for the dust rings along the orbits of Phobos / Deimos

2.4.2 Instrument Specifications

2.4.2.1 Hardware Specifications

Since PLANET-B is a spin-stabilized spacecraft, MIC uses linear CCD aligned with elevation (i.e. perpendicular to spin) direction and scans azimuth (i.e. along spin) direction using spacecraft rotation. Hardware Specification of MIC is shown in Table 2.4.2-1.

MIC has three CCD which have different color filters.

Table 2.4.2-1 Hardware specifications of MIC

Optics	Aperture	21.4 mm
	Focal length	30 mm
	F number	F1.4
CCD	linear 3 color CCD (Kodak KLI-4103)	
	4104 pixels (only 2560 pixels are used)	
	Responsivity	RED 9 V/ μ J/cm ² @ 650 nm
		GREEN 8 V/ μ J/cm ² @ 550 nm
		BLUE 4 V/ μ J/cm ² @ 450 nm
	Pixel pitch	12 μ m
	Integration time	0.49 ms
Total Field Of View*	Azimuth	360 deg
	Elevation	54.2 deg
Pixel Resolution	Azimuth	79.1 arcsec @ 7.5 rpm
	Elevation	82.5 arcsec (center of FOV)
		73.4 arcsec (edge of FOV)
A/D conversion	8 bit, 6 MHz	
Image memory	1 MByte	
Image compression module	JPEG revision 5 algorithm	
	Compression range 3 to 100	
	Compression speed 4 Mpels/s @ 14 MHz	

* The total area among which an imaging area can be taken by commands.

2.4.2.3 Hardware functions

MIC can take a picture in every rotation of the spacecraft. To take a full-color picture, three rotations (about 24 sec) are required because MIC has only one electronics circuit. Before imaging, imaging parameters such as Color, Threshold, Ampgain, Image size must be sent to MIC.

MIC has a large FOV ($360 \text{ deg} \times 54.2 \text{ deg}$) and takes an image of designated area within it. Azimuth angle and width of an image are designated by commands as the start phase of the spacecraft rotation and the number of lines to be taken, respectively. Elevation angle and width of an image is designated by commands as the start pixel of imaging and the number of pixels to be taken, respectively. Size of an image can be selected from alternatives listed below.

Azimuth	256,	512,	1024	lines
	(5.62,	11.25,	22.5	deg @ 7.5rpm)
Elevation	256,	512,	1024	pixels
	(5.86,	11.7,	23.1	deg)

Start phase can be set at intervals of $2\pi/128 \text{ rad}$ ($= 2.8125 \text{ deg}$) and start pixel can be set at intervals of 128 pixels ($2.6 \sim 2.9 \text{ deg}$).

Alternatives to be chosen concerning color are:

RED, GREEN, BLUE, FULLCOLOR

When FULLCOLOR is selected, MIC takes RED, GREEN and BLUE pictures in consecutive three rotations.

Alternatives of Amp-gain are as follows:

LOW, NOMINAL, HIGH

While imaging, MIC converts output voltage of CCD into 8 bits digital signal with A/D converter and saves digital data into the image memory. After imaging, nominally ICM (Image Compression Module) is activated. It reads image data from the image memory, executes data compression, and writes compressed data to the image memory again. MIC has three operation modes concerning the usage of the image compression.

1. Store only compressed data. Original raw image data is deleted.
2. Store both compressed and original raw image data.
3. Store only raw image data, that is, ICM is not activated.

Both compressed and uncompressed images are stored in the image memory until telemetry mode becomes "MIC MODE". While "MIC MODE", images are sent to DHU (Data Handling Unit) through PIM (Peripheral Interface Module).

MIC has 4 hardware modes as follows:

a. Command Operation Mode

MIC takes images according to the imaging parameters which are set by commanding from ground or onboard software. MIC starts imaging from designated phase and pixel and stops imaging after designated size image has been taken. Then MIC sends INT-7 interrupt to SI-CPU.

b. Auto Operation Mode

In this mode, MIC detects a bright object and takes image of it automatically. That is, MIC searches a pixel which is brighter than the threshold level and takes image of neighborhood of the pixel (from -256 pixels to +256 pixels, from -5 lines to 506 lines). The size of the image is fixed to 512 pixels $\times$ 512 pixels. When imaging ends, MIC sends INT-7 interrupt to SI-CPU. If MIC can not find any bright object, it remains in this mode until MIC_STOP command is received.

c. Oneshot Mode

This mode is used for CCD test on ground. The image of 2560 pixels $\times$ 8 lines is taken by MIC_TAKE command and saved into the image memory. When imaging ends, MIC sends INT-7 interrupt to SI-CPU.

d. Endless Mode

This mode is used for CCD test on ground. CCD is driven by twice clock of PC (Phase Clock) signal until MIC_STOP command is received. No data are saved into the image memory in this mode. This mode ends by MIC_STOP command.

The state transition diagram of MIC hardware is shown in Fig.2.4.2-1.

2.4.2.4 Software functions

Software running on SI-CPU controls MIC hardware. It has two modes as follows:

A. Manual Mode

The software receives commands from DHU and transfers them to MIC hardware. The software has the capability of keeping commands cue, that is, to cope with limitation of DHU, it can hold some commands and send them to MIC at the proper instance.

B. Software— control Mode

The software traces a small body such as Phobos or Deimos using orbit estimation of them. The software detects the direction of the target by image processing, estimates the direction of it at the next spin, and generates proper commands to control MIC hardware.

In both modes, the software handles telemetry data. HK status of MIC is output through PIM in every telemetry mode. Image data is output only when MIC telemetry mode. The software also manages image memory. According to commands, it controls write and read pointer of memory access.

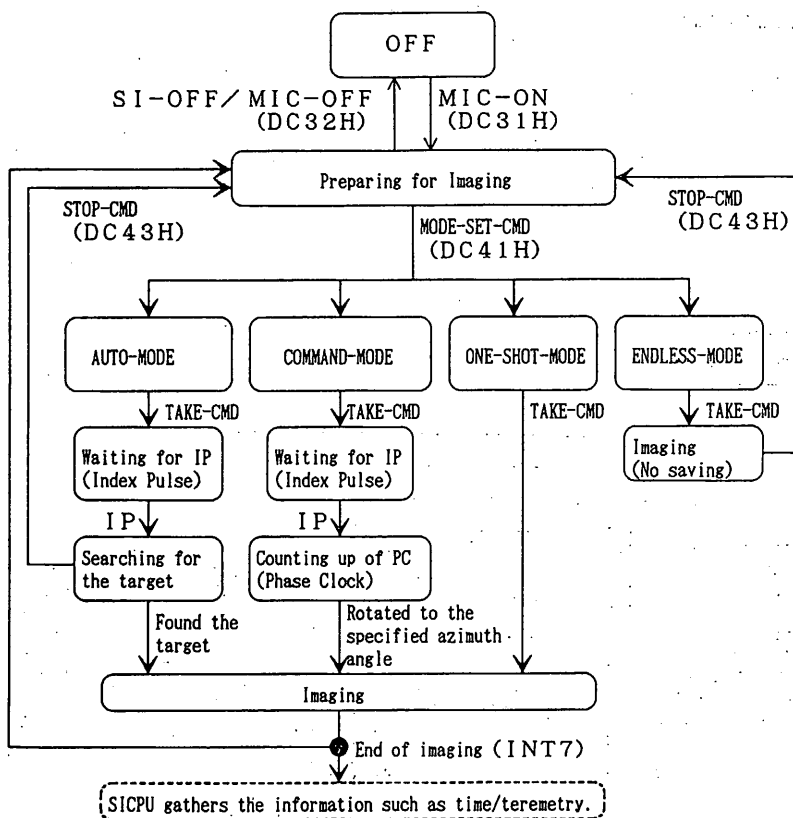


Fig.2.4.2-1 State transition diagram of MIC hardware

2.4.3 Instrument Configuration

MIC consists of

- 1) Optics : lens and hood
- 2) MIC-PWB : CCD drive electronics, Image memory, etc.
- 3) JPEG-PWB : Image compression module, etc.
- 4) SICPU-PWB : CPU for command and telemetry handling
including PIM interface
- 5) PSU : power circuits and interface with spacecraft system

PWB : Print Wiring Board

Configuration of MIC is shown in Fig.2.4.3-1.

2.4.3.1 Optics

Optics consists of radiation hardened lens system, a tri-linear CCD image sensor, and their support assembly.

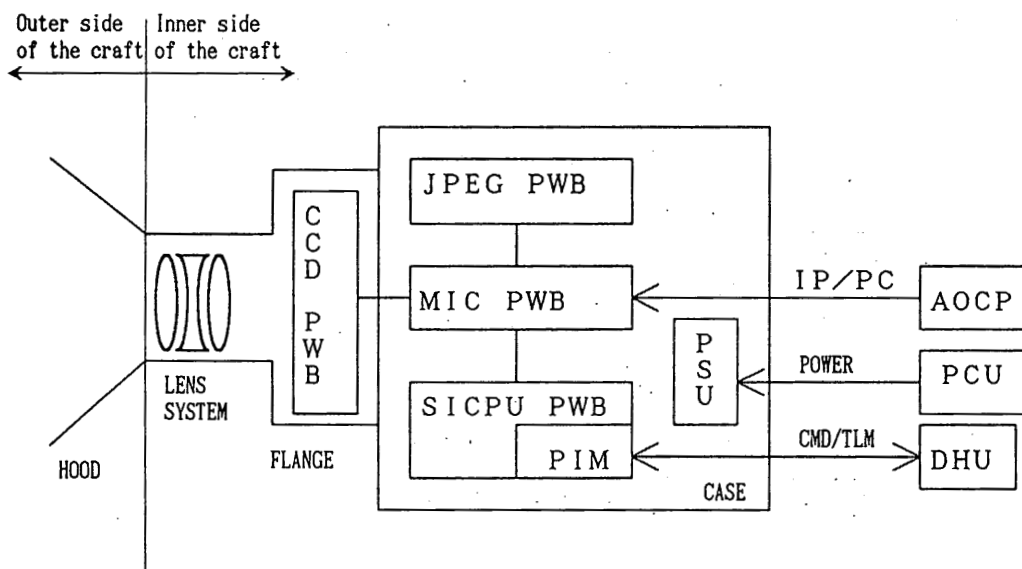


Fig.2.4.3-1 Configuration of MIC

2.4.3.2 MIC-PWB

MIC-PWB is the main electronics circuits of MIC. It controls the tri-linear CCD, derives output voltage of CCD, performs A/D conversion, and saves digitalized image data in the image memory. The block diagram of it is shown in Fig.2.4.3-2.

The multiplexer chooses one among the three output signals generated from RED, GREEN, and BLUE CCD, respectively. The field through level of this signal is clumped to the desirable level in order to avoid the fluctuation of the offset level. Then, the signal is converted to 8 bits digital signal by A/D converter and saved in FIFO (First In First Out) memory. The data select controller chooses the data of specified pixels, and transfers them from FIFO to the image memory.

As a result, data from CCD is written in the memory directly in quasi real time. The memory consists of 1 MByte SRAM and the capacity of it corresponds to a 1024×1024 pixels image.

After whole image is taken, the data in the memory are read out and transferred to ICM (Image Compression Module) on JPEG-PWB. Output of ICM is rewritten to the same memory.

2.4.3.3 JPEG-PWB

JPEG-PWB consists of ICM and other peripheral circuits. ICM is supplied by CNES (Centre National d'Etudes Spatiales) under international cooperation. It uses JPEG revision 5 which is a standard non-reversible compression algorithm. Compression rate is expected from one third to twentieth. Maximum data conversion rate is 4 M pels/s and it achieves compression speed of 0.25 sec / 1Mbyte. Block diagram of JPEG-PWB is shown in Fig.2.4.3-3.

2.4.3.4 SICPU-PWB

SICPU-PWB is a standard CPU board developed for scientific instruments of PLANET-B spacecraft. It consists of a CPU (i80C86 8MHz), 512 kbytes SRAM with ECC, Programmable Timer, Interrupt Controller, PIM (Peripheral Interface Module) which is used to communicate with DHU, 2 kbytes Dual Port RAM which is used for data transmission between CPU and PIM, and other peripherals.

Software on SI-CPU performs camera control, management of the image memory, command and telemetry handling, and also estimation of the orbit of a target in Software-control Mode.

Block diagram of SICPU-PWB is shown in Fig.2.4.3-4.

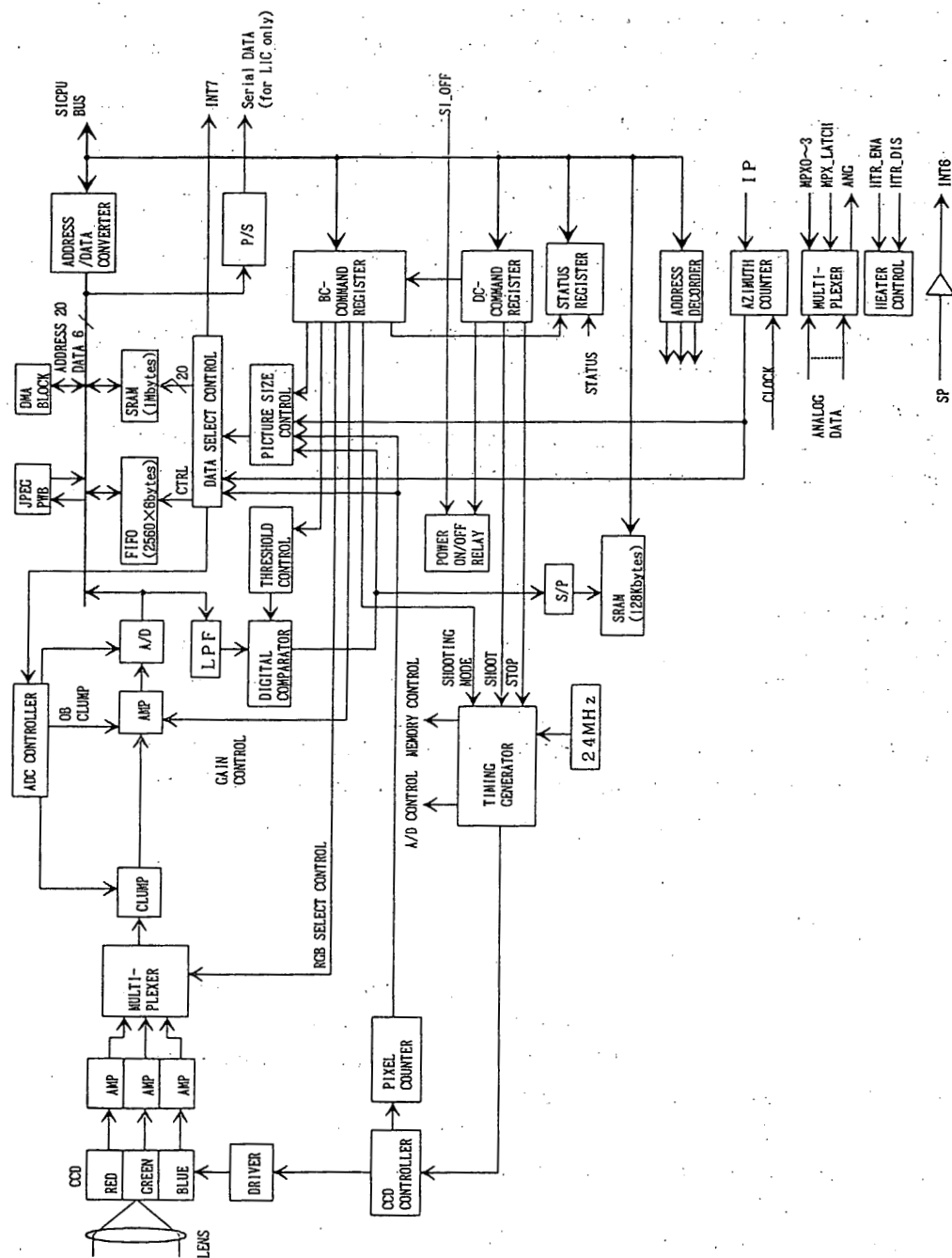


Fig.2.4.3-2 Block diagram of MIC-PWB

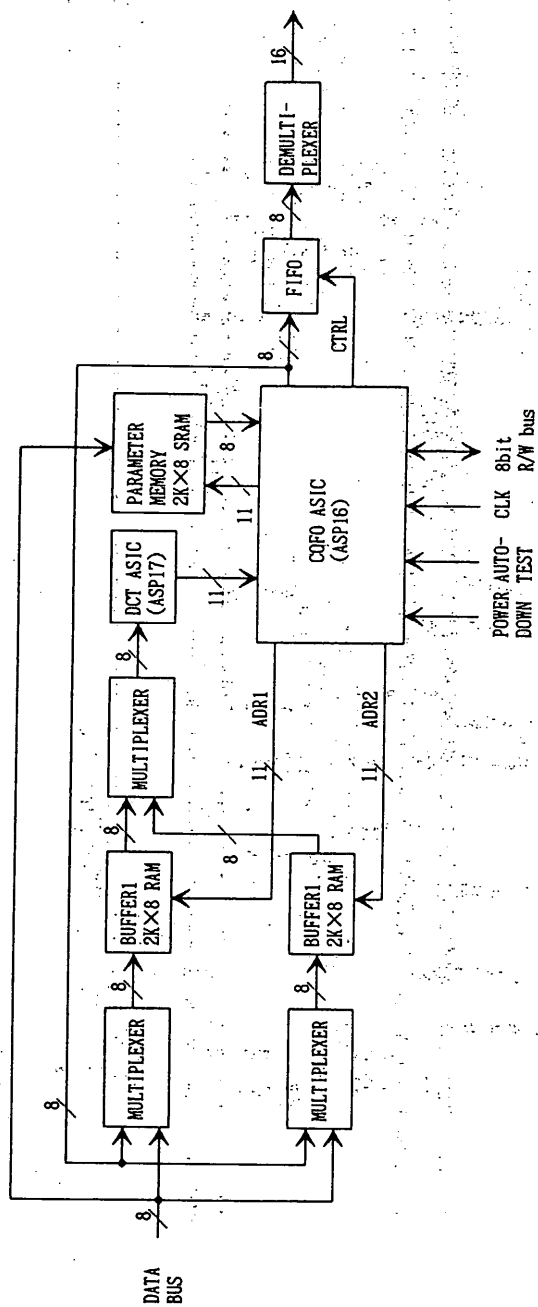


Fig.2.4.3-3 Block diagram of JPEG-PWB

2.4.4 Operation

MIC has several hardware and software modes to meet various mission objectives. They are summarized in Table 2.4.4-1.

Table 2.4.4-1 Modes of MIC

Mission Objectives	Software Mode	Hardware Mode
Mars Geological Observation	Manual	Command Operation
Mars Meteorological Observation	Manual	Command Operation Auto Operation
Mars Dust storm Observation	Manual	Command Operation
Phobos/Deimos Encounter	Manual Soft Control	Auto Operation Command Operation
Dust ring search	Manual	Command Operation
Flight calibration	Manual	Command Operation
Ground test	TBD TBD	Oneshot Endless

2.4.5 Size, Weight, and Power Consumption

Size ($W \times D \times H$: mm) $92 \times 150 \times 235$
excluding hood, connectors and cables

Weight $2.0 \text{ kg} \pm 0.5 \text{ kg}$

Power consumption

CPU— on Stand— by 3.4 W MAX
(only CPU, Image memory, ICM and other digital circuits on)

CCD— on Stand— by 13.2 W MAX
(also CCD driver, A/D converter and other analog circuits on)

While Imaging 15.7 W

While Image compressing 15.3 W

2.4.6 Command and Telemetry Items

2.4.6.1 Command Items

Discrete Commands to PIM

(For PIM only.)

X	Y	COMMAND NAME	FUNCTION
0	1	MIC_CPU_ON	Refer to "DHU user's manual" (PLANET-B-0409)
0	2	MIC_CPU_OFF	
0	3		
0	4	MIC_MCRP_OUT	
0	5	MIC_REQ_ACK	
0	6	MIC_TI_CNT_SET	
0	7	MIC_TI_CNT_RESTART	
0	8	MIC_A-BUS_GUARD	
0	9	MIC_B-BUS GUARD	
0	A	MIC_AG_CANCEL	
0	B	MIC_BG_CANCEL	

Discrete Commands to SI-CPU

(SICPU ADDRESS : 4 F E 0 0 H)

X	Y	COMMAND NAME	FUNCTION
1	0	MIC_HTR_ENA	- With this command, SICPU sends the pulse command (30~34ms / logic level) to MIC-PWB. - With this pulse command, MIC-PWB makes the relay closed, and enables the heater control by CPU.
1	1	MIC_HTR_DIS	- With this command, SICPU sends the pulse command (30~34ms / logic level) to MIC-PWB. - With this pulse command, MIC-PWB makes the relay opened, and disables the heater control by CPU.
1	2	MIC_ECC_ENA	- Enable the ECC (Error Check Code) for the SRAM in SICPU. - Clear the ECC error flag.
1	3	MIC_ECC_DIS	Disable the ECC for the SRAM in SICPU
1	4	MIC_WDT_ENA	- Enable the WDT(Watch Dog Timer) in SICPU - Clear the WDT error flag in SICPU.
1	5	MIC_WDT_DIS	Disable the WDT in SICPU.
1	6	MIC_CPU_RUN	- Make the CPU running. - CPU becomes to control MIC-PWB.
1	7	MIC_CPU_RESET	- Generate NMI (Non Maskable Interrupt) to CPU. 4 seconds later, "SI-OFF command" is sent to MIC-PWB, and CPU becomes to be reset.
2	0	MIC_BUS_ACS_ENA	Connect PIM-bus and CPU-bus.
2	1	MIC_BUS_ACS_DIS	Disconnect PIM-bus and CPU-bus.

Discrete Commands to MIC hardware

(SICPU ADDRESS: 4 F E 0 0 H) → (MIC ADDRESS: 5 0 0 0 0 H)

X	Y	COMMAND NAME	FUNCTION
3	1	MIC_CCD_ON	• Supply the power to CCD and analog circuits of MIC.
3	2	MIC_CCD_OFF	• Shut off the power of CCD and analog circuits of MIC.
4	1	MIC_MODE_SET	• Specify the parameter of taking a picture followed by BC commands
4	2	MIC_TAKE	• Start taking a picture after receiving the IP (Index Pulse) and the direction of the MIC becomes as specified.
4	3	MIC_STOP	• Stop taking a picture in the case of ENDLESS-MODE. • Stop searching for the target in the case of AUTO-MODE.
4	4	MIC_SRCH_AREA_SET	• Specify the search area of AUTO-MODE followed by BC commands.

Discrete Commands to MIC software

(SICPU ADDRESS: 4 F E 0 0 H)

X	Y	COMMAND NAME	FUNCTION
2	2	MODE_CHANGE	• Specify the new format and bit-rate of telemetry followed by BC commands
5	1	MIC_SOFT_MODE	• Change the mode of software followed by BC commands.
5	2	MIC_TRK_PARAM	• Specify the parameter of SOFT-CONTROL-MODE followed by BC commands.
5	3	MIC_TRK_START	• Start the SOFT-CONTROL-MODE and track the target.

Block Commands

BC set command MODE_CHANGE(22H)

Number of BC 3 Bytes

(SICPU ADDRESS : 4 F E 0 1 H)

First byte	B 0	B 1	B 2	B 3	B 4	B 5	B 6	B 7
<Contents> Telemetry format	Not used (Set to 0)			Format No. ← MSB LSB 00H: No. 00 1FH: No. 31				

(SICPU ADDRESS : 4 F E 0 2 H)

Second byte	B 0	B 1	B 2	B 3	B 4	B 5	B 6	B 7
<Contents> Rate of telemetry gathering	Not used (Set to 0)			Bit rate of telemetry ← MSB LSB 3H: 64bps DH: 65536bps				

(SICPU ADDRESS : 4 F E 0 3 H)

Third byte	B 0	B 1	B 2	B 3	B 4	B 5	B 6	B 7
<Contents> Rate of downlink telemetry	Bit-rate of X-band ← 8H: 2048bps CH: 32768bps				Bit-rate of S band ← 3H: 64bps 7H: 1024bps			

BC set command MIC MODE SET(41H)

Number of BC 5 Bytes

(SICPU ADDRESS : 4 F E 0 1 H) → (MIC ADDRESS : 5 0 0 0 1 H)

First byte	B 0	B 1	B 2	B 3	B 4	B 5	B 6	B 7
< Contents > Parameters for taking a picture	Color		Threshold		AMP-gain		Mode	
	←-----→		←-----→		←-----→		←-----→	
	MSB	LSB	MSB	LSB	MSB	LSB	MSB	LSB
	00: RED		00: LEVEL0		00: LOW		00: AUTO	
	01: GREEN		01: LEVEL1		01: Nominal		01: COMMAND	
	10: BLUE		10: LEVEL2		10: High		10: ONESHOT	
	11: RGB		11: -		11: -		11: ENDLESS	

(SICPU ADDRESS : 4 F E 0 2 H) → (MIC ADDRESS : 5 0 0 0 2 H)

Second byte	B 0	B 1	B 2	B 3	B 4	B 5	B 6	B 7
< Contents > Size of a picture	Elevation angle(pixel)				Azimuth angle (line)			
	←-----→				←-----→			
	MSB		LSB		MSB		LSB	
	0001: 256				0110:1536			
	0010: 512				1000:2048			
	0100:1024				0000:2560pixels or 8lines			

(SICPU ADDRESS : 4 F E 0 3 H) → (MIC ADDRESS : 5 0 0 0 3 H)

Third byte	B 0	B 1	B 2	B 3	B 4	B 5	B 6	B 7
< Contents > Azimuth angle to start taking a picture	Not used	Start angle (line)						
		←-----→						
		MSB	01H:	1×128 =	128line	LSB		
			7FH:	127×128 =	16256line			
			00H:	128×128 =	16384line			

(SICPU ADDRESS : 4 F E 0 4 H) → (MIC ADDRESS : 5 0 0 0 4 H)

Fourth byte	B 0	B 1	B 2	B 3	B 4	B 5	B 6	B 7
< Contents > Elevation angle to start taking a picture	Not used			Start pixel				
				←-----→				
				MSB				LSB
				00H:	0×128 =	0pixel		
				12H:	18×128 =	2304pixel		

(SICPU ADDRESS: 4 F E 0 5 H)

Fifth byte	B 0	B 1	B 2	B 3	B 4	B 5	B 6	B 7
< Contents > Parameters for the compression of images	Scale factor ← MSB LSB →				(*1) ← MSB LSB →		NLS	MAL- GO

- *1: 00: Compress the image data and delete the raw data.
 01: Compress the image data and don't delete the raw data.
 10: Don't compress the image data.

[illegible]

Third byte	B 0	B 1	B 2	B 3	B 4	B 5	B 6	B 7

<Contents>		Start angle (line)	
azimuth angle	Not	← MSB	→ LSB
to start searching	used	01H: $1 \times 128 = 128$ line	
		7FH: $127 \times 128 = 16256$ line	
		00H: $128 \times 128 = 16384$ line	

Third byte	B 0	B 1	B 2	B 3	B 4	B 5	B 6	B 7

[illegible]

Fourth byte	B 0	B 1	B 2	B 3	B 4	B 5	B 6	B 7

< Contents > levation angle o start searching	Not used	Start pixel ←──────────────────→ MSB LSB 00H: 0 × 128 = 0pixel 12H: 18 × 128 = 2304pixel

Fourth byte	B 0	B 1	B 2	B 3	B 4	B 5	B 6	B 7

< Contents > levation angle o stop searching	Not used	Stop pixel $\longleftrightarrow$ MSB LSB 00H: $0 \times 128 = 0\text{pixel}$ 12H: $18 \times 128 = 2304\text{pixel}$

BC set command MIC SOFT MODE(51H) Number of BC 1-Byte

(SICPU ADDRESS : 4 F E 0 1 H)

First byte	B 0	B 1	B 2	B 3	B 4	B 5	B 6	B 7
< Contents > Mode of software	To Be Determined							

BC set command MIC TRK PARAM(52H) Number of BC 5 Bytes

(SICPU ADDRESS : 4 F E 0 1 H)

First byte	B 0	B 1	B 2	B 3	B 4	B 5	B 6	B 7
< Contents > Parameters for software tracking	To Be Determined							

(SICPU ADDRESS : 4 F E 0 2 H)

Second byte	B 0	B 1	B 2	B 3	B 4	B 5	B 6	B 7
< Contents > Parameters for software tracking	To Be Determined							

(SICPU ADDRESS : 4 F E 0 3 H)

Third byte	B 0	B 1	B 2	B 3	B 4	B 5	B 6	B 7
< Contents > Parameters for software tracking	To Be Determined							

(SICPU ADDRESS : 4 F E 0 4 H)

Fourth byte	B 0	B 1	B 2	B 3	B 4	B 5	B 6	B 7
< Contents > Parameters for software tracking	To Be Determined							

(SICPU ADDRESS : 4 F E 0 5 H)

Fifth byte	B 0	B 1	B 2	B 3	B 4	B 5	B 6	B 7
< Contents > Parameters for software tracking	To Be Determined							

2.4.6.2 Telemetry Items

Status of MIC and analog HK items are output in HK packet. Image data including imaging parameters is output in MIC packet which can be output only when telemetry mode is "MIC MODE".

Bilevel status data of MIC

Address (Hex)	S/S NAME	Bit	ITEMS	STATUS	
				1	0
8000	MIC1	B0	CPU ON/OFF	ON	OFF
		B1	CPU RUN/RESET	RUN	RESET
		B2	WDT ENA/DIS	ENA	DIS
		B3	WDT ERR	ERROR	NO ERROR
		B4	HTR CNT ENA/DIS	ENA	DIS
		B5	ECC ENA/DIS	ENA	DIS
		B6	ECC 1BIT ERR	ERROR	NO ERROR
		B7	ECC 2BIT ERR	ERROR	NO ERROR
F800	MIC2	B0	MIC_CCD PWR ON/OFF	ON	OFF
		B1	Software Mode	To Be Determined	
		B2			
		B3	Parameters for Image Compression	To Be Determined	
		B4			
		B5	Waiting for IP	ON	OFF
		B6	Searching for a target	ON	OFF
		B7	Taking a picture	ON	OFF

Address (Hex)	S/S NAME	Bit	ITEMS	STATUS	
				1	0
F801	MIC3	B0	Hardware Mode	B1B0	
		B1		0 0 : AUTO MODE 0 1 : COMMAND MODE 1 0 : ONESHOT MODE 1 1 : ENDLESS MODE	
		B2	AMP gain	B3B2	
		B3		0 0 : LOW 0 1 : NOMINAL 1 0 : HIGH 1 1 : Not used	
		B4	Threshold	B5B4	
		B5		0 0 : Level0 0 1 : Level1 1 0 : Level2 1 1 : Not used	
		B6	Color	B7B6	
		B7		0 0 : RED 0 1 : GREEN 1 0 : BLUE 1 1 : FULL COLOR	
F802	MIC4	B0	Azimuth	B3B2B1B0	
		B1	Size of a picture	0 0 0 1 : 256 lines	
		B2		0 0 1 0 : 512 lines	
		B3		0 1 0 0 : 1024 lines	
				0 1 1 0 : Not used	
				1 0 0 0 : Not used	
				0 0 0 0 : 8 lines	
		B4	Elevation	B7B6B5B4	
		B5	Size of a picture	0 0 0 1 : 256 pixels	
		B6		0 0 1 0 : 512 pixels	
				0 1 0 0 : 1024 pixels	
				0 1 1 0 : Not used	
				1 0 0 0 : Not used	
		B7		0 0 0 0 : 2560 pixels	

Address (Hex)	S/S NAME	Bit	ITEMS	STATUS	
				1	0
F803	MIC5	B0	Azimuth angle (line) to start taking a picture	01 H : 64 line ↓ 7F H : 8128 line 00 H : 8192 line	
		B1			
		B2			
		B3			
		B4			
		B5			
		B6			
		B7	Not used	Fixed to 0	
F804	MIC6	B0	Elevation angle (pixel) to start taking a picture	00 H : 0 pixel ↓ 12 H : 2304 pixel	
		B1			
		B2			
		B3			
		B4	Not used	Fixed to 0	
		B5			
		B6			
		B7			
		B6	Unknown command (Software)	ERROR	NO ERROR
		B7	Unknown command (Hardware)	ERROR	NO ERROR

Analog HK items of MIC

WORD	ADDRESS (HEX)	ITEM	UNIT	RANGE	CONVERSION SYSTEM
382	8010	LENS-T	°C	-50~+80	
383	8011	T. B. D.			
384	8012	T. B. D.			
385	8013	T. B. D.			
386	8014	T. B. D.			
387	8015	T. B. D.			
388	8016	T. B. D.			
389	8017	MIC+5V	V	0~+15	
390	8018	MIC+12V	V	-15~0	
391	8019	MIC-12V	V	0~+6	
392	801A	T. B. D.			
393	801B	T. B. D.			

Telemetry format of MIC packet

Transfer Frame (512 bytes)

Sync. Code	Transfer Frame Header	Packet Header	User Data	CLCW Data	Reed Solomon
4 bytes	6 bytes	4 bytes	432 bytes	2 Byte	64 bytes

- Format for compressed image data (output of ICM)

1st packet

Secondary Header	Picture Header	GOB 0	GOB 1	.....	GOB 21
4 bytes	32 bytes	18 bytes	18 bytes		18 bytes

GOB : Group of Block

2 bytes GOB Header

16 bytes Compressed image data

2nd ~ [last-1] packet

Secondary Header	GOB m	GOB m+1	.....	GOB m+22	Dummy
4 bytes	18 bytes	18 bytes		18 bytes	14 bytes

last packet

Secondary Header	GOB p	.....	GOB p+q	Dummy
4 bytes	18 bytes		18 bytes	410-18q bytes

- Format for uncompressed image data (raw image data)

1st packet

Secondary Header 4 bytes	Picture Header 32 bytes	Raw image data 396 bytes

2nd ~ [last-1] packet

Secondary Header 4 bytes	Raw image data 428 bytes

last packet

Secondary Header 4 bytes	Raw image data r bytes	Dummy 428-r bytes

2.5 Thermal Plasma Analyzer (TPA)

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CRL, Tokyo

Hokkaido Institute of Information
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ISAS

Aoyama Gakuin University

Instrument Team

Principal Contractor : COM DEV

Subcontractors : CAL

Pakwa

Amptek

Epitek

Sensor Assembly, Instrument Software
power and Controller Unit Hardware

Boom, Cradle and Strap

High Voltage Power Supply

Charge Amplifier Card

Anode

2.5.1 Observation Objectives

The thermal (cold) or lowest energy components of the Martian magnetospheric plasmas play important, if not dominant, roles in the interactions between the neutral atmosphere, ionosphere, magnetosphere and solar wind. Indeed, the cold plasma characteristics are usually the starting point for all macroscopic and microscopic theories of plasma interactions and charged particle acceleration. We present below specific examples of such interactions and accent the role the thermal plasma plays in the processes.

2.5.1.1 Martian Ionosphere

The dynamics and composition of the Martian ionosphere and even the magnitude of the magnetic moment of the planet are the subject of considerable interest and debate, mainly due to the scarcity of in-situ observations. The PLANET-B orbit, with periapsis at 130 km, provides an excellent opportunity to rectify this situation.

Results from the Viking landers are in (approximate) agreement with current models of the day-side ionosphere of Mars which indicate that O_2^+ and CO_2^+ are the dominant ions near 130 km and that at higher altitudes (> 300 km) O^+ and then H^+ becomes the major ion. Densities in the Martian ionosphere peak near 130 km at values similar to those on Earth ($\sim 10^5 \text{ cm}^{-3}$) and the temperature profiles are also similar with $T_i \approx 150 \text{ }^\circ\text{K}$ near the density peak and increasing rapidly to several thousand degrees at 300 km.

Bulk plasma motions (drifts), along with (possible) night-side energetic particle precipitation, are believed to be responsible for the maintenance (or lack thereof) of the Martian night-side ionosphere. Ionospheric plasma transport, from the day-side to the night-side, is dependent on the magnitude of the Martian intrinsic magnetic field as well as solar wind conditions. At times these sources are inadequate to maintain the night-side ionospheric densities above the limit of detectability for radio occultation techniques. The PLANET-B orbit should provide the Thermal Plasma Analyzer with an excellent chance to directly observe, for the first time, the composition and dynamics of the Martian Ionosphere.

Particle heating and energization at the interface between the Martian ionosphere and magnetosphere is also of significant scientific interest. The cold ionospheric plasma, through collisions with neutral atmosphere, tends to anchor magnetic field lines to the neutrals. This effect, often referred to as "line tying", produces, in the presence of convection electric fields, magnetospheric current systems which are to a great degree carried by the cold plasma (electrons). These currents in turn generate instabilities, plasma waves and cold ionospheric plasma heating, which tends to release the convection induced magnetic stress and accelerate the cold ions. Similarly, down-flowing, hot magnetospheric plasma may also be unstable and generate plasma waves which strongly heat the local cold plasma. These plasma heating (energization) effects, many of which are expected to be operative in the Martian high altitude ionosphere, lead to rapid adiabatic expansion and flow away from the ionosphere and eventually to loss to interplanetary space. These loss processes are important to terrestrial magnetospheric modeling but are not of major importance from a cosmogonical standpoint. Signatures of similar ion heating effects in the Martian ionosphere and enhanced ion outflows have also been reported. In these cases the flows are large enough to be a major factor in the evolution of the Martian atmosphere.

Another particle acceleration process unique to planets with little or no intrinsic magnetic field is the "pick up" process which results when neutrals in the planetary exosphere populate the magnetosheath region. These neutrals may be photo-ionized or ionized by charge exchange and "picked up" in the plasmasheath flow in a fashion similar to that near cometary nuclei. The end result is the production of energetic (keV) ion fluxes in the Martian magnetotail. The study of thermal plasma role in all these particle acceleration and loss processes will be one of the major TPA science goals.

2.5.1.2 Magnetosphere and Bow Shock

The solar wind interaction with the Martian magnetosphere is very different from that at earth. Because of the weak planetary magnetic field and low atmospheric pres-

sure, the bow shock occurs only a few thousand kilometers upstream of Mars at the sub-solar point. Both the shock foot (the precursor to the shock) and the magnetosheath have dimensions of the order of a solar wind ion gyro-diameter (~ 1000 km); therefore, the shocked solar wind plasma in the magnetosheath can interact directly with the ionospheric particles. This interaction is similar to that at Venus but has no analogue in the terrestrial environment.

The PLANET-B orbit is well suited to studies of the Martian bow shock. The TPA energy range will however be limited to a few hundred eV; therefore, only the electron component of the hot magnetosheath and solar wind plasma will be adequately covered by TPA measurements. Typical ion energies in these regions are 500 eV. Of interest here is the study of the microstructure of the bow shock, turbulent heating in the shock and scale sizes for these processes. The TPA will be capable of much higher temporal resolution observations than any previous spacecraft and should provide interesting new information on planetary shocks.

The magnetosheath is dominated by shocked, anti-sunward flowing solar wind plasma and the low-altitude ionosphere is composed mostly of stationary (in the planet frame) heavy ions. The interactions of these two vastly different plasma regimes leads to: the formation of a magnetotail and large out-flows of heated planetary ions and electrons, ionospheric and magnetotail plasma depletions, and (perhaps) large scale plasma energization processes similar to those in the terrestrial magnetosphere. The exact nature of the structure and plasma interactions in the transition region between the magnetosheath and ionosphere is poorly understood. Therefore, the PLANET-B orbit, with periapsis at 130 km, was selected to allow for detailed studies of this region as well as the cold Martian ionospheric plasma.

The terrestrial magnetosheath is the site of one of the most interesting and perhaps the most controversial plasma processes proposed for the conversion of magnetic field energy to particle kinetic energy; reconnection. Plasma flow and energization near reconnection (x-type) neutral lines have been studied extensively. However, the physics of these regions, which apparently is common to many astrophysical objects, is yet to be fully understood. The cold plasma of ionospheric origin, which populates the terrestrial as well as the Martian magnetosheath along with solar wind particles, serves as an excellent diagnostic tool to trace electric and magnetic field geometries in the reconnection region and may at times serve as a major sink for energy released by the mechanism.

If Mars has a small intrinsic magnetic moment, reconnection with the solar wind magnetic field lines may occur causing, among other things, Martian substorms. The recurrence time-scales for these events will, however, be significantly shorter than on earth (approximately six minutes). The high conductance of the Martian ionosphere will short-out any convection electric field in the ionosphere, leading to highly stressed magnetic field configurations above the ionosphere and in the Martian magnetospheric tail. Shearing or tearing of magnetic field lines may allow for a decoupling of magnetospheric convection from the "line-tied" ionospheric field lines. This implies a large energy dissipation in or near the ionosphere and large outflows of energetic plasma into the magnetospheric tail. The PLANET-B apoapsis of $15 R_M$ is ideally suited to studies of these Martian magnetotail phenomena. The PLANET-B mission, therefore, provides an opportunity to study, under conditions different than those in the terrestrial environment, many of the important plasma processes which are apparently common to many astrophysical objects.

2.5.1.3 Solar Wind and Martian Moons

Two other targets of opportunity are presented by the PLANET-B mission. Firstly, the spacecraft will spend a substantial fraction of time in the solar wind, which presents the team with an opportunity to study the micro-structure of the solar wind plasma. Typical energies (temperatures) here are tens of eV for electrons, which falls within the TPA energy bandwidth, and hundreds of eV to keV for solar wind ions, which is well in excess of the TPA upper energy limit. The small scale (high-frequency) observations will provide a unique data set for the study of energy and momentum flow in the solar wind, for the investigation of plasma waves and turbulence in interplanetary medium and for the analysis of interplanetary shocks structures.

The second targets of opportunity are the plasma perturbations associated with the Martian moons, Phobos and Deimos. Enhancements in the local plasma density and ion temperature consistent with the existence of a "plasma torus" along the Phobos orbit have been reported. This torus is presumed to originate when the trail of neutrals, off-gassed from the Martian moons, interacts with the solar wind in a manner similar to that observed near comets. The PLANET-B orbit is expected to intersect the Martian moon orbits and should provide many opportunities for studies of these interesting plasma phenomena.

2.5.2 TPA Instrument Characteristics

Particles Detected	: Electron and Ions
Energy Resolution	: $\Delta E/E = 0.1$
Mass Resolution	: $\Delta M/M = 0.2/\sqrt{M}$
Angular Resolution	
Azimuth	: $\Delta\theta = 0.39$ radians (22.5°)
Elevation	: $\Delta\phi = 0.05$ radians (2.86°)
Temporal Resolution	
Complete 3-D Distribution	: 1/2 spin period (4 s)
Parameterized Distribution	: 0.01 seconds

where:

- E and M are the particle energy and mass
- θ and ϕ are azimuth and elevation angles of arrival of the particles at the Sensor.

The Sensor dynamic range is defined as follows:

Energy per charge	$0.05 < E/Q < 200V$
Field-of-View	4π (using satellite spin)
Density (n)	$10^{-3} < n < 10^5 \text{ cm}^{-3}$
Temperature (T)	$0.05 < T < 100 \text{ eV}$
Drift Velocity (V)	
Ions	: $0.1 < |V| < 200 / \sqrt{M} \text{ km/s}$
Electrons	: $1.0 < |V| < 10^4 \text{ km/s}$

Maximum resolution in energy and angle will be achieved by varying the Sensor electrode potentials and by utilizing satellite spin.

2.5.3 Instrument Configuration

The TPA instrument is shown in Figure 2.5.3-1.

2.5.3.1 TPA-S

2.5.3.1.1 Sensor Assemble (TPA-S-A)

The TPA-S-A (sensor Assembly) conducts plasma measurements under the supervision of the TPA-E (power and Controller Unit).

TPA-S-A (Sensor) includes the following:

- Sensor Enclosure
- Heater and temperature Control Circuit
- Boom Adapter Piece
- Inboard Electronics Module
 - TPA-S-A Bulkhead Adapter Board
 - Digital Interface Card
 - Telemetry Thermistor
 - VTF Voltage Switching Card
- Ion Optics Subassembly
 - Hemispherical Electrostatic Analyzer (HEA)
- Detector Subassembly
 - Anode Sub-assembly
 - Detector Interface Board
- Outboard Electronics
 - Charge Amplifier Circuit
 - High Voltage Filter Board
- Outboard Radiator Plate

The major characteristics of the Sensor (TPA-S-A) are defined as follows:

- Orientation : Co-linear with Boom (TPA-S-B)
- Length : 125 mm
- Diameter : 105 mm
- Rotational distortion : $\leq 1^\circ$
- Elevation Field of View : $\pm 45^\circ$
- Event detection rate : $\leq 10^6$ events / second
- FIFO storage : ≤ 512 events (single FIFO IC)
- Implements precision medium and high voltages for ion optics and detector sub-assemblies
- Controls Time-Of-Flight gate rate and duty cycle
- Supports TPA diagnostic tests on TPA-S-A
- Supports data transfer to/from TPA-E at up to 5 Mbps

2.5.3.1.2 Boom (TPA-S-B)

This summarizes the design baseline for the TPA boom:

General

Distance from satellite wall to Sensor entrance slit : 1.0 meters

Mounting location : Center on satellite side panel #5

Angle at which inboard boom segment is released : 30°

Thermal mass : $325 \text{ J}^\circ\text{C}$

Forces at Sensor

Along boom axis : $\leq 15\text{g}$

Direction of deployment : $\leq 15\text{g}$

Well

Material : Aluminum

K_{WELL} : 160 N-m / rad.

Boom segments

Material : Carbon Fiber reinforced Plastic (from ACPT)

Filament winding angle : TBD

Diameter : 1.4 inches within 100 mm of shoulder hinge
1.102 inches (28 mm) elsewhere

EI : $500 \text{ N-m}^2 \pm 20\%$

Thermal Conductivity

Axial : TBD

Radial : TBD

Plating

Layer 1 (inner) : Electroless copper

Layer 2 : Plated silver (0.0005 inches)

Surface finish : 75 % rhodium, 25 % Aquadag

Emissivity : 0.25

Absorptivity : 0.43

Shoulder hinge

Diameter : 1.4 inches

Thickness : 0.005 inches

Gap width : 2°

Buckling moment : 70 N-m^2

Maximum deployment moment : 40 N-m^2

K_{SHOULDER} : 1550 N-m / rad.

Elbow hinge

Diameter : 1.102 inches (28 mm)

Thickness : 0.005 inches

Gap width : 7°

Buckling moment : 30 N-m^2

Maximum deployment moment : TBD

K_{ELBOW} : TBD N-m / rad.

Boom cables

Cable length : 2.0 meters

High voltage cables : Four coaxial high voltage cables with
common outer insulation (from
CALMONT, NASA-, CPA-heritage)

Medium Voltage cable : Flexprint, stripline format, HV_RTN on one layer, signals on the other

Thickness : 0.020 inches

Width : 0.90 inches

Boom cables

Logic cable : Flexprint, stripline format, grounds on one layer

Thickness : 0.017 inches

Width : 0.75 inches

Stiffness : ≤ 0.5 N-m for entire cable bundle

2.5.3.1.3 Cradle and Strap (TPA-S-C)

This summarizes the design baseline for the TPA Cradle and Strap:

Cradle

Length : 152 mm

Width : 115 mm

Height

Top-to-Bottom (Sensor installed) : 225 mm

Outside side panel : 125 mm

Material : Magnesium

Surface finish : Chemglaze L-300

Emissivity : 0.80 estimated (to be measured)

Absorptivity : 0.92 estimated (to be measured)

Thermal mass : 150 J/°C

Strap

Material : Beryllium copper

Surface finish : Chemglaze L-300

Emissivity : 0.80

Absorptivity : 0.92

Tensile force applied to Sensor : 50 lbf nominal

Actuator

Heater power : 10 W maximum at 28 Vdc

piston travel : 0.75 inches

Rated piston force : 50 lbf

Non-activation temperature : + 80°C

Activation temperature

Onset : 82°C

Paraffin melting point : 86°C

Micro-switch : Shuts off primary heater when piston extends to strap release point

2.5.3.2 TPA Power and Controller Unit (TPA-E)

This summarizes the design baseline for the TPA Power and Controller Unit (TPA-E):

Enclosure

Length	: 210.82 mm
Width	: 125.7 mm
Height	: 64.0 mm
Material	: Magnesium alloy
Surface finish	: Gold plating

Processor

Type	: RTX-2010
Instruction speed	: 2.5 MIPS
Wait states	: None, except when correcting single bit errors

Data storage memory

Type	: 16 32k × 8 Micron devices on-card
Size	: 2 Megabytes
Error protection	: 256 kbyte Program RAM area only 1-bit correction 2-bit detection

Purge

Intake npzzle	: Deleted
Volume vented / aperture area	: 250,000 mm

2.5.4 Size, Weight, and Power Consumption

2.5.4.1 Size

Refer to descriptions in Section 2.5.3.

2.5.4.2 Weight

The mass of the TPA instrument is budgeted as follows:

TPA Power and Controller Unit (TPA-E)	: 1.313 kg
Sensor (TPA-S-A)	: 0.924 kg
Boom (TPA-S-B)	: 0.470 kg
Cradle and Strap (TPA-S-C)	: 0.288 kg
TOTAL	: 2.995 kg

2.5.4.3 Power Consumption

TPA power consumption will be less than 8 Watts per Mars orbit. Peak power consumption is as follows:

Sleep state	: 1.954 mW
Deploy state	: 12.454 mW
Boot state	: 3.915 mW
Idle state	: 1.876 mW
Stanby	: 7.780 mW
Active	: 8.822 mW

2.5.5 Operation

The TPA instrument will consist of a Power and Controller Unit (TPA-E), internal to the satellite, and a Sensor (TPA-S-A) to be deployed several meters from the satellite on the end of a boom (TPA-S-B). Prior to deployment, TPA-S-A (Sensor) will be secured to the satellite by a cradle and strap assembly (TPA-S-C).

The TPA-S-A (Sensor Assembly) conducts plasma measurements under the supervision of the TPA-E (Power and Controller Unit). The Sensor receives commands from the TPA-E via a bi-directional interface. Science and telemetry data are also passed to the TPA-E via the same interface. This interface is implemented via a cable set which runs from the TPA-E to the Sensor (TPA-S-A) through the hollow boom (TPA-S-B).

The TPA-S-A contains a Hemispherical Electrostatic Analyzer (HEA) which segregates incoming particles by energy and azimuth arrival angle. An entrance slit around the circumference of TPA-S-A permits measurement of plasma particles nominally in a plane tangential to the satellite spin axis. Electrostatic voltages within the Hemispherical Electrostatic Analyzer select the energy range and energy offset for the measured particles.

The TPA-S-A controls the voltages on the Time-Of-Flight (TOF) electrodes inside the entrance slit to pre-select the type and energy range of particles entering the Hemispherical Electrostatic Analyzer. The TOF voltages are pulsed to control the particle quantity and duty cycle.

All the electrostatic voltages are obtained from the High-Voltage power Supply (HVPS) in the TPA-E via the TPA-S-B. The HVPS also supplies the drive voltages for the TOF electrodes; however, TOF pulse timing and duration are controlled at TPA-S-A.

After particles pass through the Hemispherical Electrostatic Analyzer (HEA), they are detected by a Micro-Channel Plate (MCP) and position sensed with a 256 elements anode array -- 16 rings of 19 pixels arranged on radial lines (columns). The TPA-S-A electronics detects events ("particle hits") at each pixel and identifies its location and Time-Of-Flight relative to the TOF gate opening.

The pixel address and TOF for each detected hit are stored in a First-In-First-Out (FIFO) memory at a rate of up to 10⁶ hits per second. Data from FIFO is removed at a rate of up to 5 Mbps for transfer to the TPA-E via the bi-directional interface.

The Sensor also monitors its baseplate temperature and protects the internal electronics by activating a heater when the temperature falls below threshold. The sensor also contains a separate temperature thermistor which can be used by the TPA-E to monitor the Sensor temperature even when the Sensor is powered down.

2.5.6 Command and Telemetry Items

2.5.6.1 Command Items

2.5.6.1.1 Discrete Commands

2.5.6.1.1.1 Hardware -- Decoded

The Discrete Commands are uniquely decoded by the TPA-E hardware are shown in Table 2.5.6.1.1.1-1.

2.5.6.1.1.2 Software – Decoded

Discrete Commands decoded by TPA-E software are TBD.

2.5.6.1.2 Block Commands

A software-decoded block commands will be defined to permit portions of TPA software to be uploaded after launch.

TPA software will decode the following additional Block Commands:

Function Initial DC X-Y Code
Telemetry Edition / Bit Rate (from PLANET-B)
TBD

2.5.6.2 Telemetry Items

2.5.6.2.1 Mission Telemetry

This will include records as shown in Figure 2.5.6.2.1-1 below.

2.5.6.2.2 Housekeeping Telemetry

TPA-E hardware will provide individual bytes of an 8-byte Housekeeping Telemetry block when the PIM performs Read operations at the following TPA addresses:

Status Word 0	0xxx hex
Status Word 1	1xxx hex
Status Word 2	2xxx hex
Status Word 3	3xxx hex
PCU_TEMP (ADC 0)	Axxx hex
CRADLE_TEMP (ADC 1)	Cxxx hex
BOOM_CRADLE_RES (ADC 2)	Exxx hex
SENSOR_TEMP (ADC 3)	4xxx hex

The contents of these Housekeeping Telemetry items are defined in Tables 2.5.6.2.2-1 to 2.5.6.2.2-5 below.

Figure 2.5.3-1: Thermal Plasma Analyzer

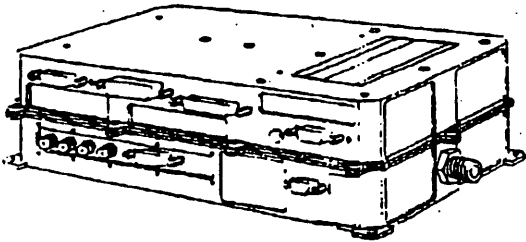
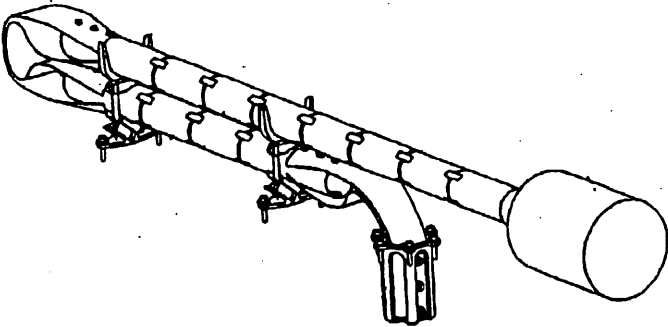
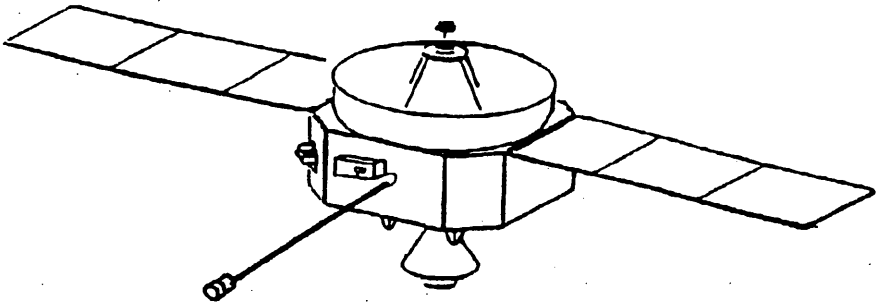
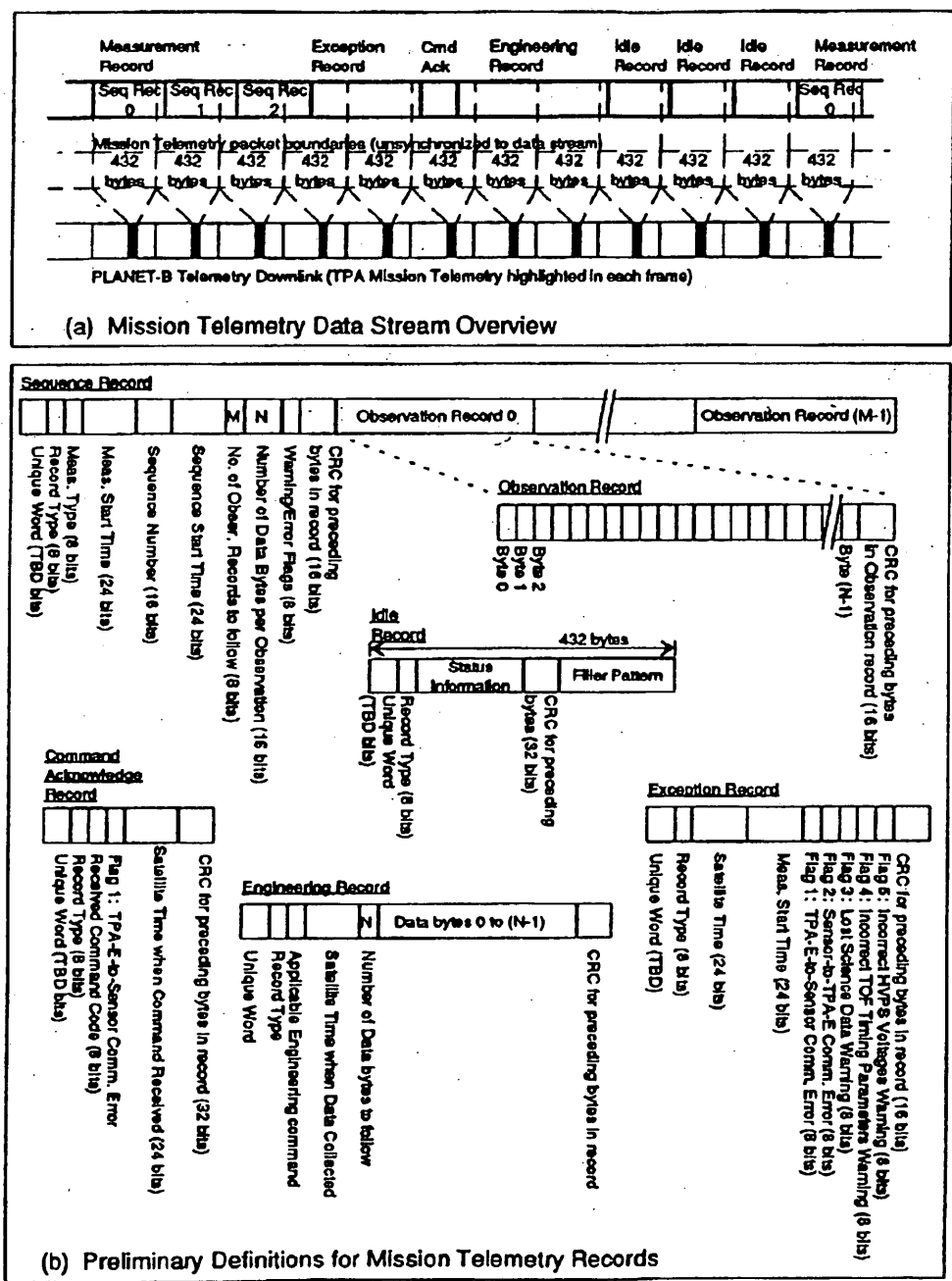


Table 2.5.6.1.1.1-1:

Hardware-decoded DC Commands

X	Y	Command Name	Function	Confirmation of Telemetry Motion (or Action)
N/A	N/A	INSTRUMENT_ON	To permit the TPA instrument to take measurements	Status_Word_0 , bit 0 set to 1
N/A	N/A	INSTRUMENT_OFF	To conserve satellite power by putting TPA into Sleep state	Status_Word_0 , bit 0 set to 0
3	1	CPU_RESET_PRIMARY	To reset the TPA processor and begin execution from the Primary EEPROM memory bank	Status_Word_0 , bit 6 set to 0
3	2	CPU_RESET_SECONDARY	To reset the TPA processor and begin program execution from the Secondary EEPROM memory bank	Status_Word_0 , bit 6 set to 1
3	4	ARM	To enable activation of boom deployment current	Status_Word_0 , bit 1 set to 1
3	6	CANCEL_ARM	To disable activation of boom deployment current	Status_Word_0 , bit 1 set to 0
3	8	DEPLOY_PRIMARY	To energize the Primary boom deployment actuator	Status_Word_0 , bit 2 set to 1
3	A	CANCEL_DEPLOY_PRIMARY	To de-energize and disable primary boom deployment actuator current	Status_Word_0 , bit 2 set to 0
3	C	DEPLOY_REDUNDANT	To energize the Redundant boom deployment actuator current	Status_Word_0 , bit 3 set to 1
3	E	CANCEL_DEPLOY_REDUNDANT	To de-energize and disable redundant boom deployment actuator current	Status_Word_0 , bit 3 set to 0

Figure 2.5.6.2.1-1: TPA Mission Telemetry Records



Tables 2.5.6.2.2-1: Housekeeping Telemetry Item Detail -- Status Word 0

Items	Telemetry			Condition Judgement		
	F	W	B			
STATUS_WORD_0		0	0	1	Sleep_state	Yes
				0		No
STATUS_WORD_0		0	1	1	Arm	Yes
				0		No
STATUS_WORD_0		0	2	1	Deploy_Primary	Yes
				0		No
STATUS_WORD_0		0	3	1	Deploy_Redundant	Yes
				0		No
STATUS_WORD_0		0	4	1	Watchdog_Timeout_Error	Yes
				0		No
STATUS_WORD_0		0	5	1	PIM_I/F_Error	Yes
				0		No
STATUS_WORD_0		0	6	1	TPA-E-U_Memory_Map	NVM1
				0		NVM0
STATUS_WORD_0		0	7	1	Boot	Boot
				0		Normal

Tables 2.5.6.2.2-2: Housekeeping Telemetry Item Detail -- Status Word 1

Items	Telemetry			Condition Judgement		
	F	W	B			
STATUS_WORD_1		1	0	1	PIM_S0	+5VDC
				0		GND
STATUS_WORD_1		1	1	1	PIM_S1	+5VDC
				0		GND
STATUS_WORD_1		1	2	1	Not Used	N/A
				0		N/A
STATUS_WORD_1		1	3	1	Not Used	N/A
				0		N/A
STATUS_WORD_1		1	4	1	HVPS_Reset	Reset
				0		Not
STATUS_WORD_1		1	5	1	Sensor_Heater	Enabled
				0		Disable
STATUS_WORD_1		1	6	1	Sensor_Power	On
				0		Off
STATUS_WORD_1		1	7	1	HVPS_Power	On
				0		Off

Tables 2.5.6.2.2-3: Housekeeping Telemetry Item Detail -- Status Word 2

Items	Telemetry			Condition Judgement		
	F	W	B			
STATUS_WORD_2		2	0	1	High_Voltage_1 (VSA) (-1000 VDC to 1000 VDC)	Active
				0		Inactiv
STATUS_WORD_2		2	1	1	High_Voltage_2 (VGD) (-1500 VDC to +1500 VDC)	Active
				0		Inactiv
STATUS_WORD_2		2	2	1	High_Voltage_3 (VCP) (-1500 VDC to +1500 VDC)	Active
				0		Inactiv
STATUS_WORD_2		2	3	1	High_Voltage_4 (VAN*) (-1500 VDC to +4000 VDC)	Active
				0		Inactiv
STATUS_WORD_2		2	4	1	Medium_Voltage_1 (VEA) (-50 VDC to +50 VDC)	Active
				0		Inactiv
STATUS_WORD_2		2	5	1	Not used	N/A
				0		N/A
STATUS_WORD_2		2	6	1	Medium_Voltage_3 (VES) (-100 VDC to +100 VDC)	Active
				0		Inactiv e
STATUS_WORD_2		2	7	1	Medium_Voltage_4 (VTFS) (-25 VDC to +25 VDC)	Active
				0		Inactiv

Tables 2.5.6.2.2-4: Housekeeping Telemetry Item Detail -- Status Word 3

Items	Telemetry			Condition Judgement		
	F	W	B			
STATUS_WORD_3		3	0	1	TPA-E-S_Error_Code, Bit 0	0000 ₁₆ = No Error
				0		
STATUS_WORD_3		3	1	1	TPA-E-S_Error_Code, Bit 1	
				0		
STATUS_WORD_3		3	2	1	TPA-E-S_Error_Code, Bit 2	
				0		
STATUS_WORD_3		3	3	1	TPA-E-S_Error_Code, Bit 3	
				0		
STATUS_WORD_3		3	4	1	Not Used	N/A
				0		N/A
STATUS_WORD_3		3	5	1	Not Used	N/A
				0		N/A
STATUS_WORD_3		3	6	1	Not Used	N/A
				0		N/A
STATUS_WORD_3		3	7	1	Not Used	N/A
				0		N/A

Tables 2.5.6.2.2-5: Housekeeping Telemetry Item Detail -- Analog Values

F. No	Analog Housekeeping Telemetry Item	Abbrev.	Type	Measurement Range	Exchange Equation	Ref. Notes
	PCU_TEMP			-55°C to 100°C	1.76°C / bit - 273.2°C	
	SENSOR_TEMP			-55°C to 100°C	1.76°C / bit - 273.2°C	
	CRADLE_TEMP			-70°C to 100°C	1.76°C / bit - 273.2°C	
	BOOM_CRADLE_RES			0 to 13,500 ohms	52.73 ohms / bit	

C:\docs\tpa\midterm.rpt

2.6 The Ion Mass Imager (IMI)

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2.6.1 Scientific Objectives

— Charged heavy atoms and molecules —

The Martian plasma environment has been explored by Mars 2, 3, 4, 5, and Phobos-2 spacecraft. Many of the important plasma boundaries were discovered such as bow-shock, the magnetopause, the magnetospheric cavity, and a plasma tail. A boundary layer with a low energy component of presumably ionospheric origin was also observed near Mars. Yet the Martian plasma environment still remains somewhat of a puzzle. The Martian magnetosphere, as defined by the region of reduced plasma flow, is more extended than previously anticipated, is dominated by ions of Martian origin, e.g. O^+ and molecular ions, and has several characteristics similar to that of the solar wind interaction with comets. One objective of the Mars mission is to clarify these matters.

Because of the small intrinsic magnetic field of Mars, the Martian upper atmosphere (dominated by O_2^+) is exposed to the solar wind. This implies that ionization in the upper atmosphere is due to both solar UV and solar wind plasma interaction. The latter may take several forms, e.g., a viscous-like interaction, and the critical velocity ionization by the solar wind interaction with the neutral atmosphere. Meanwhile, the Phobos-2 found an escape of plasma (outflow of atmospheric oxygen) at Mars, of the order 1 kg/s. This corresponds to a loss of the existing Martian atmosphere in 108 years, which puzzles us.

Another interesting topic to study is the solar wind interaction with the two Martian satellites Phobos and Deimos. They are somewhat "light weight" in terms of mass density ($1.8 \pm 0.5 \text{ g/cm}^3$ for Phobos), indicating that they contain a significant fraction of volatile elements (e.g. H_2O and CO_2 ice). If so, a very thin atmosphere is expected to form, most likely on the sunfacing side and in particular after meteorite impacts. This explains the observation from the Phobos-2 spacecraft of the cometary behavior of Phobos and Deimos as well as the indications of an oxygen corona in the Phobos orbit. Ionization of these molecules due to interaction with the solar wind definitely play an important role for such escape.

— Dusty Plasma —

One of more fascinating properties of planetary environment is the existence of ring structures. Although these are known to exist around the giant planets, speculations on ring structures around the smaller planets have also occurred. As for Mars the speculations on a dust ring close to the Phobos orbit dates back to 1971. Micro-meteorite impacts on the Phobos surface may substantially contribute to the hot oxygen corona around Mars. Study of the "dusty" plasma behavior is interesting from a cosmogonic point of view too. Fine grains with masses up to 10^{12} of the molecular weight may, if electrically charged, be strongly controlled by magnetic and electric forces. Such a "dusty" plasma is then likely to be the source of larger grains which eventually accrete into larger bodies.

Magnetic and electric forces are therefore expected to control matter over an extended period of time throughout the formation of a planetary system. Therefore, measuring dusty plasma is also an important scientific objective.

— Task for IMI —

Under these circumstances, we need an ion composition instrument which covers dusty plasma. Identification of the flow direction is also important, so that the instrument must have 3D coverage. IMI instrument onboard Planet-B consists of an ion mass imaging spectrograph for ions in the energy range 10 eV/e - 40 keV/e and mass range 1 - 10^{12} amu. A 360° intrinsic field of view of IMI gives a 4 π (3D) coverage of the ion distribution after half a spin of the spacecraft.

2.6.2 Instrument Specification

Maximum energy range	10 eV/e - 40 keV/e (16~64 steps)
Energy resolution (FWHM)	$\Delta E/E = 0.14$ for full scale
Angular resolution (FWHM)	5° x 22°
Elevation	11°~22° (16~32 direction)
Azimuth	22° (16 direction)
Intrinsic field of view	5° x 360°
Mass range	1 - 10^{12} amu/e
Mass resolution (m/ Δm)	1-6 (hot), 4-30 (cold)
Time resolution for full 3-D data	1/2 S/C spin
Conversion Factor (22°)	$\approx 2 \cdot 10^{-4}$ (cm ² sr keV/keV)
Conversion Factor (360°)	$\approx 3 \cdot 10^{-3}$ (cm ² sr keV/keV)
Dynamic range (full particle image)	0.1 - 10^6 cts/s

— Heritage —

IMI is a heritage of the successful ASPERA experiment on the Soviet Phobos-mission (1988) and TICS on the Swedish-Germany FREJA mission (1992).

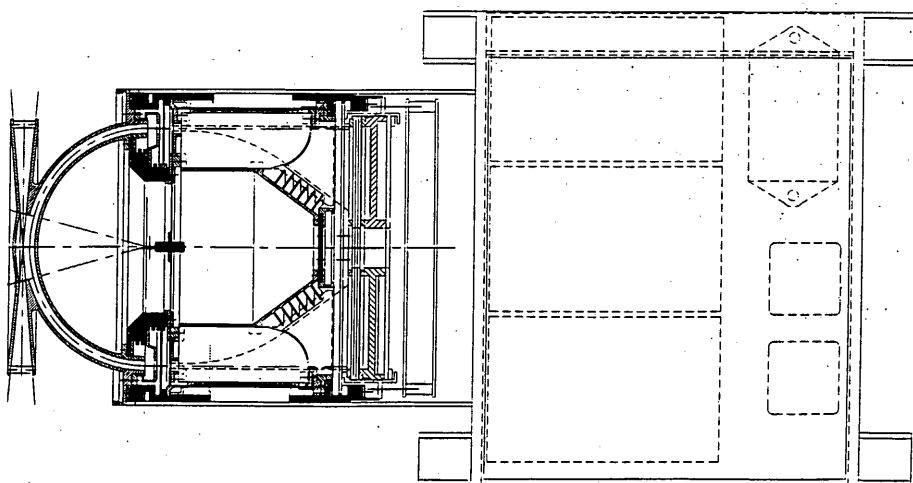
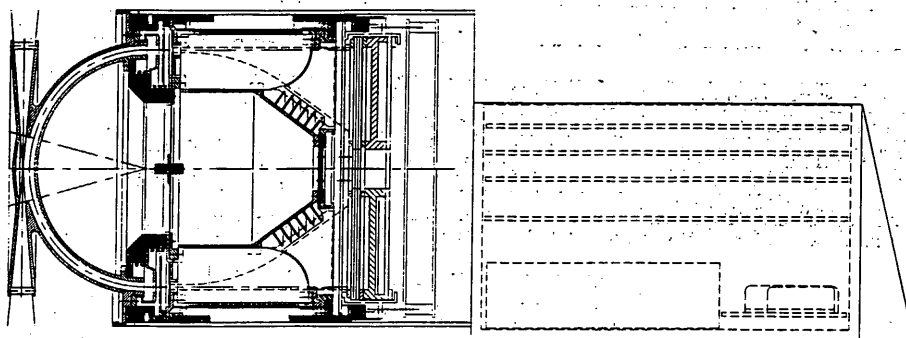
2.6.3 Instrument Configuration

IMI comprise an integrated unit of IMI-S and IMI-E (including DPU). IMI-E has a 360°x 5° field of view divided in 16 azimuthal sectors (22°x 5°). The overall configuration is shown in Figure 1.

— IMI-S —

The IMI-S comprises an electrostatic "top hat" analyzer with 360° field of view and 90° deflection angle, followed by a cylindrical sector magnet momentum analyzer with lateral magnetic field. Particles are detected using a macrochannel-plate assembly with position sensitive features. The particle imaging system (360° field of view) provides simultaneously the azimuth and mass per unit charge (m/q) of the incident ion distribution in a 32 x 32 (angle mass) matrix. The mass detection technique utilized by IMI is ideal for the detection of ions with all masses (1 to $\approx 10^{12}$ amu), including submicron sized "dusty" plasma components, an "unexplored" plasma component believed to be of great importance in some cosmogonic scenarios.

— IMI-E —



The IMI-E contains one 16-bit processors (DPU) for spectrometer control, commanding, telemetry-interfacing, on-board data handling, and on-board processing of scientific data (computing e.g. moments of the plasma distribution function). The IMI-E also contains four HV supplies (3 kV) with 12 bit accuracy (0.75 - 3000 V) at its bottom part.

2.6.4 Size, Weight, and Power Consumption

(1) IMI-S

weight	1.5 kg $\pm$ 0.1 kg	
shape	18 $\times$ ϕ 12 cm	Figures 1

Temp. for best performance	- 15 °C ~ 20 °C	(*)
operatable Temp.	- 30 °C ~ 50 °C	(*)
required Temp. for storage	- 50 °C ~ 50 °C	(*) 2.9 W heater
safe Temp. when OFF-to-ON	- 50 °C ~ 35 °C	(*) 2.9 W heater
safe Temp. when ON-to-OFF	any	

(*) Thermally isolated and may need heater. Sensor itself warms up with its own power.

thermal dissipation
(for each mode)

mode	dissipation	
HV-ON	3.25 W + heater	(*) (**)
CPU-ON	3.25 W + heater	"ON" immediately follows
standby	2.9 W $\pm$ 0.1 W	when T < -50 C
OFF	0 W	only for emergency case

(*) Thermally isolated and may need heater. Sensor itself warms up with its own power.

(**) Preliminary value: Sensor = 2.7 W and MCP (Micro Channel Plate) = 0.5 W.

(2) IMI-E

weight	1.45 kg $\pm$ 0.1 kg	
shape	18 $\times$ 17 $\times$ 9 cm (*)	Figure 1

(*) We are trying to reduce the board for the electric circuit from three plates to two plates. If we can succeed this optimization, we can reduce the size (height) little more.

Temp. for best performance	- 15 °C ~ 50 °C	warms up by itself (*)
operatable Temp.	- 30 °C ~ 50 °C	warms up by itself (*)
required Temp. for storage	-50 °C ~ 50 °C	
safe Temp. when OFF-to-ON	-50 °C ~ 50 °C	
safe Temp. when ON-to-OFF	any	

(*) Since the electric circuit warms up with its own power, and the thermal conduction is not clear, we cannot specify the temperature that the satellite have to provide.

thermal dissipation
(for each mode)

mode	dissipation	
HV-ON	9 $\pm$ 1 W	5 W, bottom of box (HV)
CPU-ON	7 $\pm$ 1 W	"ON" immediately follows
standby	1.5 W	no heater
OFF	0 W	only for emergency case

(*) within the S/C thermal system

2.6.5 Operation

We plan continuous operation, with different mode for different regions of interest and telemetry rate.

2.6.5.1 Data telemetry for IMI (in bps)

total telemetry rate		64k	32k	16k	8k	4k	2k	1k	512	256	128	64
Mode	IMI-allocation											
Obs-P (periapsis)	IMI = 3/16	o 12k	o 6k	o 3k								
Obs-S (standard)	IMI = 3/16	o 12k	o 6k	o 3k	o 1.5k	o 768	o 384	Δ 192	o 96	Δ 48		Δ 12
UVS	IMI = 3/32	o 6k	o 3k	o 1.5k	o 768	o 384	o 192					
MIC	IMI = 3/32	o 6k	o 3k	o 1.5k	o 768	o 384	o 192			Δ 24		Δ 6
WFC-M	IMI = 3/32		o 3k	o 1.5k	o 768	o 384	o 192			Δ 24		Δ 6
MDC	IMI = 3/32		o 3k	o 1.5k	o 768	o 384	o 192			Δ 24		Δ 6

One frame = 512 byte (in fact, only 432 byte data) = minimum unit for scientific data.

We use "3-frame" concept which may contain 1296 byte IMI data.

12 kbps	= 3 frame / sec	
6 kbps	= 3 frame / 2 sec	
3 kbps	= 3 frame / 4 sec	
1.5 kbps	= 3 frame / 8 sec	(≈ 3 frame / 1 spin)
768 bps	= 3 frame / 16 sec	(≈ 3 frame / 2 spin)
384 bps	= 3 frame / 32 sec	(≈ 3 frame / 4 spin)
192 bps	= 3 frame / 64 sec	(≈ 3 frame / 8 spin) ≈ 3 frame / 1 min
96 bps	= 3 frame / 128 sec	(≈ 3 frame / 16 spin) ≈ 3 frame / 2 min
48 bps	= 3 frame / 256 sec	(≈ 3 frame / 32 spin) ≈ 3 frame / 4 min
24 bps	= 3 frame / 512 sec	(≈ 3 frame / 64 spin) ≈ 3 frame / 8 min
12 bps	= 3 frame / 1024 sec	(≈ 3 frame / 128 spin) ≈ 3 frame / 17 min
6 bps	= 3 frame / 2024 sec	(≈ 3 frame / 256 spin) ≈ 3 frame / 34 min

note: Data output rate from MCP (16×32=512 sectors) for 30 / 15 msec sampling-time is

2 byte × 512 / 0.03 sec = **250 kbps** (≡ normal rate)

2 byte × 512 / 0.015 sec = **500 kbps** (≡ high rate)

2.6.5.2 Raw-Data Output (for 8 second spin & 16 θ -sectors divided by magnets):

What can we measure with 15 msec sampling time and 30 msec sampling time?

rate	spin period	ϕ -direction	θ -direction	energy step	sampling time	mass
high	8 sec	8 sectors	16 sectors	64 steps $\Delta E/E=0.14$	$8000 / (8 \times 64)$ = 15 msec	2, 5
high	"	16 sectors	"	32 steps $\Delta E/E=0.3$	$8000 / (16 \times 32)$ = 15 msec	2, 5
high	"	32 sectors	"	16 steps $\Delta E/E=0.7$	$8000 / (32 \times 16)$ = 15 msec	2, 5
normal	"	4 sectors	"	64 steps $\Delta E/E=0.3$	$8000 / (4 \times 64)$ = 30 msec	2-32
normal	"	8 sectors	"	32 steps $\Delta E/E=0.3$	$8000 / (8 \times 32)$ = 30 msec	2-32
normal	"	16 sectors	"	16 steps $\Delta E/E=0.7$	$8000 / (16 \times 16)$ = 30 msec	2-32
normal	"	32 sectors	"	8 steps narrow E	$8000 / (32 \times 8)$ = 30 msec	2-32

note: Raw Data output rate for 5 mass mode (possible to compress to 3-12 kbps?)

$$250 \text{ kbps} \times 5 / 32 = 40 \text{ kbps} \quad (\text{normal})$$

$$500 \text{ kbps} \times 5 / 32 = 80 \text{ kbps} \quad (\text{high})$$

2.6.5.3 Basic Modes (preliminary)

* 4 mass modes:

M1: High-mass-1 (32) = all

M2: High-mass-2 (16) = mass channel: 1+2, 3+4, 5+6, ...

M3: normal-mass (5) = H^+ , He^{++} , He^+ , O^+ , heavier

M4: low-mass (2) = light (H, He) and heavy (CNO)

* 3 energy sweep modes:

S1: 16 steps **S1:** 32 steps **S1:** 64 steps

* 3 energy ranges:

E1: All-energy = 10 eV - 40 keV ($\Delta E/E = 0.3$ for 32 step, $\Delta E/E = 0.7$ for 16 step)

E2: High-energy = 500 eV - 40 keV ($\Delta E/E = 0.15$ for 32 step, $\Delta E/E = 0.3$ for 16 step)

E3: Low-energy = 50 eV - 4 keV ($\Delta E/E = 0.15$ for 32 step, $\Delta E/E = 0.3$ for 16 step)

* 4 types of directions (integrated)

D3: 3 directions (Max/anti-Max, other) * **note:** Max is defined by 0.5-3 keV or flux

D5: 5 directions (Max/anti-Max, second-Max/anti-second-Max, other)

D6: 6 directions (3 axis)

D7: 14 directions (if possible, **D8:** 16 dir, **D9:** 18 dir, **D12:** 24 dir)

* 6 integration times

T1: half spin **T2:** 1 spin (8 sec) **T3:** 16 sec **T4:** 32 sec **T5:** 2 min **T6:** 8 min

* we also have a compromising solar wind mode to see only limited velocity range

2.6.6 On-Board Data Processing

Without introducing data compression IMI could easily provide a data rate of some 500 kbps. This is of course an inconceivable data rate for this mission although we adopt some data-compression technique. The data rate will be substantially reduced by on-board data processing. This includes for instance computations of the plasma moments for various ion species, distribution functions for various ion species, and averaged energy-mass ($E/q \times M/q$) matrices for different directions (1-12 directions).

2.6.6.1 Plasma Moment (preliminary)

13 moments = density: $N_i(1)$, velocity: $V_i(3)$, pressure: $P_i(1-6)$, and heat flux: $H_i(3)$
16 bit/word

*1) Directions (see also Appendix):

F_s = flux at sector s ($1 < s < 256$), where

$s = "m"$: maximum sector $s = "w"$: opposite sector of "m"

$s = "n"$: 2nd maximum sector, $s = "v"$: opposite sector of "n"

("n" is not neighbour of "m" or "w")

F_m, F_w , and neighbouring 8×2 sectors (summation and subtraction) $\Rightarrow n_1, V_1(3), P_1, "m"$

F_n, F_v , and neighbouring 8×2 sectors (summation and subtraction) $\Rightarrow n_2, V_2(3), P_2, "n"$

All other sectors (224 sectors) $\Rightarrow n_{rest}, V_{rest}(3), P_{rest}(1-6), H_{rest}(3)$

*2) Maximum data rate for one mass, one direction:

A. Sample ratio of N: V: P: H = 8: 4: 2: 1 $\Rightarrow 8+12+(2 \sim 12)+3 = 25 \sim 35$ moments (probably 29)

$\Rightarrow 25 \sim 35 \times 16 \text{ bit/word} = 400 \sim 560 \text{ bit (every four spins)} = 1 \text{ frame / four spins}$

$\Rightarrow 13 \sim 18 \text{ bps (} 4\pi \text{) or } 25 \sim 35 \text{ bps (} 2 \times 2\pi \text{)}$

B. Sample ratio of N: V: P: H = 4: 2: 1: 0 $\Rightarrow 4+6+(1 \sim 6) = 11 \sim 16$ moments (probably 13)

$\Rightarrow 11 \sim 16 \times 16 \text{ bit/word} = 176 \sim 256 \text{ bit (every two spins)} \approx 0.5 \text{ frame / two spins}$

$\Rightarrow 11 \sim 16 \text{ bps (} 4\pi \text{) or } 22 \sim 32 \text{ bps (} 2 \times 2\pi \text{)}$

*3) Maximum data rate for one mass, multi direction:

Sample ratio of N: V: P: H = 8: 4: 2: 1 for "rest" $\Rightarrow 29$ moments ($P=3$)

Sample ratio of N: V: P: H = 8: 4: 2: 0 for "s" $\Rightarrow 25$ moments ($P=1$)

$\Rightarrow 29 \times 16 \text{ bit/word} = 464 \text{ bit (every four spins)}$

+ $25 \times 16 \text{ bit/word} = 400 \text{ bit (every four spins)}$

864 bit / four spin (3 directions)

1264 bit / four spin (5 directions)

1392 bit / four spin (6 directions)

$\Rightarrow 27 \sim 44 \text{ bps (} 4\pi \text{) or } 54 \sim 87 \text{ bps (} 2 \times 2\pi \text{)}$

*4) Multi-mass (2 or 5 or 16 or 32)

1~3 direction for high-mass ($> O^+$)

multi-direction for low-mass ($< O^{++}$)

*5) Possible integration time (for single direction))

W1T2 (304-608bps), W1T4 (76-152bps)
W2T2 (152-304bps), W2T4 (38-76bps)
W3T1 (95-190bps), W3T2 (48-95bps), W3T3 (24-48bps), W3T4 (12-24bps)
W4T2 (10-20bps), W2T4 (2.5-5bps)

2.6.6.2 Energy-Mass matrix (preliminary)

16 or 32 masses, 16 or 32 energy levels, 8 bit/word, 3~12 directions, spin = 8 sec

mode (step #)	M=32, E=64	M=32, E=32	M=32, E=16	M=16, E=16
one direction telemetry	16384 bit 3-34 frames	8192 bit 3-17 frames	4096 bit 2-8 frames	2048 bit 1-4 frames
12 directions	200 kbit	100 kbit		
6 directions		50 kbit		
3 directions		25 kbit		
2 directions		16 kbit	8 kbit	4 kbit

2.6.6.3 Distribution Function (preliminary)

2-5 masses, 32 energy levels, 8 bit/word, 3 ~ 12 directions, spin = 8 sec

* example-1: highest rate possible

$$4 \text{ mass} \times 64 \text{ energy} \times 8 \text{ bit} \times 12 \text{ dir} / 4 \text{ sec} = 6144 \text{ bps}$$

* example-2: feasible high rate

$$4 \text{ mass} \times 64 \text{ energy} \times 8 \text{ bit} \times 6 \text{ dir} / 4 \text{ sec} = 3072 \text{ bps (for High 1 mode ?)}$$

* example-3: lower rates

$$4 \text{ mass} \times 64 \text{ energy} \times 8 \text{ bit} \times 6 \text{ dir} / 16 \text{ sec} = 768 \text{ bps (for High 2 mode ?)}$$

$$4 \text{ mass} \times 32 \text{ energy} \times 8 \text{ bit} \times 4 \text{ dir} / 64 \text{ sec} = 64 \text{ bps (for Low 1 mode ?)}$$

2.6.6.4 Possible Content of Data Package (TBD)

2.6.7 Command and Telemetry Items

2.6.7.1 Command Items

HV on/off and HV ena/dis commands will go through even if the decoder failed.

Hex	name (19 characters)	function	telemetry
30	IMI_HVall=Off	HV-all off	f / w / b
31	IMI_HVall=On	HV-all on	
32	IMI_HV1=Off	HV-1 off	
33	IMI_HV1=On	HV-1 on	
34	IMI_HV2=Off	HV-2 off	
35	IMI_HV2=On	HV-2 on	
36	IMI_HV3=Off	HV-3 off	
37	IMI_HV3=On	HV-3 on	
38	IMI_HV4=Off	HV-4 off	
39	IMI_HV4=On	HV-4 on	
3A			
3B			
3C			
3D			
3E	IMI_Debug=Off	Debug off	
3F	IMI_Debug=On	Debug on	
40			
4*		(TBD)	
4D		BD-load	
4E		4*BD	
4F		2*BD	

2.6.7.1 Command Items (continued)

Hex	name (19 characters)	function	telemetry
50	IMI_Mode=Test	mode-0	f / w / b
51	IMI_Mode=Opr1	mode-1	
52	IMI_Mode=Opr2	mode-2	
53	IMI_Mode=Opr3	mode-3	
5n		mode-n (n=4,5,...15)	
6*		(TBD)	
7*		(TBD)	
80	IMI_HV=Off	HV-main (28V) off / disable	F800 / 4 = 0 & F800 / 5 = 0
81	IMI_HV=On	HV-main (28V) on	F800 / 4 = 1 & F800 / 5 = 1
82	IMI_HV=Enb	HV-main (28V) enable	F800 / 4 = 0 & F800 / 5 = 1
83		B1 (+28V) on	F800 / 3 = 1
84		B2 (+28V) off	F800 / 2 = 0
85		CPU reset	F800 / 7 = 1 (?)
86		Heater off	F800 / 6 = 0
87		Heater on	F800 / 6 = 1
8B		B1 (+28V) off	F800 / 3 = 0
8C		B2 (+28V) on	F800 / 2 = 1

—— Block Commands (BC) ——

(function) (Hex)

2*BD = 4F + BD + BD + ECW

4*BD = 4E + BD + BD + BD + BD + ECW

BD-load = 4D + n*BD + ECW (n<252)

(*1) Each element is called "BD" while the entire sequence is called "BC."

(*2) "2*BD (4F)" and "4*BD (4E)" are the same as "Parameter Set" of the Document.

(*3) "BD-load" is the same as "Data Transmission" of the Document.

Details are TBD

2.6.7.2 Telemetry Items

—— bi-level status —— (for HV etc.)

Item (symbol)	telemetry		Status Judge		
	address	bit	0 / 1	meaning	symbol
IMI-CPU on/off (TBD)	F8 00	7 = lsb	0 1	off on	OFF ON
IMI-Heater on/off (TBD)	F8 00	6	0 1	off on	OFF ON
IMI-HV (+28V) enable/disable (TBD)	F8 00	5	0 1	disable enable	DIS ENA
IMI-HV (+28V) on/off (TBD)	F8 00	4	0 1	off on	OFF ON
IMI-B1 (+28V) on/off (TBD)	F8 00	3	0 1	off on	OFF ON
IMI-B2 (+28V) on/off (TBD)	F8 00	2	0 1	off on	OFF ON
TBD	F8 00	1	0 1		
TBD	F8 00	0 = msb	0 1		
(*1) IMI-HV1 on/off (TBD)	F8 01	7	0 1	off on	OFF ON
(*1) IMI-HV2 on/off (TBD)	F8 01	6	0 1	off on	OFF ON
(*1) IMI-HV3 on/off (TBD)	F8 01	5	0 1	off on	OFF ON
(*1) IMI-HV4 on/off (TBD)	F8 01	4	0 1	off on	OFF ON
TBD (*1)	F8 01	3	0 1		
TBD (*1)	F8 01	2	0 1		
TBD (*1)	F8 01	1	0 1		
TBD (*1)	F8 01	0 = msb	0 1		
TBD (*1)	F8 02	0-7	0 1		

(*1) The signal is meaningless during Standby-By because it is processed by IMI-CPU.

2.6.7.2 Telemetry Items (continued)

—— 8-bit digital status —— (for house keeping)

address	item	symbol	unit	range	conversion
F8 F0	IMI Temperature	(TBD)	°C	(TBD)	(TBD)
F8 F1	(*1) IMI HV1 voltage	(TBD)	V	(TBD)	(TBD)
F8 F2	(*1) IMI HV2 voltage	(TBD)	V	(TBD)	(TBD)
F8 F3	(*1) IMI HV3 voltage	(TBD)	V	(TBD)	(TBD)
F8 F4	(*1) IMI HV4 voltage	(TBD)	V	(TBD)	(TBD)
F8 F5	(*1) IMI T1 temperature	(TBD)	°C	(TBD)	(TBD)
F8 F6	(*1) IMI T2 temperature	(TBD)	°C	(TBD)	(TBD)
F8 F7	(*1) IMI Current	(TBD)	mA	(TBD)	(TBD)
F8 F8 - F8 FA	(TBD)				

(*1) The signal is meaningless during Standy-By because it is processed by IMI-CPU.

—— Data telemetry ——

TBD

2.6.8 Appendix: Axis-defined Directions

(1) 6 sector (3 axis)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z
2																
3																
4	X			Y	Y			-x	-x			-y	-y			X
5	X			Y	Y			-x	-x			-y	-y			X
6																
7																
8	-z	-z	-z	-z	-z	-z	-z	-z	-z	-z	-z	-z	-z	-z	-z	-z
9	-z	-z	-z	-z	-z	-z	-z	-z	-z	-z	-z	-z	-z	-z	-z	-z
10																
11																
12	-x			-y	-y			X	X			Y	Y			-x
13	-x			-y	-y			X	X			Y	Y			-x
14																
15																
16	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z

(2) 14 sectors

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z
2																
3																
4	X			Y	Y			-x	-x			-y	-y			X
5	X			Y	Y			-x	-x			-y	-y			X
6																
7																
8	-z	-z	-z	-z	-z	-z	-z	-z	-z	-z	-z	-z	-z	-z	-z	-z
9																
10																
11																
12																
13																
14																
15																
16																

(3) 16 sectors

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z
2																
3																
4	X			Y	Y			-x	-x			-y	-y			X
5	X			Y	Y			-x	-x			-y	-y			X
6																
7																
8	-z	-z	-z	-z	-z	-z	-z	-z	-z	-z	-z	-z	-z	-z	-z	-z

(4) 18 sectors

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z
2																
3																
4	X			Y	Y			-x	-x			-y	-y			X
5	X			Y	Y			-x	-x			-y	-y			X
6																
7																
8	-z	-z	-z	-z	-z	-z	-z	-z	-z	-z	-z	-z	-z	-z	-z	-z

(5) 24 sectors

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z
2																
3																
4	X			Y	Y			-x	-x			-y	-y			X
5	X			Y	Y			-x	-x			-y	-y			X
6																
7																
8	-z	-z	-z	-z	-z	-z	-z	-z	-z	-z	-z	-z	-z	-z	-z	-z

2.7 Mars Dust Counter (MDC)

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Principal-Engineer:	Ralf Münzenmayer	LRT, TU-München,

2.7.1 Observation Objectives

An investigation is proposed to improve the knowledge of interplanetary and circumplanetary dust. In particular, small Martian satellites Phobos and Deimos are considered to be significant dust sources around Mars but no successful direct dust measurements have been performed around Mars. There would be also some particles from upward transfer (through the atmosphere) of the dust from the Martian dust storms. The proposed instrument is a improved version of the MDC (MUNICH DUST COUNTER) flown on the Japanese MUSES-A-satellite (HITEN) and on the German BREM-SAT. The instrument is a multi-coincidence detector measuring particles with masses between 10^{-15} and more than 10^{-7} g and velocities between 1 and more than 70 km/s. Charge measurement can be also possible by option. These mass and velocity ranges can cover the expected mass and relative velocity of interplanetary and circumplanetary dust particles; from this investigation it is expected to get highly reliable and quantitative data on interplanetary dust and dust around Mars (and the Earth).

The scientific objectives are related to the three phases of the PLANET-B mission:

1st Phase (Parking Phase; 4 months): The first phase is similar to the orbit of the MUSES-A mission (HITEN spacecraft) which spent 3 years in the vicinity of earth and moon. This parking phase provides the possibility of comparing the new dust measurements with the old MDC data. Preliminary data calibration and parameter set-up for dust measurement in subsequent phases will be done using the first phase data.

2nd Phase (Cruising Phase; 10 months): During the cruising phase, MDC can measure the interplanetary dust flux and there will be the possibility to compare the data with the data of the dust experiments on board the spacecraft's of the Galileo and Ulysses mission. Since the zodiacal dust cloud expands up to a distance of 2-3 AU from the sun, there could be the possibility to contribute with the MDC measurements on the solution of the question, what role are the asteroids and comets playing in forming the zodiacal dust particles.

3rd Phase (Planet Mars Phase; 2 years): Impacts of interplanetary meteoroids on the surface of Phobos and Deimos generate ejecta particles. Some fractions of this ejecta particle will leave the satellites. There are some questions which could be investigated with help of the MDC:

- How much ejected particles are in orbits around Mars?
Are there dust rings?
What is the consistence of the possible dust rings (mass and velocity distribution)?
How many particles are recaptured by the satellites?
What are the loss mechanisms?

Dust in the vicinity of Earth and Moon:

During the Parking Phase of the PLANET-B spacecraft in a highly eccentric orbit around the Earth with some Moon fly-by's there is the excellent possibility to extend the measurements of the MUSES-A MDC. The MUSES-A MDC measured the mass-, velocity- and angular distribution of cosmic dust particles within the ecliptic plane. First analysis of the MUSES-A proved the existence of pro- and retrograde β -meteoroids and gave evidence for particles with high inclinations. The spin axis of PLANET-B will be in the ecliptic plane. Therefore the MDC will now scan also the northern and southern hemisphere. This allows together with the MUSES-A data to determine the three dimensional-angular distribution of cosmic dust particles.

The cumulative particle flux measured by MUSES-A MDC for masses greater 10^{-13} g is higher than that of the interplanetary flux model of Grün et al. (1985). This is in agreement with other data from spacecrafts in the vicinity of the earth, for example with measurements of HEOS 2. With the PLANET-B mission this flux will be measured again in the vicinity of the Earth and Moon but also at the Cruise Phase from Earth to Mars which allows to determine the dust enhancement around the earth and to improve the interplanetary flux model.

Measurements of HEOS 2 dust experiment showed that the dust flux near Earth is very inhomogeneous. Fechtig (1978) divided the impact events in three categories depending on the time differences between subsequent events: swarm-, group- and random-particles. The MUSES-A MDC measured also enormous variations of the impact rates and it was also possible to find swarm and groups. This swarms were only detected close to the earth. Fechtig et al. (1976) showed that there is evidence for near-Earth-fragmentation and described possible break-up mechanisms, but the origin of this swarms is still not proved. The new MDC can help to solve this problem.

Recently Dermott et al. (1994) advocated that asteroidal dust particles larger than $5 \mu\text{m}$ should be rocked by orbital resonance with the Earth. They may form a circumsolar ring (enhancement of dust particles around the Earth orbit) which could explain the higher dust flux measured with the MDC. The PLANET-B MDC with its good mass and velocity resolution can investigate the number of large particles and make sure (or withdraw) this hypothesis.

Interplanetary dust:

During the cruising phase from the Earth to the Mars the interplanetary dust flux can be measured from 1 to 1.5 AU without the influence of the planets (Earth or Mars). This new data of the interplanetary flux of dust particles could be correlated with the MDC data on board the spacecraft HITEN (Igenbergs et al. 1990) and the data of the spacecraft's of the Galileo and Ulysses mission. As the MDC-PB on board PLANET-B will determine the flight direction of impacting particles, it would be possible to distinguish between interplanetary and Mars or Mars satellites related particles during the mission phase in the orbit around the Mars.

The continuation of the β -meteoroid measurements of MDC-HITEN (Igenbergs et al. 1991a) is also a significant aspect. The measurement of β -meteoroids depends on the location of the MDC on the spin stabilized S/C. According to the present position, MDC detector is avoid of sunlight. Then β -meteoroid coming directly from the sun cannot be measured by MDC although eccentric particles from behind can be measured. MDC will be able to discriminate Keplerian particles from the zodiacal cloud and β -meteoroid.

Extrasolar particles:

Ulysses dust counter detected flow of extrasolar particles whose velocity is the same as interstellar gas media at Jovian region (Grün et al. 1993). Size of those particles ($\sim 0.4 \mu\text{m}$) are larger than typical interstellar particles ($\sim 0.1 \mu\text{m}$). They are interpreted as some aggregate of icy particles. Those particles would be evaporated in the terrestrial zone. However silicate (and metallic) nucleus of icy particles may enter the terrestrial zone with the same velocity. Detection of such particles and measurement of their size will be important to clarify characteristics of interstellar particles. (If their size is too small $\ll 0.1 \mu\text{m}$, they cannot enter the terrestrial zone because of solar radiation pressure.)

Size and velocity distribution of impact ejecta from Phobos and Deimos:

Faint dust rings have been observed by Voyager spacecraft's around Jupiter, Saturn, Uranus and Neptune. Small satellites are considered to supply dust particles (Colwell and

Esposito 1990). Because of the small masses of the Martian moons, escape velocity from their surface is less than 20 m/s. Impact ejecta from micrometeoroid bombardments would easily escape from their surfaces; dust rings or tori are expected to exist at Phobos and Deimos orbits (Soter, 1971). Duxbury and Ocampo (1988) examined image data by Viking Orbiter 1, but they could not find a dust ring whose optical depth is greater than 3×10^{-5} . However, PHOBOS-2 ASPERA detected decrease in magnetic field and increase in plasma density at Phobos orbit (Dubinin et al. 1990). A gas torus with dust is suggested. Horanyi et al. (1990) showed that the magnetic field due to solar wind as well as radiation pressure should change the orbit of small particles and they would not form a confined ring. Assuming that dust loss is due to Pointing-Robertson effect, Ip and Banaszkiewicz (1990) obtained a dust ring whose optical thickness is 6.6×10^{-6} . However, recapture of dust by the satellite is the most efficient mechanism for dust loss and this mechanism may reduce the estimated dust density by a factor 10-100.

Juhasz et al. (1993) reported a estimation of the average number of dust particles accumulated around Mars. As investigated earlier, submicron sized grains (radius $a < 1 \mu\text{m}$) are perturbed by electromagnetic forces and solar radiation pressure. Of larger grains ($1 \mu\text{m} < a < 7 \mu\text{m}$), perturbation by solar radiation pressure resulting in the collision with Mars is the major loss mechanism. The corresponding lifetime ranges from a few tens of days to half a Martian year. Dust grains with $a > 7 \mu\text{m}$ have relatively stable orbits forming a disk/torus around Mars, and their lifetime is determined by collision with the satellite since they stay close to its orbit. Despite the short lifetime of submicron-sized particles and the relatively large volume which contains their trajectories, their number density is comparable with that of particles whose size is between 7 and 50 μm . This is due to the fact that submicron-sized grains are thought to dominate the number of escaping particles. Juhasz et al. (1993) concluded that particle with sizes $a < 0.5 \mu\text{m}$ and $7 \mu\text{m} < a < 50 \mu\text{m}$ will be the most abundant in the Martian dust environment.

Recently Ishimoto et al. (1994), Hamilton (1994) and Horanyi and Juhasz (1994) take into account oblateness of Mars along with solar radiation pressure. Eccentricity of dust particles from Phobos largely increase and they are easily captured by Mars. Dust torus would be comprised of particles from Deimos. However, Sasaki (1994) points out that dust ejection when torus particles collide with satellites may keep high abundance of large (20-200 μm) particles from Phobos.

The PLANET-B orbiter with the eccentric equatorial orbit which crosses Phobos and Deimos orbits provides the opportunity to study the mass and velocity distribution of particles ejected from the surface of Phobos and Deimos by shower-meteors. The planned retrograde PLANET-B orbit assures larger relative velocity with prograde circumplanetary dust. The precise impact speed and mass distribution of shower meteors is known for meteors which are visible on Earth and approach the Mars (Terentjeva 1993). With an instrument much more sensitive than the Lunar Explorer 35 instrument it is expected to get highly reliable and quantitative data on ejecta particle fluxes and the suggested rings or tori at Phobos and Deimos orbits.

Efficiency of mass ejection from satellites at meteoroid impacts is one of the most important parameters that should control the dust abundance around Mars. Laboratory studies of micron and submicron ejecta particles were conducted by Schneider 1975 and Alexander et al. 1975 using millimeter-size primary particles at app. 4 km/sec impact speed. These measurements show that a very small mass ratio (10^{-4}) of high velocity ejecta particles to primary particle occurs. But all of the high speed ejecta are concentrated in the micron and submicron mass range. It is expected that the ratio of the mass of high velocity ejecta particles to the mass of the primary particle is significantly increased at higher impact speeds at which meteor impacts occur (15 km/sec - 60 km/sec). Zook et al. 1984 reported results from new hypervelocity impact experiments which showed that the number of secondary impact pits is more than 2 orders of magnitude higher than that previously thought (Schneider 1975) when oblique impacts dominate. MDC can measure both the interplanetary dust flux and the number density and size distribution of dust ring particles. Comparing with theoretical estimations of orbital motions of dust, we can give constraints on dust ejection efficiency and possibly surface property of satellites.

Charge of Martian dust is also one of important physical properties. Since Mars is lack of strong dipole magnetic field and then significant magnetosphere, the solar wind interacts with the atmosphere. Around Mars is only a low energetic plasma like on earth. Surface potential (equilibrium potential) of small particles could be app. 1 volt. It will be very difficult to measure

the influence charge of such small charged particles because the noise level of the MDC electronic is probably higher than the charge of the particles, but there will be some changes of the MDC compared to the MUSES-A MDC in order to decrease the noise level. With an enhanced sensitivity, it could be possible to determine the surface charge at least of bigger particles.

The upward transfer process of the dust from the Martian dust storms:

Since the periapsis of the S/C is 150 km from the Martian surface, it will be probably possible to detect dust coming from the Martian atmosphere. Carr (1990) reported that dust storms, such as the 300 km wide one found scurrying across the floor of the Argyre basin early 1977, carry micron-size particles high into Mars atmosphere. Dust storms often grow so large that they cloak the entire planet - as happened twice during 1977 as the Viking spacecraft looked on. At PLANET-B periapsis, relative velocity at dust impact is a few km/s. At TUM/LRT is a low velocity sand dust accelerator in operation. With this accelerator the MDC-PB could be calibrated in the velocity range below 1 km/s.

2.7.2 Instrument Specifications

The experiment will detect individual particles impacting on the sensor and will measure their mass, impact speed, direction and possibly charge. The MDC is based on an impact plasma detector. Figure 1 shows a basic principle of our measurement.

Dust particles - charged or uncharged - are detected by the plasma produced during the impact on the gold surface of the sensor box. The basic set-up of the MDC consist of a target and two charge collectors which are biased by positive and negative high voltage, separating the impact plasma into positively and negatively charged components. Connected to the charge collectors are charge sensitive amplifiers which convert the input charge into an output voltage. For each charge signal amplitude and risetime are evaluated. The risetime is a function of velocity and the pulse height is proportional to the mass and the speed to a constant power.

$$\begin{aligned} t &= c_g v^\eta \\ \pm Q/m &= c_r v^\beta \end{aligned}$$

with: m particle mass; v particle velocity; Q maximum charge; t signal risetime; c_r, c_g, β, η calibration constants.

The used charge sensitive amplifiers will be capable to measure charges in the order of $1 \cdot 10^{-15}$ Cb to $1 \cdot 10^{-10}$ Cb, which corresponds to a mass range of app. $2.5 \cdot 10^{-15}$ g to $2.5 \cdot 10^{-10}$ g or a diameter of app. $0.12 \mu\text{m}$ to $5.6 \mu\text{m}$ (with 2.7 g/cm^3) at a velocity of 10 km/s. In Figure 2 the sensitivity range of the MUSES-A MDC is displayed. The output of the amplifiers is digitized and stored by a transient recorder consisting of two 8 bit A/D converters, clocked with 2.5 or 5 MHz each and using a FIFO memory (see Figure 3). In order to minimize the error when converting four decades of input charges to 8bit data, the charge sensitive amplifiers have logarithmic response curves. A microprocessor system, 80C85 CPU with 4 Kbytes ROM and 32 or up to 64 Kbytes RAM, processes measured signals, controls the spacecraft interface and monitors voltages and temperatures. A switching power supply uses between 16 and 27 V input to generate a +5V output for the digital electronic, a ± 6 V output for the charge sensitive amplifiers and ≥ 200 V for the bias voltages of the charge collectors. The power consumption of the MDC will be between 3.5 and 4.5 Watts.

Over a measuring time of 200 μs around the impact time, the charge versus time information is recorded. The amount of impact data is 512 Byte per channel. Together with the impact data, calibration and housekeeping data valid for the time of impact are stored and transmitted down to the ground, giving the opportunity to inspect the real signals measured in space on the ground.

2.7.3 Instrument Configuration

The MDC consists of an electronic box with the electronics and a sensor box on top of the electronic box (see Figure 4). The sensor box has an opening of $100 \times 100 \text{ mm}^2$ which is covered with a steel grid. The MDC will be mounted with four flanges on to the side panel of the spin stabilized S/C (see Figure 5). The sensor will scan with its field of view, which is rotated by 360° around the rotational axis. There is the possibility to mount the MDC with an angle on the side panel to achieve that the centerline of the field of view of the MDC is shifted toward the rear side of the spacecraft in order to avoid sun light shining inside the sensor box. This eliminates noise signals due to photo ionization.

The MDC experiment measures the electrical charges generated by high velocity impacts of small mass particles on a gold-coated surface. The setup consists of a target and two charge collector plates which are biased by negative and positive voltages. The impact plasma is separated into positive ions on the negative collector and electrons and negative ions on the positive collector.

2.7.4 Size, Weight and Power Consumption

Size of MDC (W D H; mm): 120 * 120 * 180 (preliminary)

Weight of MDC : 0.6 kg

Power consumption (24V): 3.5(-4.5) W (preliminary)

2.7.5 Operation

The MDC is operated continuously during the whole mission. There will be no stand-by mode (TBD).

The on-board RAM will be large enough to store the detected impacts of two weeks if the dust flux don't exceed the expected mean flux. But it could occur that the memory is filled up already during one day or less if the MDC measures much higher dust fluxes in the case of dust rings at orbits of the mars satellites Deimos and Phobos. Normally every day, but at least once per week, the data should be transmitted to the ground station.

There is a Plasma Wave Sounder experiment on board PLANET-B, which could increase the measured noise of the MDC very much. There will be an onboard information sent to the MDC if the Plasma Wave Sounder is switched on and off, in order to minimize the noise measurements of the MDC. During the operation time of the Plasma Wave Sounder (around 20 minutes during periapsis) the Trigger Level of the MDC could be increased and additional the trigger logic of the MDC could be disabled during the time of the pulses. To achieve this, a programmable trigger logic will be implemented.

2.7.6 Commands and Telemetry Items

The format of all commands and telemetry items is similar to the Intel-Hex-format. There are two different types of commands:

Type 1: Discrete Commands

0	AA	1	C

Type 0: Block Commands (and Telemetry)

L	AA	0	data	C

L: number of data bytes (Length)

AA: Address (2 byte)
data: L data bytes
C: Checksum:

2.7.6.1 Commands

Discrete Commands:

XY	name	function
01 (preliminary)	MDC ON	MDC Power On
02 (preliminary)	MDC OFF	MDC Power Off
22	Mode Change	Communication Mode Change
30 (preliminary)	FCALL	Initialize Function Call Block Command
31 (preliminary)	PSET	Initialize Parameter Set or Data Transmission Block Command
40 (preliminary)	HV OFF	switch HV off (TBD)
80 (preliminary)	HV ENABLE	enable HV switch on (TBD)
C0 (preliminary)	HV ON	switch HV on (TBD)

Block Commands:

Each Command Block starts with one DC followed by some BC (max 254 bytes) and one ECW. The first BC (nr) gives the number of all BC in the Command Block the second (A) and third BC (A) gives a address and the last BC consists of a Check Sum. At the end of each Command Block follows the ESC byte, which gives the number of all bytes of the Command Block.

DC	nr	A	A	data		data	CS	ECW

There are two different types of Block Commands:

Function calls:

30	3	A	A	CS	ECW

Parameter Set:

31	3+L	A	A	data		data	CS	ECW

L: number of data bytes (Length)
AA: Address (2 byte)
data: L data bytes
CS: Checksum:

As the software of the MDC is not finished yet, here only a preliminary list of Block Commands is given.

DC	nr	A	A	CS	ECW	name	function

30	3	00	02	FB	5
30	3	00	04	F9	5
30	3	00	06	F7	5
30	3	00	08	F5	5
30	3	00	0A	F3	5

RESET	reset MDC CPU
CLEAR	clear MDC-RAM and start RESET
TEST	generation of test pulses for amplifier calibration
PWSON	PWS is ON (TBD)
PWSOF	PWS is OFF (TBD)

DC	nr	A	A	data....	CS	ECW
31	3+L	?	?	L*data	?	5+L
31	3+L	?	?	L*data	?	5+L
31	3+L	?	?	L*data	?	5+L
31	3+L	?	?	L*data	?	5+L
31	3+L	?	?	L*data	?	5+L
31	3+L	?	?	L*data	?	5+L
31	3+L	?	?	L*data	?	5+L

name	function
SETCSA1	set sensitivity of charge amplifiers (1)
SETTL1	set Trigger Level 1
SETTLPWS1	set Trigger Level 1 valid during PWS operation
SETCSA2	set sensitivity of charge amplifiers (2)
SETTL2	set Trigger Level 2
SETTLPWS2	set Trigger Level 2 valid during PWS operation
SETTMSA	set Telemetry Start Address

2.7.6.2 Telemetry Items

Housekeeping Values

Bilevel Data of MDC

Address (Hex)	S/S NAME	Bit	ITEMS	STATUS	
				1	0
F800	MDC1	B0	Temp Out of Range		
		B1	HV Out of Range		
		B2	AnalogV Out of Range		
		B3	DigitalV Out of Range		
		B4	CPU RUN/RESET	RUN	RESET
		B5	DC Test Handling		
		B6	Noise Alarm		

F801	MDC2	B7			
		B0	HV ON/OFF	ON	OFF
		B1	HV ENA/DIS	ENA	DIS
		B2			
		B3			
		B4			
		B5			
		B6			
		B7			

Analog HK Item of MDC

WORD	Address (HEX)	ITEM	Unit	Range	
	F802	HV +200V	V		
	F803	HV -200V	V		
	F804	Temp. (electronics)	C	-50- +100	
	F805	Command status/count			
	F806	Impact Count			
	F807	Noise Count (MSB)			
	F808	Noise Count			
	F809	Noise Count (LSB)			
	F80A	Event/Reject Count			

Data: ** TBD **

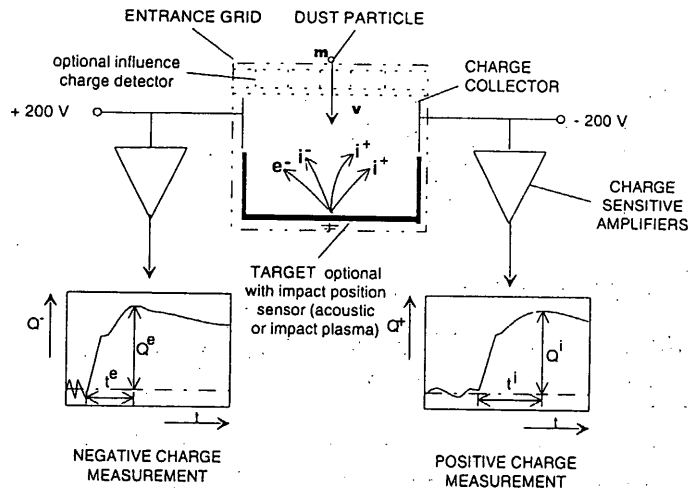


Figure 1: Measurement principle of the MDC plasma impact detector. The velocity and mass of the particles is calculated from the charge signal measured on the two electrodes.

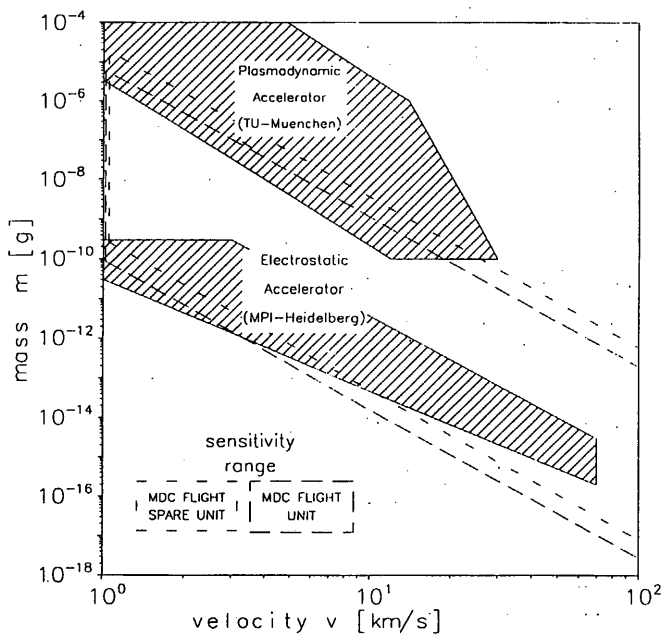


Figure 2: Sensitivity range of the MUSES-A MDC and capability of the accelerators which are used for calibration.

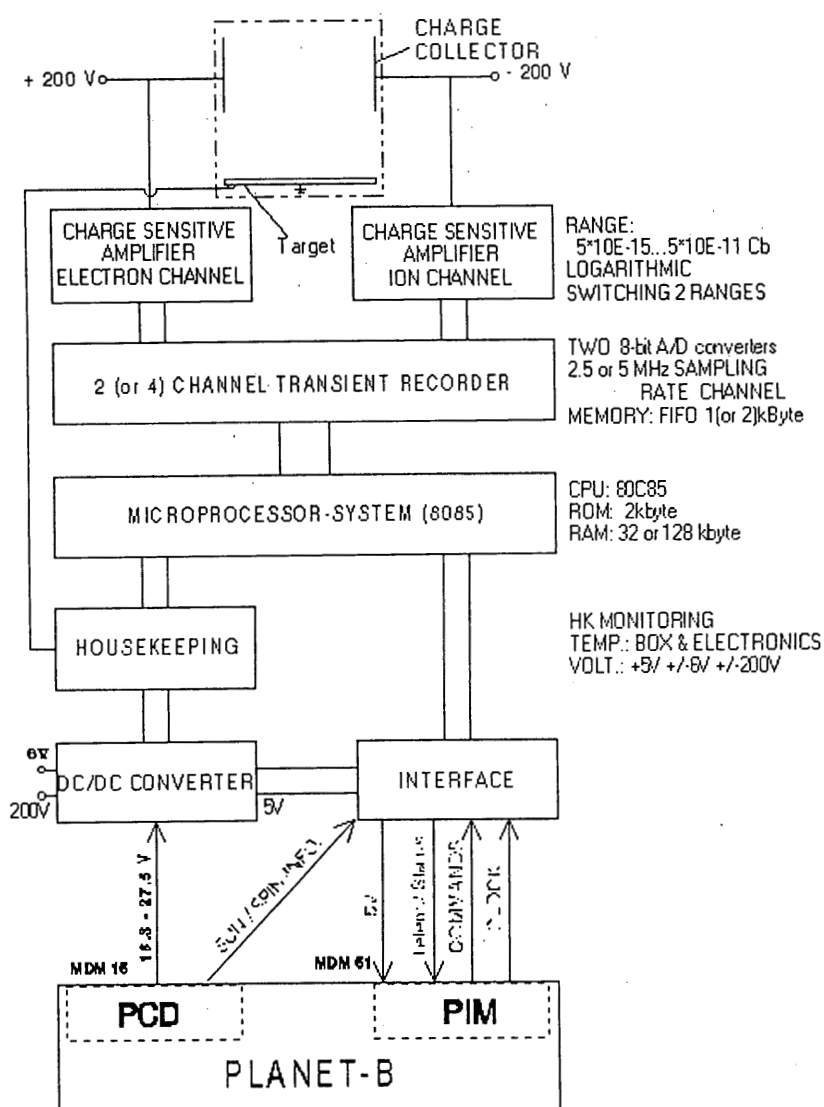


Figure 3: Functional block diagram of the Mars Dust Counter.

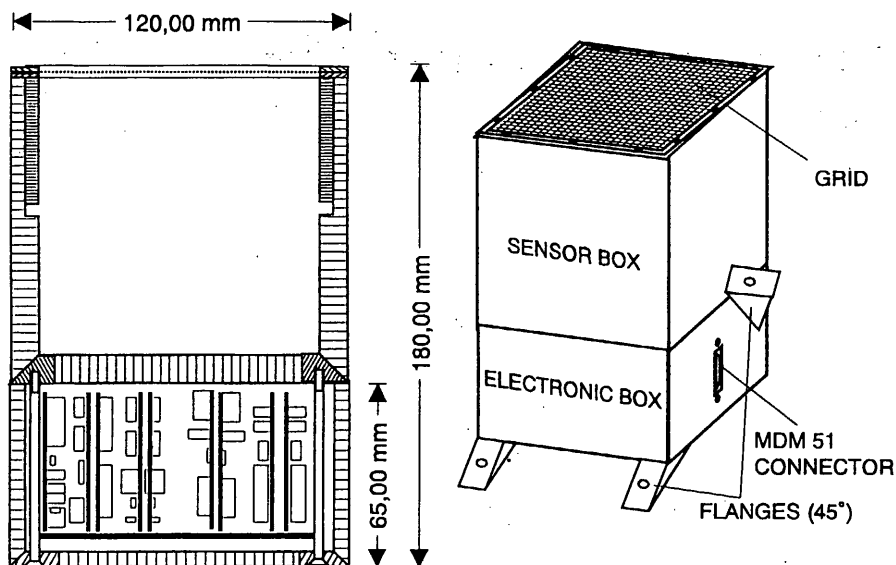


Figure 4: Outline of Mars Dust Counter mechanical design. The dimensions of the MDC which are displayed in this figure will be corrected in dependence of the size of the electronics and the type of honeycomb structure which will be used.

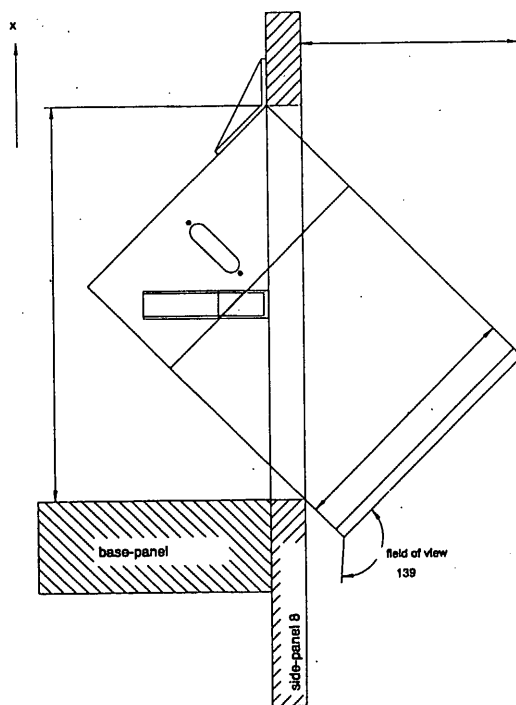


Figure 5: The MDC will be mounted with four flanges on to the side panel of the spin stabilized S/C. The sensor will scan with its field of view, which is rotated by 360° around the rotational axis.

2.8 Neutral Mass Spectrometer (NMS)

T.B.S.

2.9 Radio Science

Principal investigator

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2.9.1 Objectives of Radio Science Observation

The purpose of the radio science observation is summarized as follows.

- (1) Temperature-pressure profile of Martian neutral atmosphere, from the surface to the altitude of 60 km, for various latitudes and longitudes.
- (2) Electron number density of the ionosphere as a function of altitude both for dayside and night side with daily basis.
- (3) Turbulance in the solar plasma density

2.9.2 Observation

Radio science observation is possible only when the raypath of the radio wave transmitted from the spacecraft to the earth penetrates the atmosphere or the ionosphere of Mars (Fig.1). Since the refractive index there is slightly (several parts in 10^{-6} at maximum) different from unity, the radio wave is refracted, or scattered while travelling near Mars. The effect appears as a variation of the amplitude and/or phase in the received signal. The information noted above ((1) to (3)) can be reconstructed from them. Therefore, the trajectory of the spacecraft during its Mars orbital phase is essential to radio science observation. We need to design an orbit which allows the spacecraft occulted by Martian atmosphere as frequently as possible. The spacecraft velocity perpendicular to the line of sight also affects the observation since the variation in the amplitude and phase of the signal is a function of the position of the spacecraft, and the position is mapped into time through the velocity. It will be discussed in detail below.

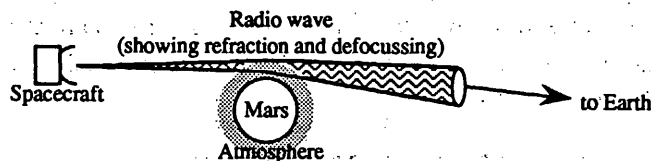


Figure 1. Radio science observation needs an occultation of the spacecraft by Martian atmosphere.

Usuda Deep Space Center, located in Usuda Town, Nagano, Japan, will be used as the main data collection station. If we can also use other receiving station equipped with an appropriate data recording system, it may increase the possible radio science observation opportunity, especially if it is located far in longitude from Usuda and can cover the time period while the spacecraft is not visible from Usuda. However, such a collaboration with other institute has not yet been planned at this moment.

The observation and preparation for it are scheduled in the following way:

Before launch:	Characterization of the onboard oscillator stability
Cruise phase:	Characterization of the onboard oscillator stability, the effect of Earth ionosphere and neutral atmosphere, including the front-to-end test of the system
Solar conjunction:	Solar plasma
Mars orbital phase:	Atmosphere and ionosphere of Mars

All the items after the launch of the spacecraft need to be conducted using one way (based on the onboard oscillator) mode to eliminate the effect of the media onto the uplink radio wave, and any modulation be turned off to increase the carrier power (Table 1). Coherently related S and X band signals need to be used simultaneously to know the frequency dependence of the phase and amplitude variation. It is important to distinguish or remove the effect of plasma in the ionosphere or solar wind from other effects (neutral atmosphere) with better accuracy than using only one of them.

One way / two way	One way (downlink based on the onboard oscillator)
Modulation to the downlink carrier	Off
Frequency band	S and X (simultaneously)

Table 1. Spacecraft mode for radio science observation

2.9.3 Data Collection

Since this observation is based on the amplitude and phase of the radio wave, those information need to be preserved all through the data recording process. An open-loop receiver (Fig.2) will be used for this purpose. It simply records the received signal coherently after converting the frequency from S or X band down to video band ($\sim 20\text{kHz}$). H-maser will be used for creating all the local signals at the downconverters to preserve the phase information (Table 2: phase stability of the H maser time standard equipped in Usuda). The total data rate is $\sim 160\text{kBytes/s}$, and ~ 20 hours of data can be recorded on one magnetic tape ($\sim 10\text{GBytes/tape}$).

Time scale	Square root of Allan variance
1 s	5×10^{-13}
10 s	5×10^{-14}
100 s	5×10^{-15}
1000 s	1×10^{-15}

Table 2. Stability of H maser. It must be much better than the oscillator onboard the spacecraft.

The collected data will be shipped to ISAS soon after the observation and physical information will be extracted using software library currently being developed on Sun SPARC station. Compressed and archived dataset will also be created from the original data and distributed using anonymous ftp and/or WWW service to other researchers.

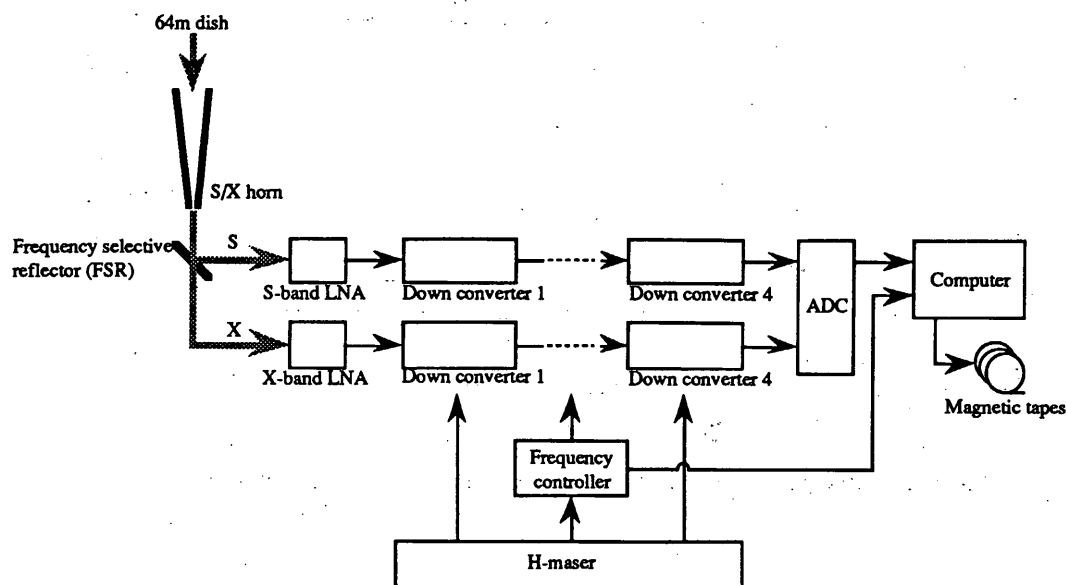


Figure 2. Usuda Open-loop data recording system

2.9.4 Requirement to the onboard system

For the observation of neutral atmosphere of Mars, the onboard oscillator needs to be accurate enough because the frequency dependence of the phase variation is the same for the two ($\Delta\phi \propto \nu$), while the effect of plasma has a different dependence ($\Delta\phi \propto \nu^{-1}$). In the case of S-band, the total phase variation due to the Mars neutral atmosphere is estimated to be ~ 20 cycles (Fig.3) when the radio wave travels near the surface of Mars. Ray bending angle there is ~ 0.01 degrees. To measure such a small phase variation, the phase (or frequency) stability of the onboard oscillator, seen on Earth, needs to be as good as Table 3.

Time scale	Square root of Allan variance
0.1 s	1×10^{-11}
1 s	2×10^{-12}
10 s	2×10^{-12}
100 s	2×10^{-11}

Table 3. Phase (frequency) stability required to the spacecraft

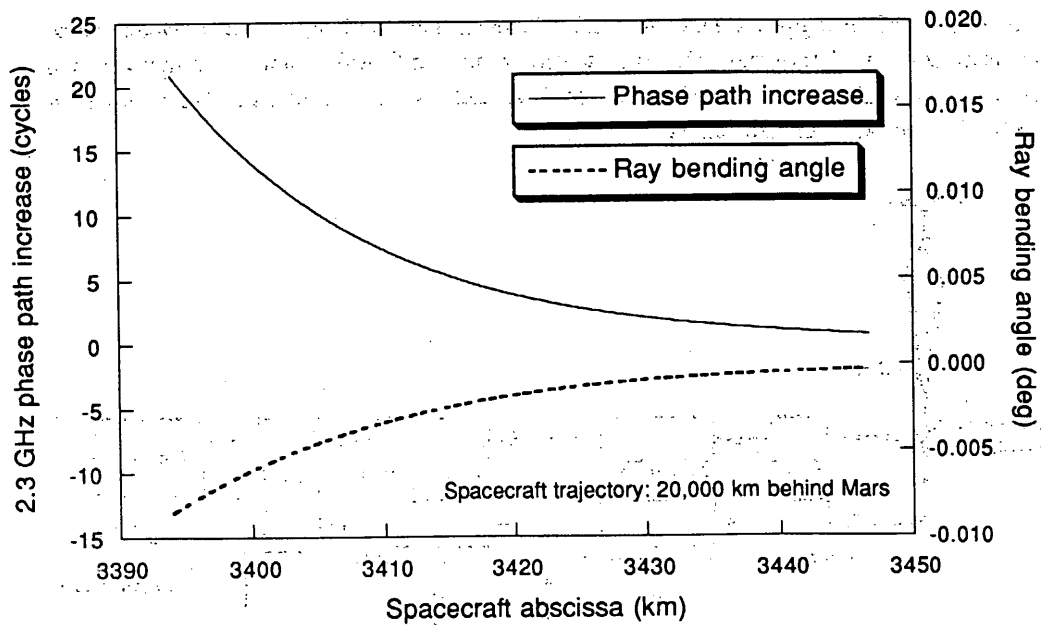


Figure 3. Phase change, and ray bending angle due to Mars neutral atmosphere.

2.10 Theory and Modeling

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2. 10. 1 Objective

The principal objective of this theoretical and modeling research is to develop comprehensive theoretical models of the atmosphere and the plasma environment of Mars. These models are used to estimate various physical parameters and to predict physical processes prior to the Planet-B launch. After the launch, the models will be improved by including new data obtained by the Planet-B for a more complete understanding of various processes at Mars.

2. 10. 2 Pre-launch Research

Numerical modeling is a primary part of this research, although basic theory of the atmosphere and plasma is also developed. Thanks to rapid development of computers, it is now possible to construct fairly realistic global models for the atmosphere and the solar wind interaction with Mars. In the pre-launch period, various simulation models are to be constructed. In particular, emphasis will be placed on the following theoretical models:

- 1) A global MHD simulation model of the solar wind interaction with Mars
- 2) A global simulation model of the thermosphere, ionosphere, and lower atmosphere
- 3) Photochemical models of the upper atmosphere and ionosphere

Using the models and the data obtained by the previous observations, we will make prediction of:

- 1) Important physical parameters, such as magnetic fields, densities, and velocities of the ionosphere.
- 2) Physical environment of previously unexplored regions, such as the subsolar region and the midnight region in the ionosphere.
- 3) Variations of the atmosphere, ionosphere, and the magnetosphere

2. 10. 3 Post-launch Research

The Planet-B will provide us with a variety of data of the Martian upper atmosphere, ionosphere, magnetosphere, and the solar wind interaction with Mars. The models developed in the pre-launch period will be further improved by including the new data. By comparing the modeling results with the data, it is possible to greatly enhance our understanding of physical processes in the Martian environment.

The goal of this post-flight research is to resolve the following major problems:

- 1) Structure and dynamics of the upper atmosphere, ionosphere, and magnetosphere
- 2) Nature of the solar wind interaction with Mars
- 3) Magnitude of a possible intrinsic magnetic field
- 4) Thermal and non-thermal escape rates of the atmosphere
- 5) Effects of dust storms on the upper atmosphere and ionosphere

In addition, the models will provide theoretical interpretation for unforeseen phenomena which might be discovered by the Planet-B.

2.11 Field of View of the Scientific Instruments

T. Yamamoto (ISAS)
NEC

Field of view of the scientific instruments is shown in Figure 2.11-1.

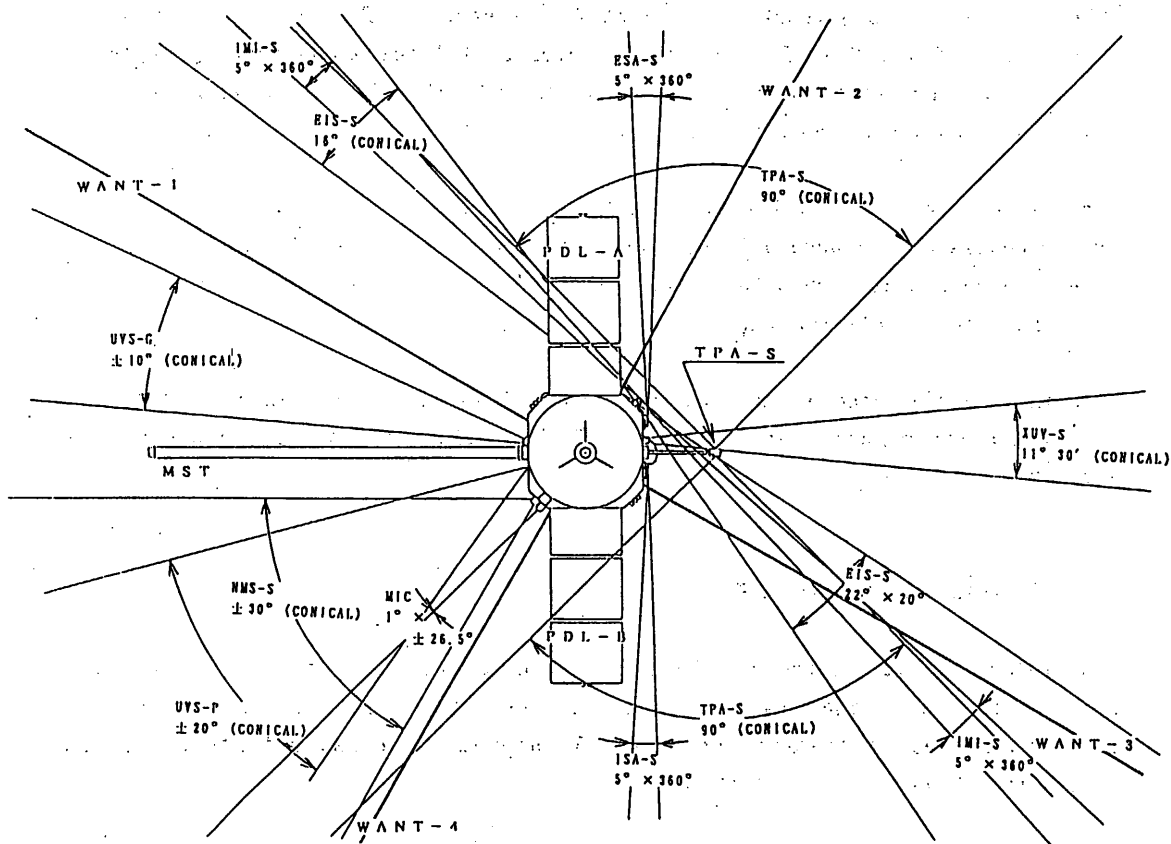


Figure 2.11-1. Field of View of the Scientific Instruments

3. Communications System

T. Takano, T. Yamada, Z. Yamamoto and M. Ichikawa (ISAS)
NEC Corporation

3.1 Parameters and Performance of the Whole System

3.1.1 TT&C Schemes

3.1.1.1 General

The communications network of the PLANET-B is shown in Fig. 1. The communications links of the PLANET-B consist of command, telemetry and ranging links in simultaneous transmission scheme in S-band, and telemetry or ranging links in switched transmission scheme in X-band.

The block diagram of the PLANET-B communications system is shown in Fig. 2. The system consists of S-band antennas, an X-band antenna, S-band duplexers (SDIP), S-band receivers (SBRs), an S-band transmitter (TMS), an X-band transmitter (TMX) and an X-band power amplifier (XPA).

The major performance of the communications subsystem is summarized in Table 1. The modulation signal characteristics of the uplink and downlink are shown in Table 2.

3.1.1.2 Telemetry Subsystem

The telemetry data transmission will be performed through S-band and/or X-band. S-band downlink signal is transmitted by one of the 3 antennas, and X-band downlink signal is transmitted by HGA-X antenna. The major features of the telemetry subsystem are as follows:

- (a) All the telemetry data are encoded in a concatenated manner using a Reed-Solomon code as the outer code and a convolutional code as the inner code.
- (b) The S-band telemetry data can be sent simultaneously with ranging signal. The X-band telemetry data will be sent independently without ranging signal.

- (c) TMS has two transmitter power modes (i.e. High Power mode and Low Power mode). The optimum combination of a transmitter power mode and an antenna should be selected by commanding. It depends upon the altitude of the spacecraft to satisfy the power flux density specification due to the Radio Regulations.

X-band transmitting system would be make use of the mission data transmission at far from the earth area. So, X-band transmission power mode is only High Power mode, not equipped Low Power mode.

3.1.1.3 Command Subsystem

- (a) A command bit rate should be selected depending upon operation conditions between 15.625bps and 125bps.
- (b) The command subsystem can be operated simultaneously with the ranging system.
- (c) A command phase modulation index should be selected depending upon operation conditions from the followings:

0.6 rad : commanding alone mode

0.5 rad : commanding & ranging mode.

- (d) Two S-band Receivers (SBRs) are connected to two of LGA-A, LGA-B and HGA-S.
- (e) The S-band uplink acquisition is achieved by sweeping a non-modulated carrier sent from an tracking station. The tracking range of SBR is $\pm 120\text{kHz}$, and the frequency sweep rate should be less than 20kHz/sec .

3.1.1.4 Ranging Subsystem

- (a) The ranging subsystem operation is performed in either combination of the S-band uplink / S-band downlink, or the S-band uplink / X-band downlink.
- (b) The spacecraft transponder can be set to either of coherent or non-coherent mode. Coherent frequency ratios are as follows:

• S-band downlink / S-band uplink = 240/221

• X-band downlink / S-band uplink = 880/221.

(c) Ranging scheme is determined by the equipments at a communicating tracking station. For example, UDSC has a sequential ranging system with clock frequency of approximately 516kHz, and JKSC has a PN code ranging system.

(d) A ranging phase modulation index of S-band uplink should be selected depending upon operation conditions from the followings:

1.2 rad : ranging alone mode

0.7 rad : commanding & ranging mode.

(e) The transponder 3dB bandwidth for the ranging signal is approximately 4MHz.

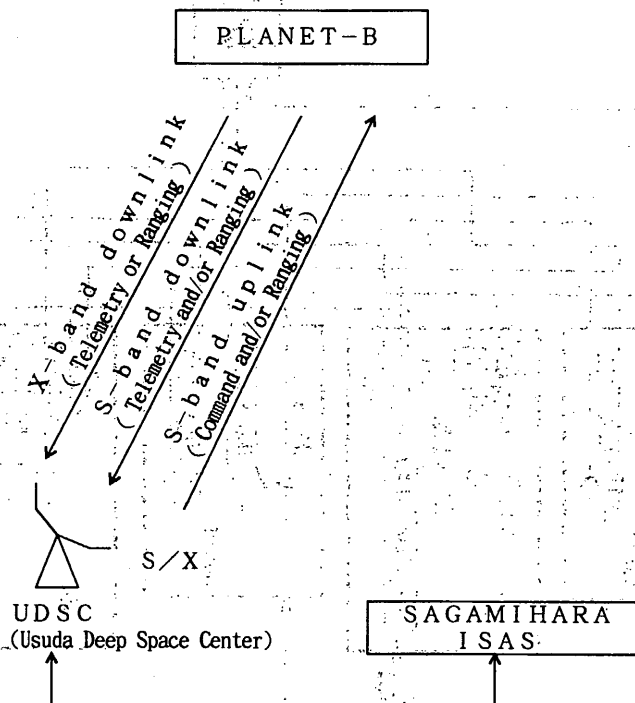
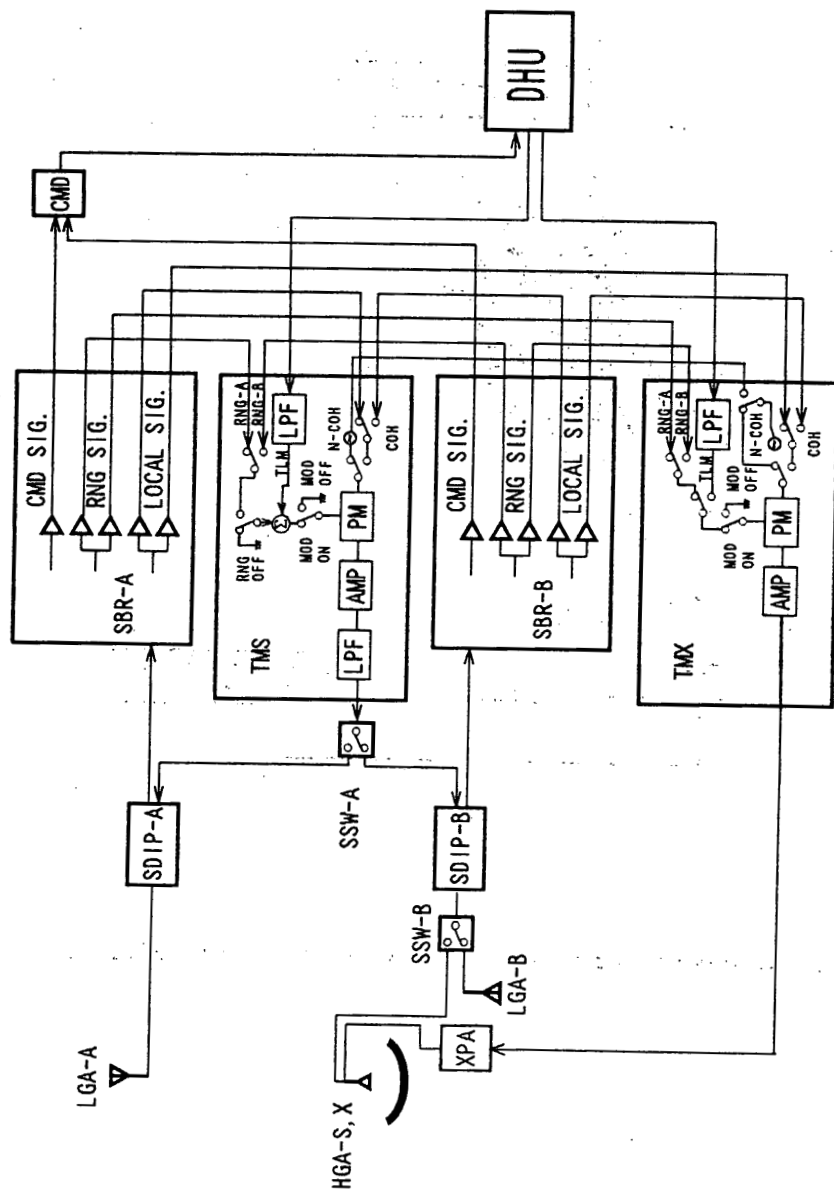


Fig. 1. Communications System for PLANET-B



CMD : Command Decoder
 DHU : Data Handling Unit

Fig. 2. Block Diagram of an On-board Communications System

Table 1. Major Performance of Communications System

Component	Performance
S-Band Transmitter (TMS)	Frequency : 2.2GHz (Tx Band) RF Output Power : 2.5W (High) TBDW (Low) Signal : Telemetry, Ranging (Refer to Table 2)
X-Band Transmitter (TMX)	Frequency : 8.4GHz (Tx Band) RF Output Power : 5.0W (with XPA : X-Band Power Amplifier) Signal : Telemetry, Ranging (Refer to Table 2)
S-Band Receiver-A, B (SBR-A, B)	Frequency : 2.1GHz (Rx Band) Signal : Command, Ranging (Refer to Table 2) Noise Figure : 2.6dB
S-Band Low Gain Antenna-A (LGA-A)	Frequency : 2.1GHz (Rx Band) : 2.2GHz (Tx Band) Type : Cross Dipole Gain : 0.0dBi min ($\pm 45^\circ$) : -10.0dBi min ($\pm 90^\circ$) Polarization : RHCP
S-Band Low Gain Antenna-B (LGA-B)	Frequency : 2.1GHz (Rx Band) : 2.2GHz (Tx Band) Type : Cross Dipole Gain : 0.0dBi min ($\pm 45^\circ$) : -10.0dBi min ($\pm 90^\circ$) Polarization : RHCP
S-Band High Gain Antenna (HGA-S)	Frequency : 2.1GHz (Rx Band) : 2.2GHz (Tx Band) Type : 1.6m ϕ Parabolic Mesh Antenna Gain : Rx 25.8dBi min (peak)/ $\pm 2.9^\circ$ (-3dB) 25.7dBi min (Off beam angle 0.4°) : Tx 28.0dBi min (peak)/ $\pm 2.7^\circ$ (-3dB) 27.9dBi min (Off beam angle 0.4°) Polarization : RHCP
X-Band High Gain Antenna (HGA-X)	Frequency : 8.4GHz (Tx Band) Type : 1.6m ϕ Parabolic Mesh Antenna Gain : Tx 38.5dBi min (peak)/ $\pm 0.7^\circ$ (-3dB) 37.6dBi min (Off beam angle 0.4°) Polarization : RHCP

Table 2. Modulation Signals

Link	Band	Signal	Bit Rate	Modulation Form	Subcarrier Frequency	Modulation Index	Coding / BER
Up	S	Command	15.625bps / 125bps	PCM-PSK -PM	4000Hz (Sine wave)	0.6 rad (Commanding alone) 0.5 rad (Commanding & Ranging)	
		Ranging	Clock Freq. ≈ 516kHz (Square wave)	Tone-PM	—	1.2 rad (Ranging alone) 0.7 rad (Commanding & Ranging)	
Down	S	Telemetry	64bps~ 1024bps	PCM-PSK -PM	8192Hz (Square wave)	0.7 rad	Concatenated coding (Reed-solomon code + Convolutional code) BER=1×10 ⁻⁵
		Ranging	Clock Freq. ≈ 516kHz (Square wave)	Tone-PM	—	0.5 rad	
	X	Telemetry	2048bps~ 32768bps	PCM-PM	—	1.2 rad	Concatenated coding (Reed-solomon code + Convolutional code) BER=1×10 ⁻⁵
		Ranging	Clock Freq. ≈ 516kHz (Square wave)	Tone-PM	—	0.9 rad	

3. 1. 2 S p a c e c r a f t S e g m e n t s

3.1.2.1 Coverages of PLANET-B Antennas

The PLANET-B antenna coverages are shown in Fig. 3. The antenna subsystem consists of an S-band High Gain Antenna(HGA-S), an X-band High Gain Antenna(HGA-X), and S-band Low Gain Antennas (S-band LGA-A and B). The S-band and X-band HGA are directed to the earth. The patterns of the LGA-A and -B cover the upper-side and the lower-side of the spacecraft, respectively.

3.1.2.2 EIRP and G/T of PLANET-B

The EIRP and G/T of the PLANET-B are shown in Table 3.
Details of circuit losses are shown in Table 4.

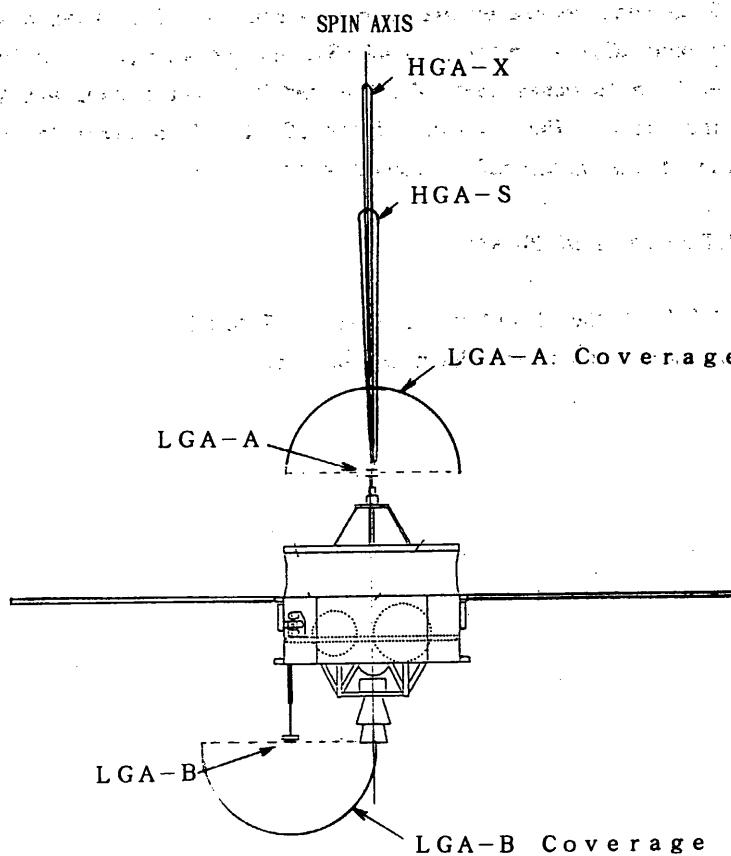


Fig. 3. Coverages of PLANET-B Antennas

Table 3. PLANET-B EIRP and G/T

Parameter	S-band			X-band
	LGA-A	LGA-B	HGA-S	HGA-X
Uplink G/T	Antenna Gain (dBi)	0.0 ($\pm 45^\circ$)	25.8 (Peak)	
	System Noise Temperature (dBK)	25.4	25.3	
	Receiver NF (dB)	2.6	2.6	
	Circuit Loss (dB)	1.4	2.1	
	Antenna Noise Temperature (K)	40 (<0.1AU)	40 (<0.1AU) 5 (>0.1AU)	
Downlink EIRP	G/T (dB/K)	-26.8	-27.8	-1.3
	RF Output Power (dBm)	34.0 (2.5W)	34.0 (2.5W)	37.0 (5.0W)
	Circuit Loss (dB)	1.9	2.5	2.2
	Antenna Gain (dBi)	0.0 ($\pm 45^\circ$)	0.0 ($\pm 45^\circ$)	38.5 (Peak)
	EIRP (dBm)	32.1	31.5	59.8

Note :
* 1 Included in Antenna Gain

Table 4. PLANET-B Circuit Losses (S-Band)

Antenna RX or TX max or min	LGA-A				LGA-B				HGA-S			
	RX		TX		RX		TX		RX		TX	
	max	min	max	min	max	min	max	min	max	min	max	min
Coaxial Cable *1 dB	0.7 (1.1m)	0.4 (1.1m)	4.1 (1.7m)	0.6 (1.7m)	1.4 (2.3m)	0.9 (2.3m)	1.6 (2.6m)	1.0 (2.6m)	1.0 (1.6m)	0.6 (1.6m)	1.2 (2.0m)	0.8 (2.0m)
SSW-A dB	—	—	0.2	0.1	—	—	0.2	0.1	—	—	0.2	0.1
SDIP dB	0.9	0.7	1.0	0.8	0.9	0.7	1.0	0.8	0.9	0.7	1.0	0.8
SSW-B dB	—	—	—	—	0.2	0.1	0.2	0.1	0.2	0.1	0.2	0.1
Total dB	1.6	1.1	2.3	1.5	2.5	1.7	3.0	2.0	2.1	1.4	2.6	1.8
Mean dB	1.4		1.9		2.1		2.5		1.8		2.2	

Note :

* 1 Semirigid Coaxial Cable (SJ50-3.6) Loss Per Unit :
max 0.6 dB/m
min 0.4 dB/m

3. 1. 3 Ground Segments

3.1.3.1 Operations

A ground segment of the communications system to be used depends on an operation mode.

(1) In Normal Operation

UDSC is used in normal operation mode. The real-time and the reproduced telemetry data are obtained in S-band and X-band. The commanding should be operated in S-band. The ranging should be operated in the S-band uplink / S-band downlink, or the S-band uplink / X-band downlink.

(2) In Emergency Operation

TBD

(3) JKSC Operation

TBD

3.1.3.2 EIRP and G/T of tracking Station

The EIRP and G/T of the UDSC ground tracking station are shown in Table 5.

RF characteristics are based on measured data except the increase of system noise temperature due to antenna elevation, which is assumed 15K for S-band, and 17K for X-band at 10-degrees elevation angle in this link analysis.

Table 5. Communications Capabilities of UDSC (Usuda Deep Space Center)

Frequency Band			S	X
Uplink	Frequency	MHz		
	RF Power Output	dBm	53(200W), 63(2kW), 73(20kW) [Selectable]	
	Feeder Loss	dB	0.9	
	Antenna Gain	dBi	61.6	
	EIRP	dBm	113.7, 123.7, 133.7 [Selectable]	
	Polarization		RCP	
Downlink	Frequency	MHz		
	Antenna Gain	dBi	61.6	70.5
	Antenna Noise Temperature	K	40.1 (EL=90°)	26.7 (EL=90°)
	Receiver NF	K	35.0	54.4
	System Noise Temperature K	EL=90°	75.1* ¹ [33]* ²	81.1* ¹
		EL=10°	90.1* ¹ [48]* ²	98.1* ¹
	G/T dB/K	EL=90°	42.8 [46.4]	51.4
		EL=10°	42.1 [44.7]	50.6
	Polarization		RCP	RCP

Note :

* 1 Values for common use of S-band and X-band.

* 2 The values for exclusive use of S-band. (measured in 1984.10)

3. 1. 4 Link Analysis

3.1.4.1 Conditions for the Analysis

(1) The spacecraft orbit

The spacecraft orbit consists of the following phases:

- (a) Trans-Lunar Phase (S/C Attitude : Solar Pointing [Except for ΔV periods])
(4 months)

Orbit : 1000km $\times$ 400,000km (11 days)

Apogee 1.71Mkm (Between 1st & 2nd Swing-by)

- (b) Trans-Mars Phase:

- Phase 1 (S/C Attitude : Solar Pointing) (75 days)

Earth Range : 7288km $\rightarrow$ 15Mkm

- Phase 2 (S/C Attitude : Earth Pointing) (7 months)

Earth Range : 15Mkm $\rightarrow$ 1.7AU (250Mkm)

- (c) Planet Mars Phase (S/C Attitude : Earth Pointing) (2 years)

Orbit : 150km $\times$ 14RM (Altitude)

Earth Range : 0.5AU (70Mkm) $\rightarrow$ 2.5AU (375Mkm)

The apogee (2.5AU) of Planet Mars Phase is the farthest distance assumed for link calculations.

(2) EIRP and G/T of PLANET-B

Refer to 3.1.2.2

(3) EIRP and G/T of earth Station

Refer to 3.1.3.2

(4) Required C/No

The required C/No for the S-band uplink is shown in Table 6.

The required C/No for the S-band and X-band downlinks are shown in Table 7.

Table 6. Uplink Required C/No

Signal Name	Uplink			
	S-Band			
	Command		Ranging	Carrier
Modulation Form	PCM-PSK-PM	PCM-PSK-PM	Tone-PM	_____
Bite Rate	15.625bps	125bps	516kHz	_____
Modulating	Sinewave sub-carrier of 4kHz	Sinewave sub-carrier of 4kHz	Squarewave	_____
Modulation Index (rad)	0.6	[0.5] ^{*1}	1.2 [0.7] ^{*2}	_____
Modulation Loss (dB)	7.84	[11.63] ^{*1}	_____	0.80 (Command) [2.88] ^{*1}
Band Width, Bite Rate (dB·Hz)	11.94	20.97	_____	16.02 (2BL=40Hz)
Hardware Loss (dB)	1.5	1.5	_____	0.0
Required S/N (dB)	9.6 (BER=1×10 ⁻⁵)	9.6 (BER=1×10 ⁻⁵)	_____	13.50
Required C/No (dB·Hz)	30.9	[43.7] ^{*1}	_____	30.3 [32.4] ^{*1}

Note :

* 1 Values for simultaneous operation with ranging.

* 2 Values for simultaneous operation with command.

Table 7. Downlink Required C/No

Signal Name	Downlink							
	S - Band				X - band			
	Telemetry	Ranging	Carrier	Telemetry	Ranging	Carrier		
Modulation Form	PCM-PSK-PM	Tone-PM	—	PCM-PM	Tone-PM	—		
Bite Rate	64bps~1024bps	516kHz	—	2048bps ~ 32768bps	516kHz	—		
Modulating	Squarewave sub-carrier of 8192Hz	Squarewave	—	Squarewave	Squarewave	—		
Modulation Index (rad)	0.7	0.5	—	1.2	0.9	—		
Modulation Loss (dB)	3.82 [4.95]* ¹	ML	[3.46]* ¹	0.61	ML	8.82 (Telemetry)		
Band Width, Bite Rate (dB-Hz)	18.06~30.10	0.0	10.0 (2BL=10Hz)	4.77 (2BL=3Hz)	0.0	10.0 (2BL=10Hz)	4.77 (2BL=3Hz)	
Hardware Loss (dB)	1.5	—	0.0	1.9	—	0.0	0.0	
Required S/N (dB)	2.7 * ² (BER 1×10^{-5})	9.0 (Threshold)	13.5	2.7 * ² (BER 1×10^{-5})	9.0 (Threshold)	13.5	13.5	
Required C/No (dB-Hz)	26.1~38.1 [27.2~39.3]* ¹	9.0+ML	[27.0]* ¹	38.3~50.4	9.0+ML	32.3	27.1	

Note :

* 1 Square brackets represent the values for simultaneous operation with ranging.

* 2 Concatenated coding (Reed-solomon code + Convolutional code)

3.1.4.2 Results of Link Calculations

The summary of link margins is shown in Table 8.

At the distance of 2.5AU, commanding with 15.625bps is capable with the margin of 3.9dB using LGA-A in S-band. Telemetry with 2048bps will be pursued with the margin of 1.9dB using HGA in X-band. Ranging using HGA-S for uplink and HGA-X for downlink has sufficient margin of 17.8dB.

Examples of link calculation are shown in Table 9, 10, 11 and 12 for command in S-band, telemetry in S-band and X-band.

The characteristics of telemetry link margin vs slant range are shown in Fig. 4 and Fig. 5.

The estimated receiving power dynamic range is shown in Table 13.

Table 8. PLANET-B Link Margin Summary

Signal Name	Slant Range	S/C Antenna	Bite rate	Link Margin	Remarks
Command	0.1AU	LCA-B ($\pm 90^\circ$)	125bps	(8.0 dB) *1	
	2.5AU	LCA-A ($\pm 45^\circ$)	15.625bps	3.9 dB	Refer to Table 9
		HCA-S	125bps	(16.4 dB) *1	Refer to Table 10
Telemetry (S-band)	2.5AU	HCA-S	64bps	2.7 dB (1.6 dB) *1	Refer to Table 11 Refer to Fig. 4
			1024bps	-9.3 dB (-10.4 dB) *1	
Telemetry (X-band)	2.5AU	HCA-X	2048bps	1.9 dB	Refer to Table 12 Refer to Fig. 5
			32768bps	-10.1 dB	
Ranging	2.5AU	HCA-S /HCA-S	—	0.2 dB [2.5 dB] *2	
	2.5AU	HCA-S /HCA-X	—	17.8 dB	

Note :

* 1 Values for simultaneous operation with Ranging.

* 2 Values for simultaneous operation with Command and Telemetry.

Table 9. PLANET-B S-BAND CMD LINK st UDSC S/C-ANT:LGA

PARAMETER		UP LINK	REMARKS
TRANSMIT. POWER	dBm	73.0	20kW
TRANSMIT. FEEDER LOSS	dB	-.9	
TRANSMIT. ANT. GAIN	dB	61.6	64m
EIRP	dBm	133.7	
TRANSMIT. POINT. LOSS	dB	-.1	
POLARIZATION LOSS	dB	0.0	
SPACE LOSS	dB	-270.4	2.1GHz, 2.5AU
ABSORB. & RAIN LOSS	dB	-.2	
RECEIV. POINT. LOSS	dB	0.0	
RECEIV. ANT. GAIN	dB	0.0	LGA-A +-45deg
RECEIV. FEEDER LOSS	dB	-1.4	
RECEIV. SIGNAL POWER	dBm	-138.4	
NOISE POWER DENSITY	dBm/Hz	-173.2	Ta=40K, NF=2.6dB
G/T	dB/K	-26.8	
C/NO	dB-Hz	34.8	
MODEM PARAMETER		CMD 15.625bps	CARRIER
MOD. INDEX	rad	.6	----
MOD. LOSS	dB	7.8	.8
HARDWARE LOSS	dB	1.5	0.0
BAND WIDTH	dB-Hz	11.9	16.0
REQUIRED S/N	dB	9.6	13.5
REQUIRED C/NO	dB-Hz	30.9	30.3
MARGIN	dB	3.9	4.5

NOTE 1) CMD BER=1E-5

Table 10. PLANET-B S-BAND CMD LINK at UDSC S/C-ANT:HGA-S

PARAMETER		UP LINK		REMARKS
TRANSMIT. POWER	dBm	73.0	20kW	
TRANSMIT. FEEDER LOSS	dB	-9		
TRANSMIT. ANT. GAIN	dB	61.6	64m	
EIRP	dBm	133.7		
TRANSMIT. POINT. LOSS	dB	-1		
POLARIZATION LOSS	dB	-1		
SPACE LOSS	dB	-270.4	2.1GHz, 2.5AU	
ABSORB. & RAIN LOSS	dB	-2		
RECEIV. POINT. LOSS	dB	-1	+0.4deg	
RECEIV. ANT. GAIN	dB	25.8	HGA-S	
RECEIV. FEEDER LOSS	dB	-1.8		
RECEIV. SIGNAL POWER	dBm	-113.2		
NOISE POWER DENSITY	dBm/Hz	-173.3	Ta=5K, NF=2.6dB	
G/T	dB/K	-1.3		
C/NO	dB-Hz	60.1		
MODEM PARAMETER		CMD 125bps	RANGE	CARRIER
MOD. INDEX	rad	.5	.7	----
MOD. LOSS	dB	11.6	----	2.9
HARDWARE LOSS	dB	1.5	----	0.0
BAND WIDTH	dB-Hz	21.0	----	16.0
REQUIRED S/N	dB	9.6	----	13.5
REQUIRED C/NO	dB-Hz	43.7	----	32.4
MARGIN	dB	16.4	----	27.7

NOTE 1) Simultaneous CMD and RANGE is employed.

2) CMD BER=1E-5

Table 11. PLANET-B S-BAND TLM LINK at UDSC S/C-ANT:HGA-S

PARAMETER		DOWN LINK	REMARKS
TRANSMIT. POWER	dBm	34.0	2.5W
TRANSMIT. FEEDER LOSS	dB	-2.2	
TRANSMIT. ANT. GAIN	dBi	28.0	HGA-S
EIRP	dBm	59.8	
TRANSMIT. POINT. LOSS	dB	-.1	+0.4deg
POLARIZATION LOSS	dB	-.1	
SPACE LOSS	dB	-271.1	2.2GHz, 2.5AU
ABSORB. & RAIN LOSS	dB	-.2	
RECEIV. POINT. LOSS	dB	-.1	
RECEIV. ANT. GAIN	dBi	61.6	64m
RECEIV. FEEDER LOSS	dB	----	Included in Antenna Gain
RECEIV. SIGNAL POWER	dBm	-150.2	
NOISE POWER DENSITY	dBm/Hz	-179.1	Ts=90.1K, EL=10deg
G/T	dB/K	42.1	
C/NO	dB-Hz	28.8	

MODEM PARAMETER		TLM 64bps	TLM 1kbps	RANGE	CARRIER
MOD. INDEX	rad	.7	.7	.5	----
MOD. LOSS	dB	5.0	5.0	----	3.5
HARDWARE LOSS	dB	1.5	1.5	----	0.0
BAND WIDTH	dB-Hz	18.1	30.1	----	10.0
REQUIRED S/N	dB	2.7	2.7	----	13.5
REQUIRED C/NO	dB-Hz	27.2	39.3	----	27.0
MARGIN	dB	1.6	-10.4	----	1.9

NOTE 1) Simultaneous TLM and RANGE is employed.

2) TLM BER=1E-5

Table 12. PLANET-B X-BAND TLM LINK at UDSC S/C-ANT:HGA-X

PARAMETER		DOWN LINK		REMARKS
TRANSMIT. POWER	dBm	37.0	5W	
TRANSMIT. FEEDER LOSS	dB	----	Included in Antenna Gain.	
TRANSMIT. ANT. GAIN	dbi	38.5	HGA-X	
EIRP	dBm	75.5		
TRANSMIT. POINT. LOSS	dB	-.9	+-0.4deg	
POLARIZATION LOSS	dB	-.1		
SPACE LOSS	dB	-282.4	8.4GHz, 2.5AU	
ABSORB. & RAIN LOSS	dB	-.8		
RECEIV. POINT. LOSS	dB	-.2		
RECEIV. ANT. GAIN	dbi	70.5	64m	
RECEIV. FEEDER LOSS	dB	----	Included in Antenna Gain.	
RECEIV. SIGNAL POWER	dBm	-138.4		
NOISE POWER DENSITY	dBm/Hz	-178.7	Ts=98.1K, EL=10deg	
G/T	dB/K	50.6		
C/N0	dB-Hz	40.3		

MODEM PARAMETER		TLM 2kbps	TLM 32kbps	CARRIER
MOD. INDEX	rad	1.2	1.2	----
MOD. LOSS	dB	.6	.6	8.8
HARDWARE LOSS	dB	1.9	1.9	0.0
BAND WIDTH	dB-Hz	33.1	45.2	10.0
REQUIRED S/N	dB	2.7	2.7	13.5
REQUIRED C/N0	dB-Hz	38.3	50.4	32.3
MARGIN	dB	1.9	-10.1	7.9

NOTE 1) TLM BER=1E-5

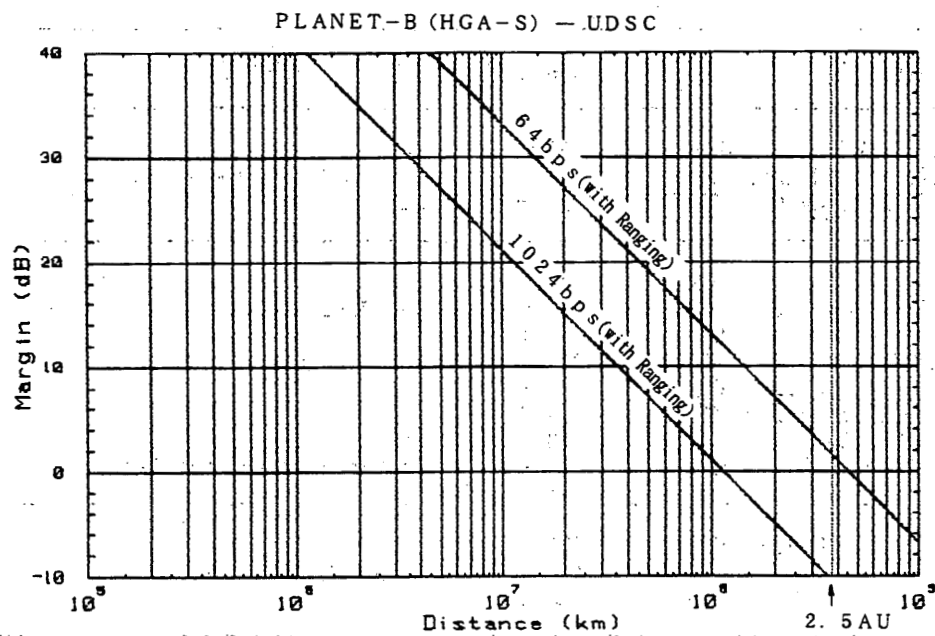


Fig. 4. S-band Telemetry Link Margin vs Slant Range

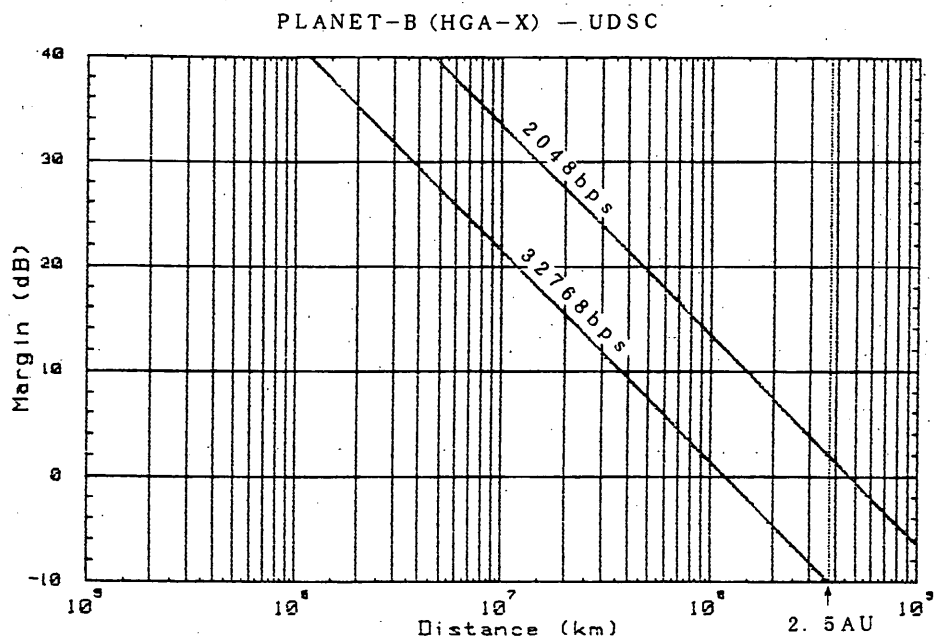


Fig. 5. X-band Telemetry Link Margin vs Slant Range

Table 13. SBR Receiving Power Dynamic Range

Parameter	minimum	maximum	Remarks
	(UDSC)	(JKSC)	
GND. Trans. Power (dBm)	73.0 (20kW)	50.0 (100W)	
GND. Feeder Loss (dB)	-0.9	-0.5	
GND. Antenna Gain (dBi)	61.6	51.8	
Free Space Loss (dB)	-270.4 (2.5AU)	-158.9 (1000km)	$10\log(\lambda/(4\pi R))^2$
Other Loss (dB)	-0.3	0.0	
Received Power Density (dBm/m ²)	-137.0	-57.6	
PLANET-B Antenna Gain (dBi)	0.0 (LGA-B)	6.0 (LGA-A)	
PLANET-B feeder Loss (dB)	-2.1	-1.4	
Received Power (dBm)	-139.1	-53.0	

ISAS
NEC Corporation

The block diagram is shown in fig. 3.2-1.



3.2.1 High Gain Antenna (HGA)

The high gain antenna (HGA) consists of an S-band high gain antenna (HGA-S) and an X-Band high gain antenna (HGA-X). The HGA is a center-fed parabolic antenna for S/X co-use. A pencil beam in circular polarization is radiated along the spin axis of the spacecraft. In order to reduce the mass, the reflector is made of the Triaxial Woven Fabric (TWF), and microstrip type radiators are used for S-Band and X-Band primary feeds. The Major performance of the antenna is shown in the table 3.2.1-1. An outline drawing of HGA-S/X is shown in fig.3.2.1-1.

TABLE 3.2.1-1 MAJOR PERFORMANCE OF HGA-S/X

	S-Band		X-Band
	RECEIVE	TRANSMIT	TRANSMIT
FREQUENCY			
ANTENNA TYPE	CENTER FED PARABOLIC ANTENNA		
APERTURE SIZE	1.6m ϕ		
ANTENNA PEAK GAIN	more than 25.8dBi	more than 28.0dBi	more than 38.5dBi
-3dB BEAM WIDTH	± 2.9 deg	± 2.7 deg	± 0.7 deg
POLARIZATION	RHCP		RHCP
IMPEDANCE	50 Ω (VSWR=1.5max.)		50 Ω (VSWR=1.5max.)
WEIGHT	7.2 kg (INCLUDING HGA-S/X & SUPPORT STRUCTURE)		

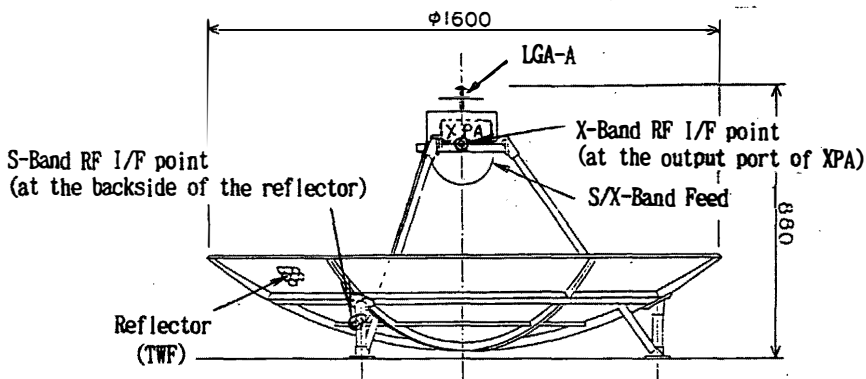


Fig.3.2.1-1 Outline drawing of HGA-S/X

3.2.2 Low Gain Antenna (LGA)

The LGA is a crossed dipole antenna atop a mast mounted parallel to the spin axis on the top of the HGA assembly (LGA-A) and on the aft side of the S/C (LGA-B). Each antenna provides a cardioid radiation pattern with maximum gain in the direction parallel to the antenna mast. These antennas are selected by SSW electrically to cover the whole solid angles from the spacecraft. The outline drawing of the LGA is shown in figure 3.2.2-1. And major performance of the antenna is summarized in the table 3.2.2-1.

TABLE 3.2.2-1 MAJOR PERFORMANCE OF LGA-A/B

	PERFORMANCE
FREQUENCY	$f=2.1\text{GHz(RX)}$ 2.3GHz(TX)
ANTENNA TYPE	CROSSED DIPOLE ANTENNA
ANTENNA GAIN	within the antenna axis $\pm 45^\circ$ more than 0 dBi within the antenna axis $\pm 90^\circ$ more than -10 dBi
POLARIZATION	RHCP
IMPEDANCE	$50\ \Omega$ (VSWR=1.5max)
WEIGHT	LGA-A:135g LGA-B:250g

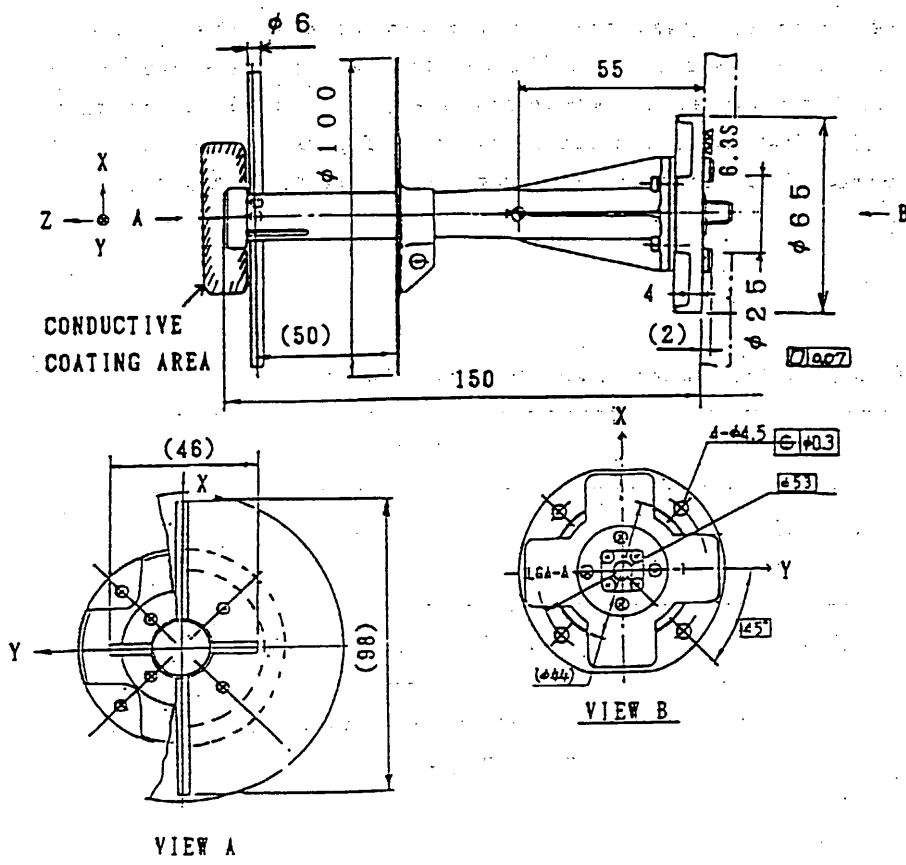


Fig. 3.2.2-1(a) OUTLINE DRAWING OF LGA-A

3. 3 Electronic Components

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3.3.1 S-band Receiver (SBR)

3.3.1.1 General

S-band Receiver (SBR)-A and -B are double super-heterodyne receivers to receive the S-band up-link signal from the antenna subsystem, and to demodulate the command signal and the ranging signal.

3.3.1.2 Functions

The block diagram of SBR is shown in Fig. 3.3.1-1.

The front-end amplifies the S-band up-link signal with low noise and frequency-converts to the first intermediate frequency (IF) of 105MHz. The 1st IF stage limits the signal bandwidth using a band pass filter and amplifies to a constant level using automatic gain control (AGC) amplifiers, and then frequency-converts to second IF of 9.5MHz.

The 2nd IF stage divides the signal to three channels for command, ranging and carrier tracking.

The command signal and the ranging signal are demodulated using phase-detectors. The tracking channel generates the voltage controlled oscillator (VCO) control-voltage and the AGC voltage. Then, the SBR outputs the command baseband signal to Command Decoder (CMD), the ranging signal and the VCO local signal to S-band Transmitter (TMS) and X-band Transmitter (TMX). SBR squelches the command signal within -148 ± 4 dBm.

SBR has the status monitors of the VCO control voltage, the AGC voltage, the phase-lock and the squelch status. And SBR has a chassis temperature sensor for house-keeping.

3.3.1.3 Performance

(1)Electrical performance	
(a)Receiving frequency(f_0)	2.1GHz
(b)Hold-in range	$f_0 \pm 90\text{kHz}$
(c)Frequency sweep rate	600Hz/sec max(-90dBm~-60dBm) 100Hz/sec max(-144dBm~-90dBm)
(d)Input level	-144dBm~-60dBm (carrier only) -142dBm~-60dBm (with command)
(e)Squelch level	-148dBm $\pm$ 4dB
(f)Impedance	50 Ω VSWR $\leq$ 1.5
(g)Receiving signals performance	
(i)Command channel	
(1)Modulation form	PCM-PSK-PM
(2)Modulation index	0.6rad0-p 0.5rad0-p (with ranging)
(3)Subcarrier frequency	4kHz sinewave
(4)Bit rate	15.625bps or 125bps
(5)Output level	1Vrms $\pm$ 2dB
(6)Output impedance	$\leq$ 200 Ω
(ii)Ranging channel	
(1)Modulation form	Tone-PM
(2)Modulation index	1.2rad0-p 0.7rad0-p (with command)
(3)Tone frequency	$\approx$ 516kHz squarewave
(4)Output level	0.83Vp-p(tentative) for TMS 1.50Vp-p(tentative) for TMX
(5)Output impedance	$\leq$ 200 Ω
(6)Polality	Inverted
(7)Delay time variation	$\leq$ 200nsec
(h)Noise figure	$\leq$ 2.6dB
(i)3dB bandwidth	
(i)Command channel	38kHz(tentative)
(ii)Ranging channel	2MHz (tentative)
(j)Telemetry items	•Loop stress •AGC voltage •Phase-lock •Squelch
(k)House keeping items	•Chassis temperature
(l)Power supply	$\pm$ 12.5V +5.2V
(m)Power consumption	3.2W nominal(tentative)
(2)Mechanical performance	
(a)Size	130 $\times$ 180 $\times$ 30 mm(tentative)
(b)Weight	0.7kg $\pm$ 0.2kg(tentative)

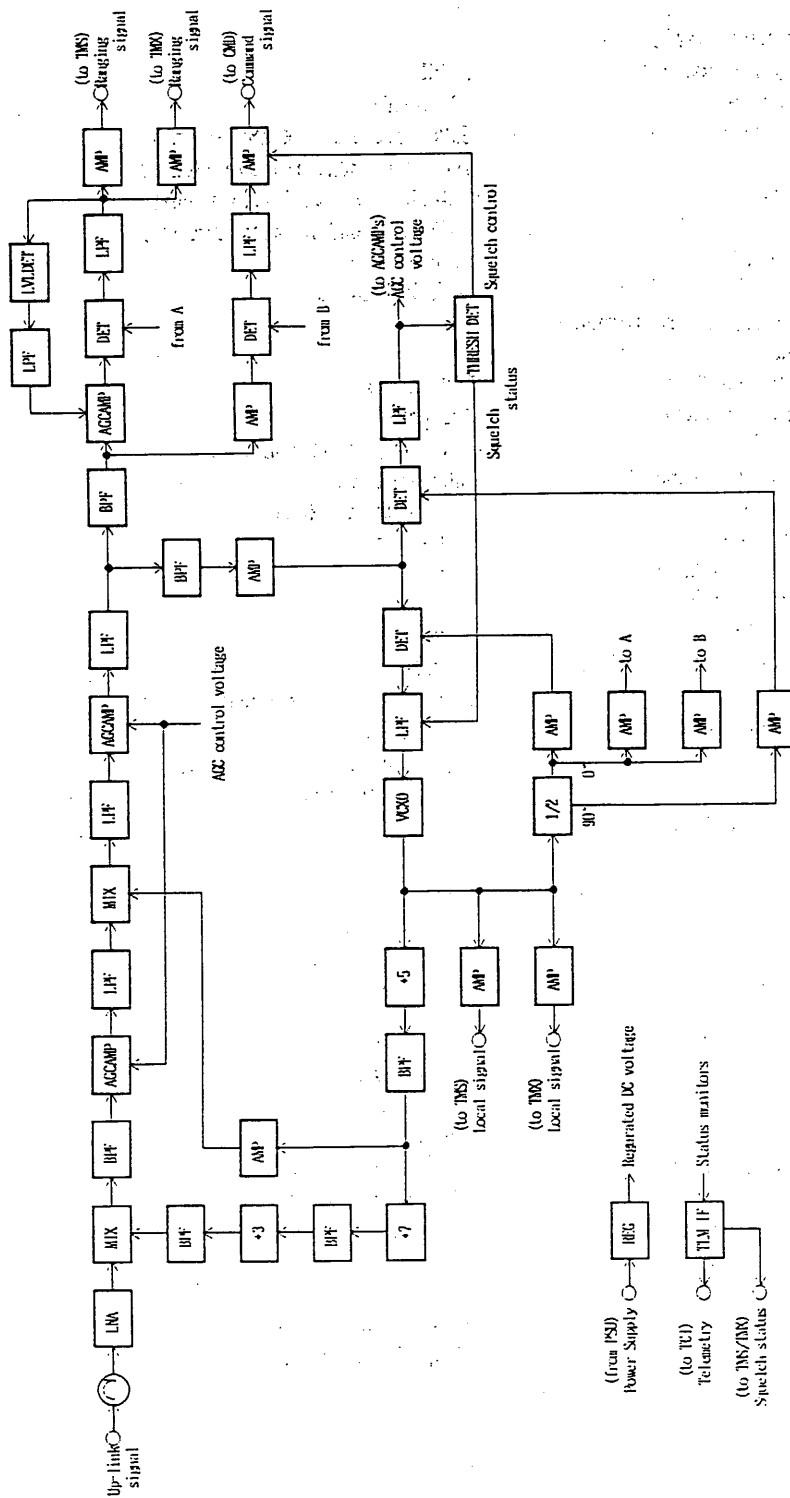
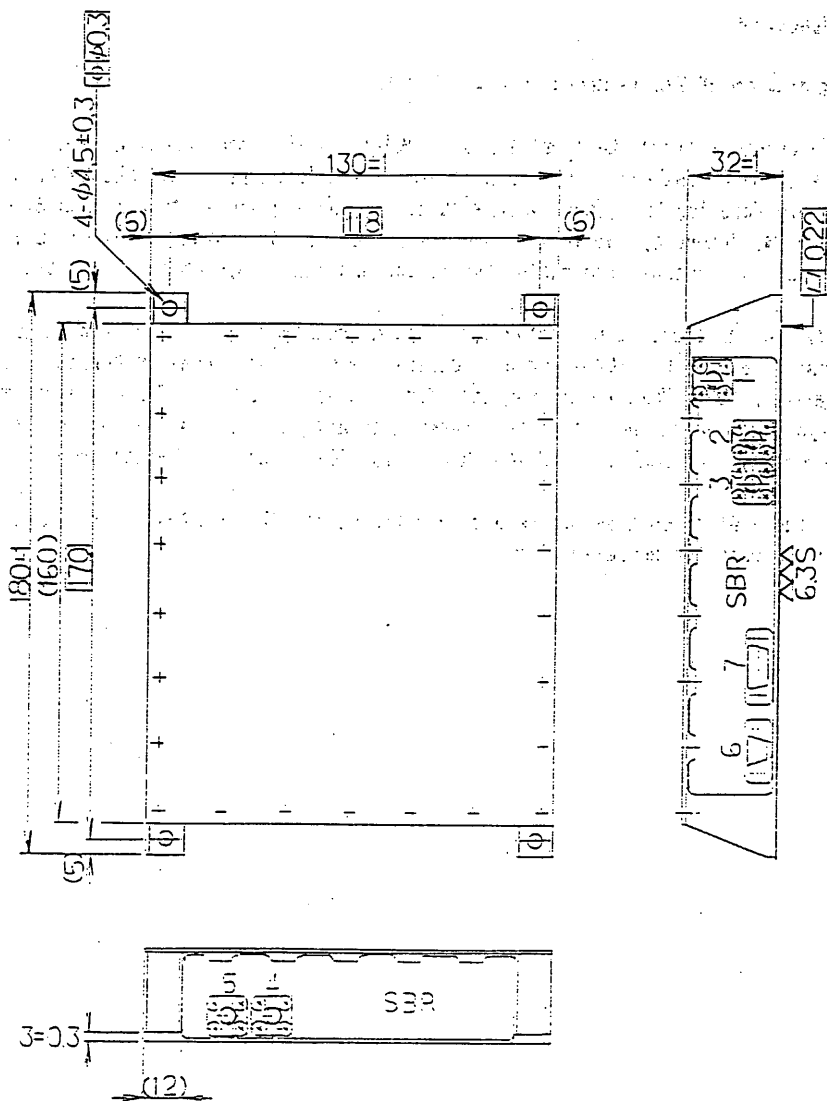


Fig. 1.1.1-1 S-band Receiver (SBR) Block Diagram



3.3.2 S-band Transmitter (TMS)

3.3.2.1 General

An S-band Transmitter (TMS) outputs the S-band down-link carrier modulated by the telemetry signals with/without the ranging signal to the antenna subsystem.

3.3.2.2 Functions

The block diagram of TMS is shown in Fig. 3.3.2-1.

TMS generates or receives the local signal (19MHz) in the local section and frequency-multiplies it by 20(382MHz), and then modulates the IF carrier by the telemetry signal from the Data Handling Unit (DHU) with/without the ranging signal from S-band Receiver(SBR). Furthermore TMS frequency-multiplies the IF carrier by 6 to make a radio wave in S-band, amplifies and then outputs the radio wave to the antenna subsystem via a isolator.

TMS can switch the local signal between the fixed frequency from the Temperature Compensated Crystal Oscillator (TCXO) for a noncoherent mode and phase-coherent frequency to S-band Receiver (SBR) VCXO local frequency for a coherent mode. TMS can also switch the power output between on and off, output power high and low, modulation on and off, and the ranging modulation on and off. And TMS outputs the TCXO signal to X-band Transmitter(TMX).

TMS has the status monitors of the above-mentioned switched status and has a chassis temperature sensor for house-keeping.

3.3.2.3 Performance

(1)Electrical performance

(a)Transponder coherency

Downlink/Uplink frequency ratio 240/221

(b)Transmit carrier frequency 2.3GHz

(c)Frequency stability $\leq \pm 2 \times 10^{-5}$

(d)Output power High power mode 2.5W nominal

Low power mode TBDW

(e)Spurious outputs $\leq -10\text{dBm}$

(f)Impedance 50Ω VSWR ≤ 1.5

(g)Modulation performance

(i)Telemetry channel

(1)Modulation form PCM-PSK-PM

(2)Bit rate 64bps~1024bps

(3)Subcarrier frequency 8192Hz. squarewave

(4)Modulation index 0.7rad0-p

(ii)Ranging channel

(1)Modulation form Tone-PM

(2)Tone frequency $\approx 51\text{kHz}$ squarewave

(3)Modulation index 0.5rad0-p

(4)Polality Inverted

(5)Delay time variation $\leq 100\text{nsec}$

(h)Occupied bandwidth 1.5MHz(tentative)

(i)Command items

·Power on. off

·Output power high. low

·Auto coherent enable. disable

·Modulation on. off

·Ranging modulation on. off

·Ranging -A. -B

(k)Telemetry items

·Power on/off

·Output power high/low

·Auto coherent enable/disable

·Coherent/noncoherent

·Modulation on/off

·Ranging modulation on/off

·Ranging-A/B

(l)House keeping items

·Chassis temperature

(m)Power supply

$\pm 12.5\text{V}$ $+5.2\text{V}$ $+20\text{V}$

(n)Power consumption

12.7W nominal(high power mode)(tentative)

(2)Mechanical performance

(a)Size

$160 \times 155 \times 66$ mm(tentative)

(b)Weight

$1.2\text{kg} \pm 0.2\text{kg}$ (tentative)

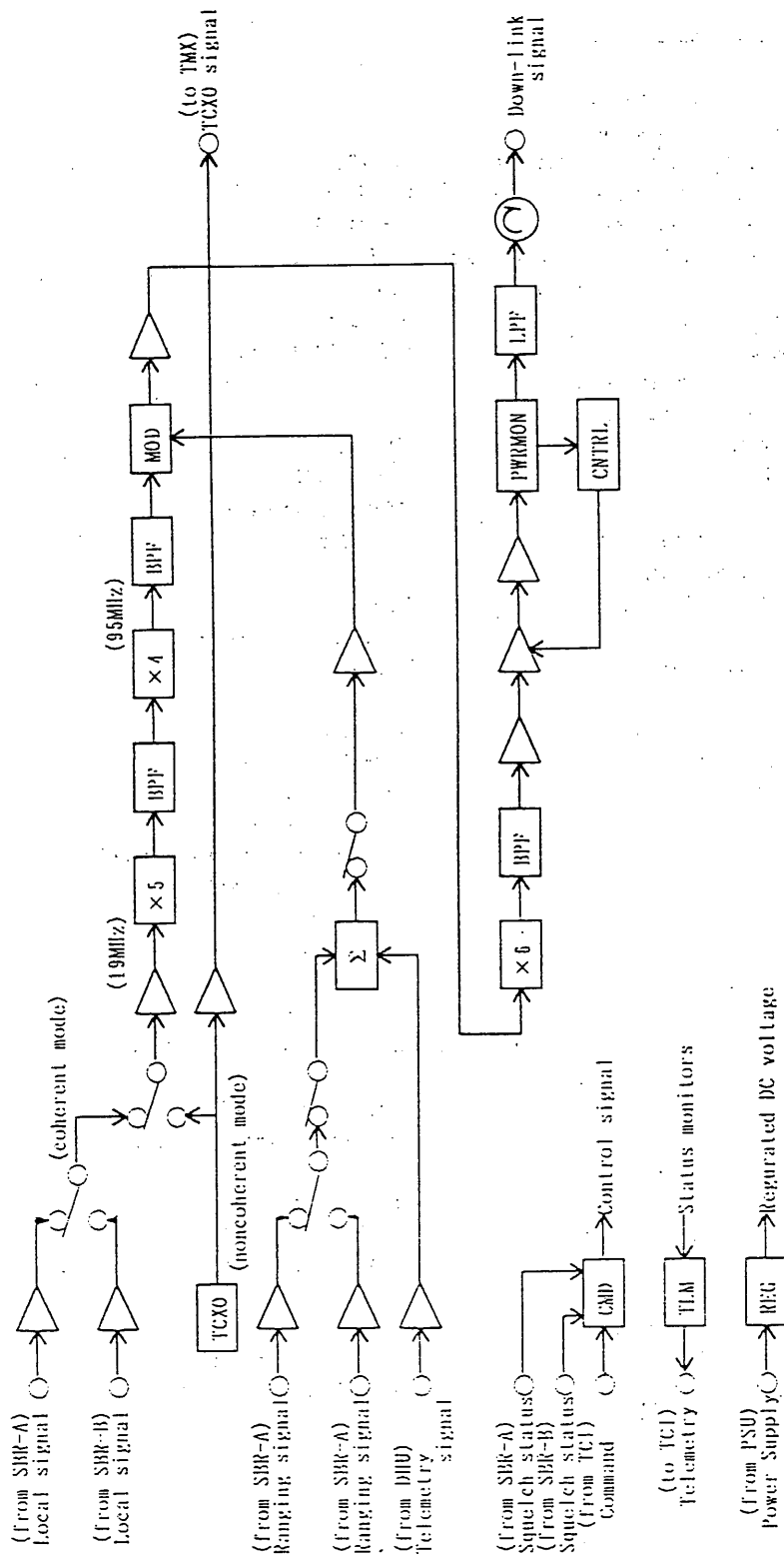


Fig. 3.3.2-1 S-band Transmitter (TMS) Block Diagram

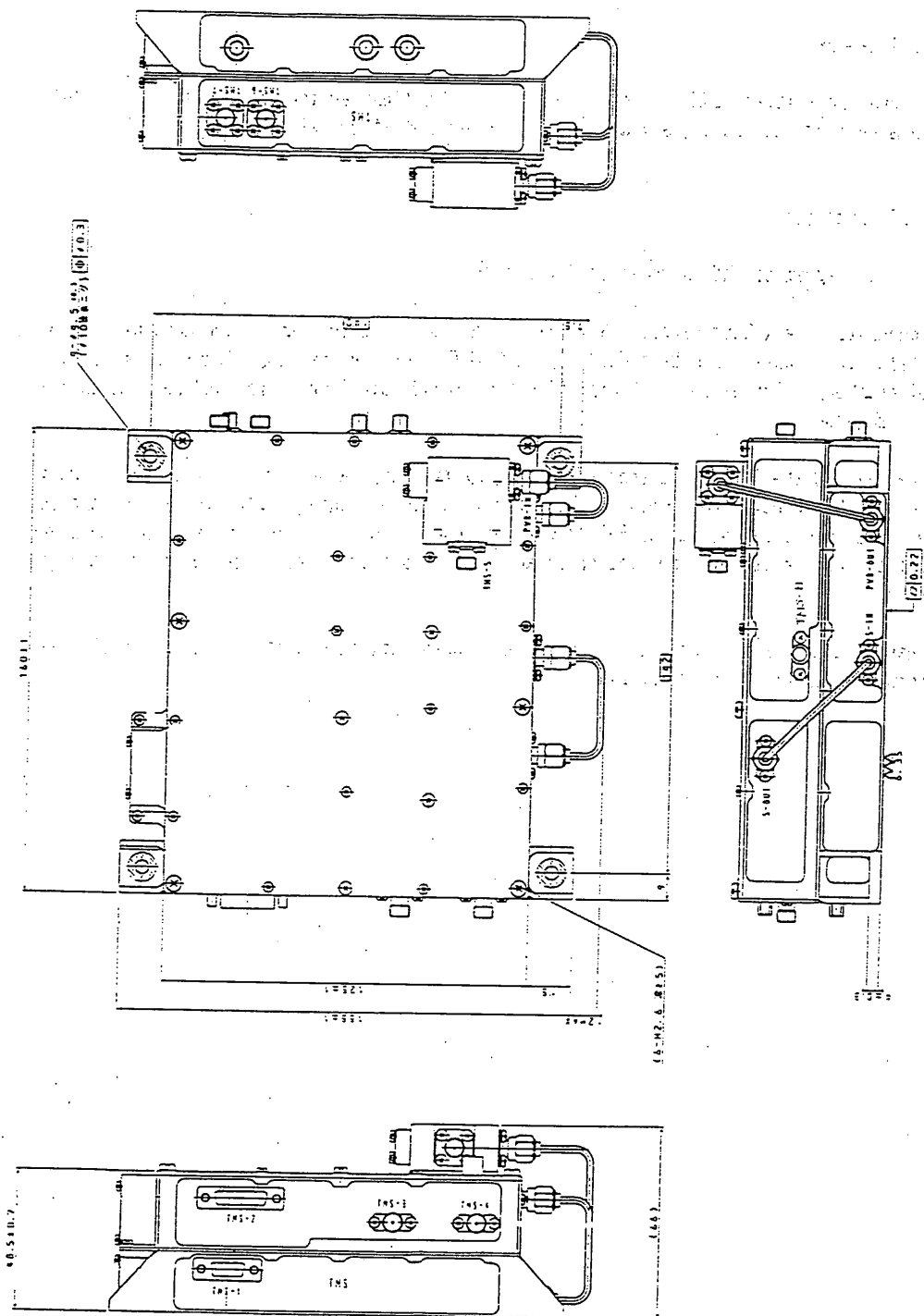


Fig. 3.3.2-2 S-band Transmitter (TMS) Outline Drawing

3.3.3 X-band Transmitter (TMX)

3.3.3.1 General

An X-band Transmitter (TMX) outputs the X-band down-link carrier modulated by the telemetry signal or the ranging signal to X-band Power Amplifier (XPA).

3.3.3.2 Functions

The block diagram of TMX is shown in Fig. 3.3.3-1.

TMX generates the X-band carrier (8.4GHz) in the local section and then modulates it by the telemetry signal from Data Handling Unit (DHU) or the ranging signal from S-band Receiver (SBR). Furthermore TMX amplifies the X-band down-link signal and outputs to XPA via a isolator.

TMX can switch the local reference (19MHz) among the Temperature Compensated Crystal Oscillator (TCXO) output and S-band Transmitter (TMS) local signal both for a non-coherent mode, and VCXO local signal of SBR-A/-B for a coherent mode. TMX can also switch power output between on and off, modulation on and off, modulating signal the telemetry and the ranging.

TMX has the status monitors of the above-mentioned switched status and has a chassis temperature sensor for house-keeping.

3.3.3.3 Performance

(1)Electrical performance

(a)Transponder coherency

Downlink/uplink frequency ratio 880/221

(b)Transmit carrier frequency 8.4GHz

(c)Frequency stability $\leq \pm 2 \times 10^{-5}$

(d)Output power 18mW nominal

(e)Spurious outputs $\leq -10\text{dBm}$

(f)Impedance 50Ω VSWR ≤ 1.5

(g)Modulation performance

(i)Telemetry channel

(1)Modulation form PCM-PM

(2)Bit rate 2048bps~32768bps

(3)Modulation index 1.2rad0-p

(ii)Ranging channel

(1)Modulation form Tone-PM

(2)Tone frequency $\approx 516\text{kHz}$ squarewave

(3)Modulation index 0.9rad0-p

(4)Polality Inverted

(5)Delay time variation $\leq 100\text{nsec}$

(h)Occupied bandwidth 1.5MHz(tentative)

(i)Command items

- Power on, off
- Auto coherent enable, disable
- Local internal, TMS
- Modulation on, off
- Modulation telemetry, ranging
- Ranging A, B

(j)Telemetry items

- Power on/off
- Auto coherent enable/disable
- Coherent/noncoherent
- Local internal/TMS
- Modulation on/off
- Modulation telemetry/ranging
- Ranging A/B

(k)House keeping items

(l)Power supply $\pm 12.5\text{V} +5.2\text{V}$

(m)Power consumption 6.0W nominal(tentative)

(2)Mechanical performance

(a)Size 155×166×62 mm

(b)Weight 1.5kg $\pm 0.2\text{kg}$

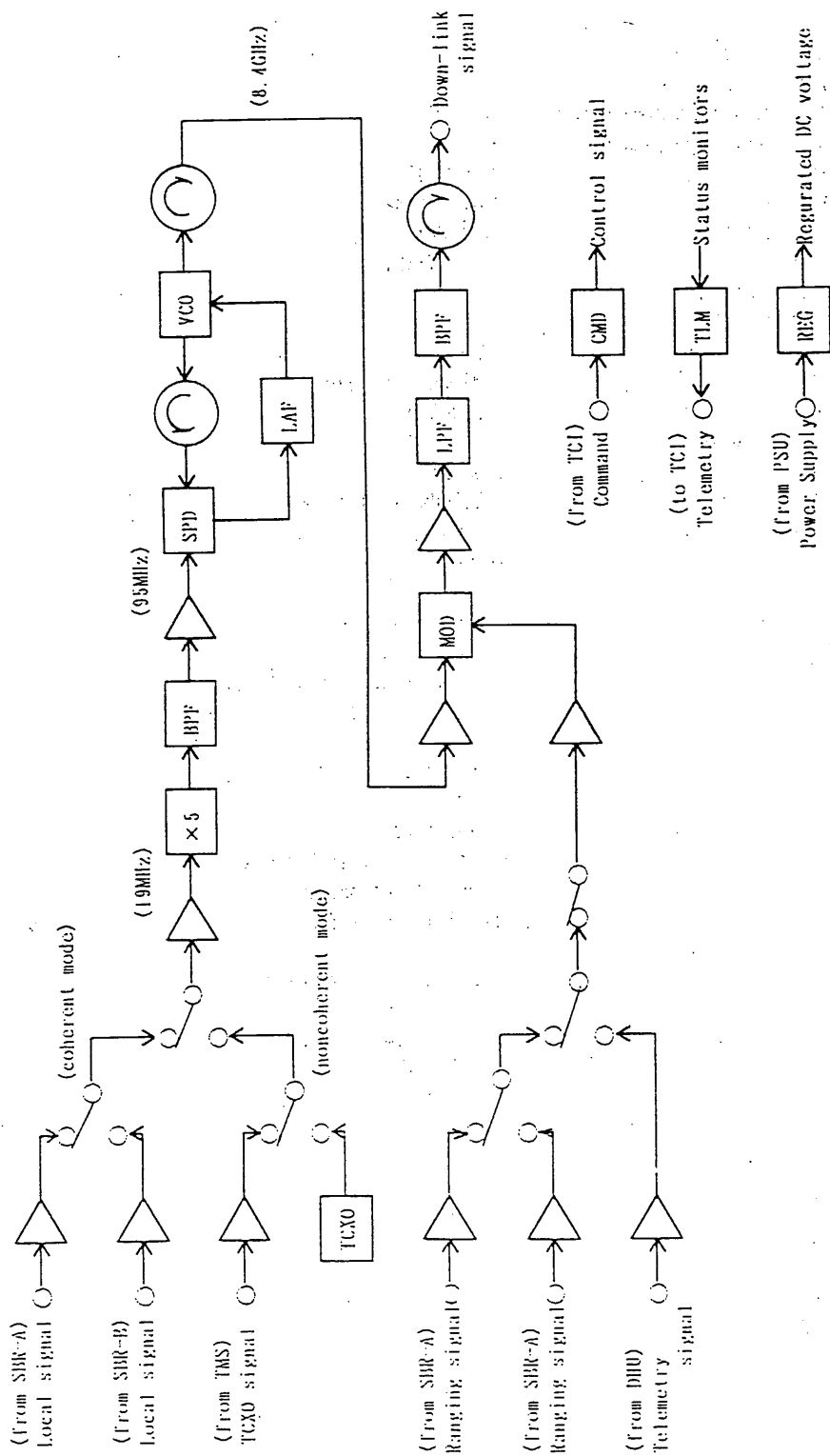


Fig. 3.3.3-1 X-band Transmitter (TMX) Block Diagram

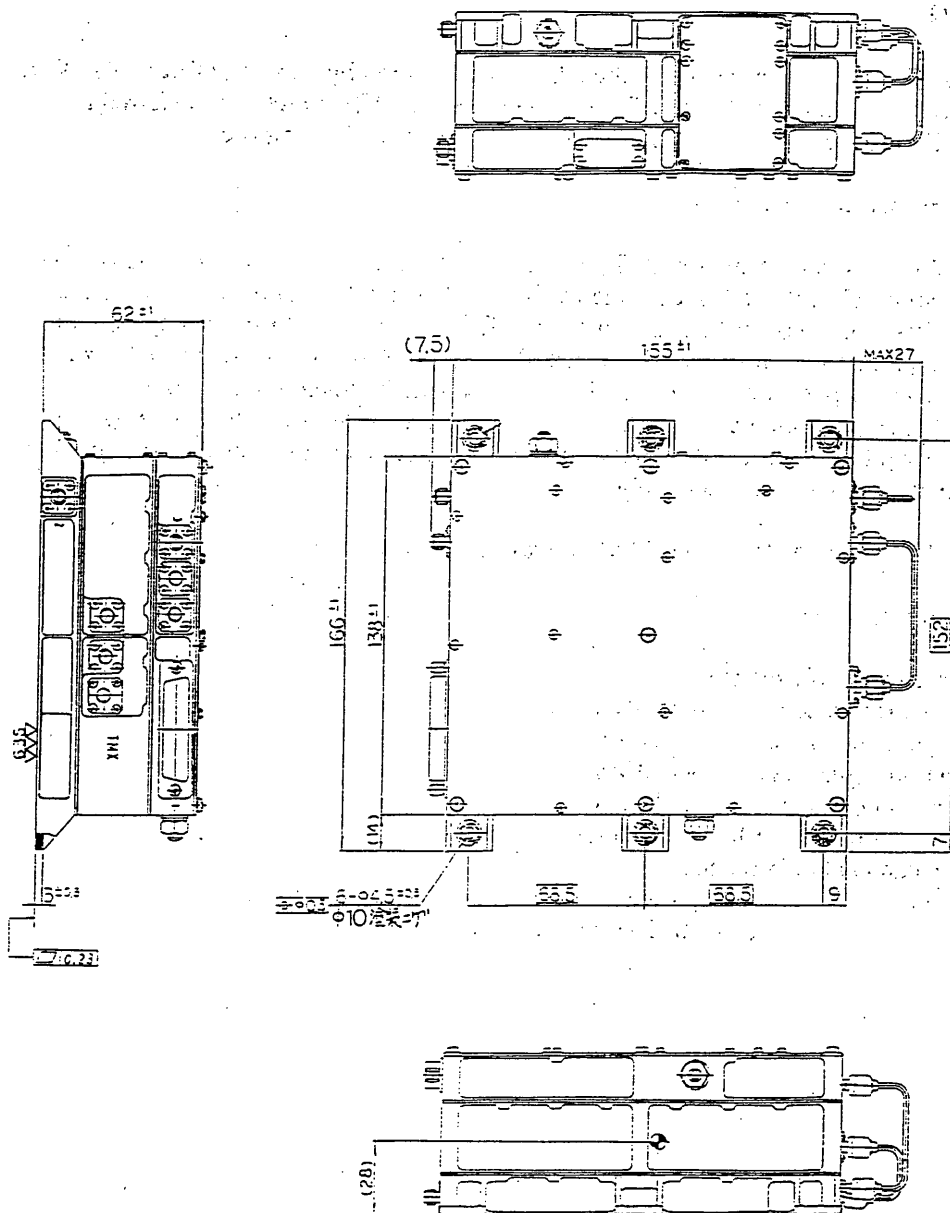


Fig. 3.3.3-2 X-band Transmitter (TMX) Outline Drawing

3.3.4 X-band Power Amplifier(XPA)

3.3.4.1 General

The XPA is located at the top of the HGA , and covered by a thermal filler. The XPA amplifies the output signal of the TMX to improve the EIRP which is transferred to the earth. The RF output power is more than 5 watts over the in-orbit life.

3.3.4.2 Electrical Function

The block diagram is shown in Figure 3.3.4-1. All amplifiers space-qualified GaAs FETs from NEC. The LPA is a hermetically shielded HMIC* amplifier. The PA and HPA use the same type of high-power GaAs FETs formerly used for other spacecraft , and their qualification tests have been already completed successfully. The HPA shows the saturated output power of 6 watts in minimum and the linear gain of 10dB in minimum. At the input and output ports , there are isolators to improve the matching.

Microstrip lines on the teflon glass substrate are used to connect the each power GaAs FETs to minimize the size and weight.

*HMIC stands for a Hybrid Microwave Integrated Circuit

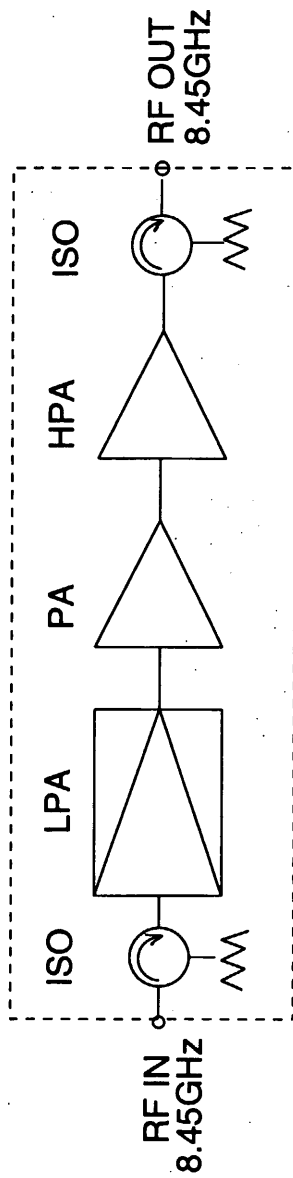
3.3.4.2 Performance

(1) Electrical Performance

- (a) input frequency 8.45GHz(nom.)
- (b) input signal level +11+/-2 dBm
- (c) output signal level +37 dBm
- (d) DC input power 20W max.
- (e) input/output VSWR 1.3 max.

(2) Mechanical Performance

- (a) mass 240 g nom.
- (b) size 130*70*20 mm (tentative)



ISO : isolator , LPA : low power amplifier
 PA : power amplifier , HPA : high power amplifier

Figure 3.3.4-1 XPA BLOCK DIAGRAM

3.3.5 S-band Switch (SSW)

3.3.5.1 General

S-band Switch (SSW)-A and -B are single pole double throw switches. SSW-A switches the S-band down-link signal from S-band Transmitter (TMS) between to S-band Diplexer (SDIP)-A and to SDIP-B. SSW-B switches the same signal from SDIP-B between to S-band High Gain Antenna (S-HGA) and Low Gain Antenna(LGA)-B.

3.3.5.2 Functions

The block diagram of SSW is shown in Fig. 3.3.5-1.

SSW is a mechanical latching relay. SSW switches when the coil is energized by the control signal from Telemetry Command Interface (TCI).

SSW has the status monitor of the above-mentioned switched status.

3.3.5.3 Performance

(1)Electrical performance

(a)Frequency	2.1GHz for RX 2.3GHz for TX
(c)Impedance	50Ω VSWR≤1.5 (each port)
(d)Insertion loss	≤0.5dB
(e)Switching time	≤20msec
(h)Command items	SSW-A •SDIP-A, SDIP-B SSW-B •S-HGA, LGA-B
(i)Telemetry items	SSW-A •SDIP-A/B SSW-B •S-HGA/LGA-B

(2)Mechanical performance

(a)Size	100×39×14 mm
(b)Weight	55gr. max

3.3.6 S-band Diplexer (SDIP)

3.3.6.1 General

S-band Diplexer(SDIP)-A and -B isolate the received up-link signal and the transmitting down-link signal for simultaneous reception and transmission with the single S-band antenna.

3.3.6.2 Functions

The block diagram of SDIP is shown in Fig.3.3.6-1.

SDIP Band Pass Filter(BPF)-1 transmits the S-band down-link signal with low insertion loss from S-band Transmitter (TMS) via S-band Switch(SSW)-A to the antenna subsystem, with isolating TMS from the S-band up-link signal.

SDIP BPF-2 transmits the S-band up-link signal with low insertion loss from the antenna subsystem to S-band Receiver (SBR), with isolating SBR from the S-band down-link signal.

3.3.6.3 Performance

(1)Electrical performance

(a)Center frequency	TX(BPF-1)	2.3GHz (f1)
	RX(BPF-2)	2.1GHz (f2)
(b)Impedance		50Ω VSWR≤1.5 (each port)
(d)Insertion loss	TX(BPF-1)	≤1.00dB
	RX(BPF-2)	≤0.85dB
(e)Isolation	TX→RX	≥76dB (at f1)
	RX→TX	≥82dB (at f2)

(2)Mechanical performance

(a)Size	175.6×64×40.5 mm
(b)Weight	0.32kg±0.03kg

4. Command and Data Handling System

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NEC Corporation

4.1 Overview

4.1.1 Operation Control System

Basically, all commands will be transmitted with PIM identification number (IC) from the ground to onboard data bus. The applicable PIM will send commands to the applicable subsystem only. So, each subsystem do not need to take care of its IC.

After sending all command information, DHU will send an ECW (End of Command Writing) signal to the subsystem to inform of the completion of the command sending. The component is able to know that DHU has finished the command writing activity by ECW. The command sending sequence is shown in figure 4.1.1-1

4.1.1.1 Types of Commands

(1) Types of Commands

PLANET-B command system is categorized as follows. Each subsystem needs to know only the "Command Block Type".

Organized Operation is the convenient spacecraft operation method. In the organized operation, the command groups stored in DHU (called OG) will be used individually or in combination.

Command Block Type	DC DC+BC+...+BC
Operation Type	Individual Operation Organized Operation
Generation Point	Ground Station DHU onboard (Onboard Generated Command)

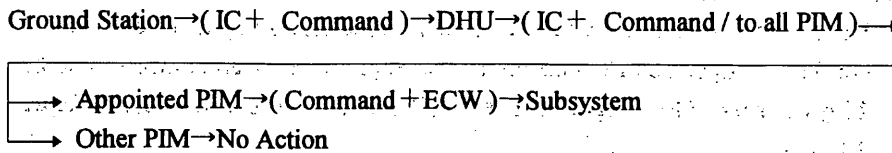


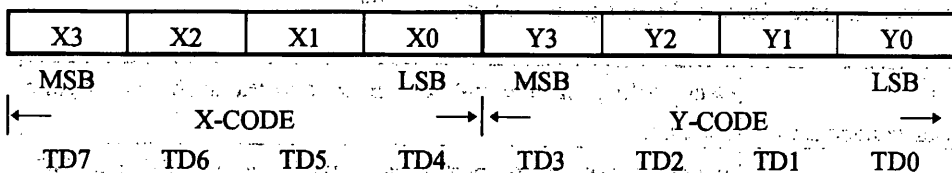
Figure 4.1.1-1 Command Transmission Flow

(2) Command Block Type

DHU's command operation task is performed in the 31.25msec period having a cycle of 62.5msec. The command operation unit, which is performed in a period, is called "Command Block". The types of command block are DC and DC+BC+.....+BC (the length of BC should be 254bytes or less.)

A) DC

DC consists of 8bits and is identified by the matrix of X-Code(HEX:Higher 4bits) and Y-Code(HEX:Lower 4bits). DC should be used for the simple operation like as ON, OFF, START, STOP, ENABLE, DISABLE etc. 254 DCs can be assigned to each PIM. The DC construction is shown in figure 4.1.1-2.



TD7-TD0 : Signal ID of data from PIM to user.

Figure 4.1.1-2 DC Construction

User can specify the command execution absolute time (LSB:1sec) for DC operation. The execution time is defined as the time when DHU sends the DC to the data bus. The absolute time is converted to TI (Time Indicator in DHU) for uplink from the ground. But in some cases, the real execution time may be affected by other operation such as interrupt command. DHU has the area of 32 command blocks for

time-specified commands.

(Note1) The 254's DC area for each PIM includes the area only for system use.

(Note2) For the time-specified DC operations, the length of command block should be 14bytes or less. (The length includes IC(1byte) and TI(4bytes). Refer to figure 4.1.1-3)

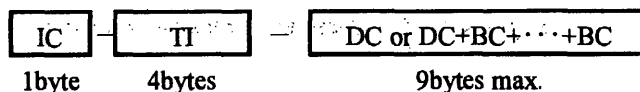


Figure 4.1.1-3 Length Limitation for Time-specified Command

B) DC+BC+.....+BC

This configuration consists of DC for function identification and BC units which is 8bits(=1byte)/unit (254units max). For the transmission of more than 254bytes, the data should be divided into several command blocks. But in some cases, other command blocks may be inserted between these command blocks.

Basically, another DC for execution should not be added.

From the view point of component's design optimization, the user can use some BCs for some functions. (Ex. "The Number of Byte" "Check Sum", etc. Refer to figure 4.1.1-4. The types of application are as follows. For this type, users can specify its execution time by absolute time. Refer to the foregoing section "A) DC".

(A) Data Transmission -	Data writing on the onboard memory area such as Program Loading.
(B) Parameter Set -	Parameter setting for performance with the first DC and BCs following the DC.
(C) Bit BC -	Only one command execution of several actions, which are identified by bit level, respectively like as ON/OFF.

(Note) For the method of (B) and (C), the upper limitations of BCs to be added should be 12bytes and 2bytes, respectively.

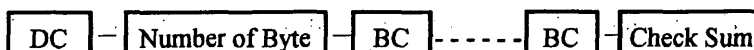


Figure 4.1.1-4 DC+BC Construction Example

C) Operation Type

C-1) Individual Operation

This operation is the method of sending each command block, independently.

The configuration of command transmission track from ground station is shown in figure 4.1.1-5.

The PIM transmit ECW (End of Command Write) to user after each command block (One command block = DC or DC+BC+...+BC). The address for ECW is FFFEh and the written data is the number of bytes in the command block.

C-2) Organized Operation

Please see Section 4.1.1.2.

Control Field	Spare	Byte Quantity	Format Field	Spare	Data #1	.....	Data #14
← 2bits →	← 2bits →	← 4bits →	← 2bits →	← 6bits →	8bits	←	←

-Control Field 11 / Individual Mode -Format Field 11 / All BC
 10 / Continuous Mode (Rear Unit) 10 / IC+TI+DC or IC+TI+DC+BC+...+BC
 01 / Continuous Mode (Lead Unit) 01 / IC+DC, IC+DC, ... IC+DC
 00 / Continuous Mode (Continuous Unit) 00 / IC+DC or IC+DC+BC+...+BC

-Byte Quantity : A number of byte including IC and TI in the unit.

Figure 4.1.1-5 Command Transmission Track Configuration (1/2)

1) IC+DC, IC+DC, ... IC+DC (INDIVIDUAL MODE)													
11110100	00111111	IC	DC	IC	DC	IC	DC	IC	DC	IC	DC	IC	DC
2) IC+DC or IC+DC+BC+...+BC (INDIVIDUAL MODE)													
11110010	00111111	IC	DC	(BC)	(BC)	(BC)	(BC)	(BC)	(BC)	(BC)	(BC)	(BC)	(BC)
3) IC+DC+BC+...+BC (CONTINUOUS MODE / LEAD UNIT)													
01111111	00111111	IC	DC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC
4) BC+...+BC (CONTINUOUS MODE / CONTINUOUS UNIT)													
00111111	11111111	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC
5) BC+...+BC (CONTINUOUS MODE / REAR UNIT)													
10110010	11111111	BC	(BC)	(BC)	(BC)	(BC)	(BC)	(BC)	(BC)	(BC)	(BC)	(BC)	(BC)
6) IC+TI+DC or IC+TI+DC+BC+...+BC (INDIVIDUAL MODE)													
11110110	10111111	IC	TI	TI	TI	DC	(BC)	(BC)	(BC)	(BC)	(BC)	(BC)	(BC)

Figure 4.1.1-5 Command Transmission Track Configuration (2/2)

4.1.1.2 OP and OG

(1) OG

A basic unit of command group for organized operation is called OG. An OG consists of 16 sets of "IC" and "Command Block". The length of command block including IC(1byte) should be 16bytes or less. (See figure 4.1.2-1.)

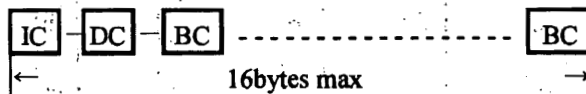


Figure 4.1.2-1 DC+BC Construction Example

The time interval of command sending is basically 62.5msec / Command Block. (In some cases, time interval may be affected by interruption command and so on.)

(2) Organized Operation

For executing an OG individually, OG execution command against DHU should be used. And the sequence operation including several OGs can be performed, too. This operation method is called OP. The sequence of OP will be controlled by the CE (Control Element) which consists of OG# and the time interval between next OG's starting time. The interval can range from 30sec to 65536sec (about 18hours) by 1sec. An OP can have 512 CEs max.

For OP operation, OP execution command for each OP system against DHU will be used with the starting CE#. Therefore, the OP operation can be started from its halfway. The organized operation sequence is shown in figure 4.1.2-2. The area of 128OGs is conserved for this OP system. Even if the OP system is operating, its edition can be performed without any effect on the operating sequence.

The OP will stop in the following cases.

- OG including "OP STOP(DC)" in OP is executed.
- "OP STOP(DC)" cuts in during OP operation.
- OG including "OP STOP(DC)" cuts in during OP operation.
- OP operation is completed (to CE#511).

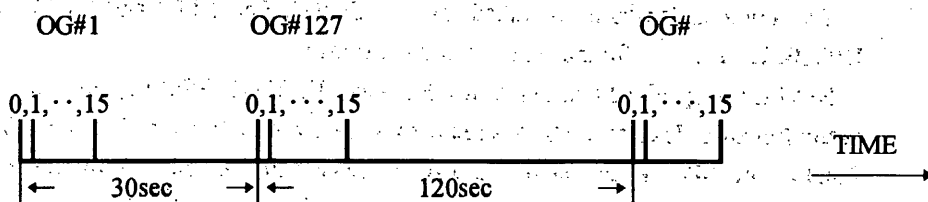
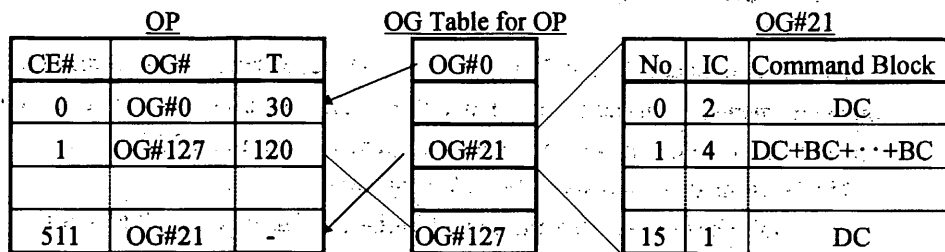


Figure 4.1.2-2 Organized Operation Sequence

4.1.1.3 Program Loading

The DHU onboard PLANET-B uses DMA (Direct Memory Access) method for the onboard memory management (onboard memory verification, rewriting onboard memory, onboard memory dumping and program loading from BFM).

The DMA method consists of the following steps.

- (1) The user transfers the control initiative of user's bus to PIM sides.
- (2) The PIM accesses the user's memory directly for required activity.
- (3) The PIM returns the bus control initiative to the user.

Two commands, which are called "BUS ACCESS ENABLE" and "BUS ACCESS DISABLE", are used for the control initiative transfer.

BFM(Back-up File Memory) with DHU has EEPROM. BFM supports the memory patrol function. Therefore, BFM is required to have high reliability. The most important function of BFM is to verify onboard memory automatically. With this function, onboard memory verification activity does not disturb the DHU's telemetry edition activity. The BFM supports only those memories which satisfy both of following conditions:

- 1) The user has no ROM for onboard program storage.
(BFM does not support any ROM data.)
- 2) The memory can be accessed from PIM side with DMA (Direct Memory Access) method, and its address seen from the PIM side is fixed and independent of subsystem status.

(1) Onboard Memory Verification

The data stored in BFM can be automatically compared with the specified data in onboard subsystem by 512bytes (32kbytes max). DHU will read the BFM data and the specified data of the subsystem. After that, DHU will compare them by its software.

Reading data will be performed during the time window for DHU's action except command sending. (This window has a 31.25msec period having a cycle of 62.5msec regardless of edition bit rate and is called Command Window.) Therefore, the onboard memory verification does not need to change the telemetry edition mode and other PIMs will have no effect from this activity. Because the time required for 32kbytes memory verification is $32\text{kbytes}/512\text{bytes} \times 62.5\text{msec} \times 2 = 8\text{sec}$, basically, the CPU of specified subsystem is changed to "HALT" and the subsystem supports the telemetry data preparation only for data of HK packet, which does not need its CPU activity.

The verification result will be informed to the ground by a simple form, which is "Good" or "No Good", in the HK packet. Data dumping will be needed for getting the detailed information (BFM ADDRESS, BFM DATA, USER DATA). Data dumping accompanies telemetry edition mode change. The command sequence for onboard memory verification is shown in figure 4.1.3-1.

(2) Rewriting on Onboard Memory

For rewriting onboard memory in the subsystem which is the area to be supported by BFM, the user should take the following procedure.

- (1) To rewrite the specified area in BFM.

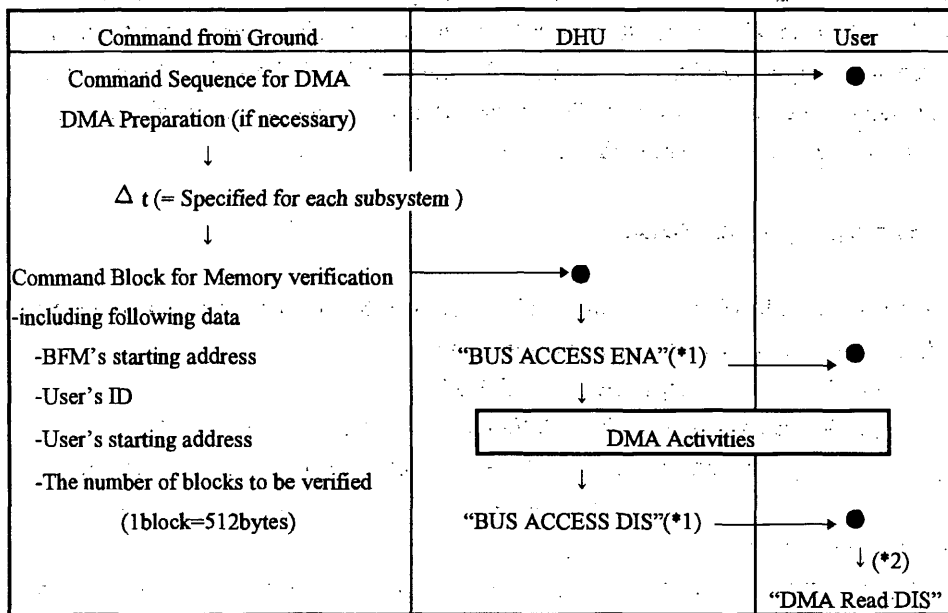
- (2) To transfer the data from BFM to the specified subsystem.

For rewriting onboard memory in the subsystem which is not the area to be supported by BFM, the component side should do the rewriting and memory data management by itself.

Onboard memory rewriting is performed by 512 bytes with DMA method during the command window as onboard memory verification. Therefore, onboard memory rewriting does not need to change the telemetry edition mode and this activity has no effect on other PIMs. The command sequence for onboard memory verification is shown in figure 4.1.3-2.

(3) Onboard Memory Dumping

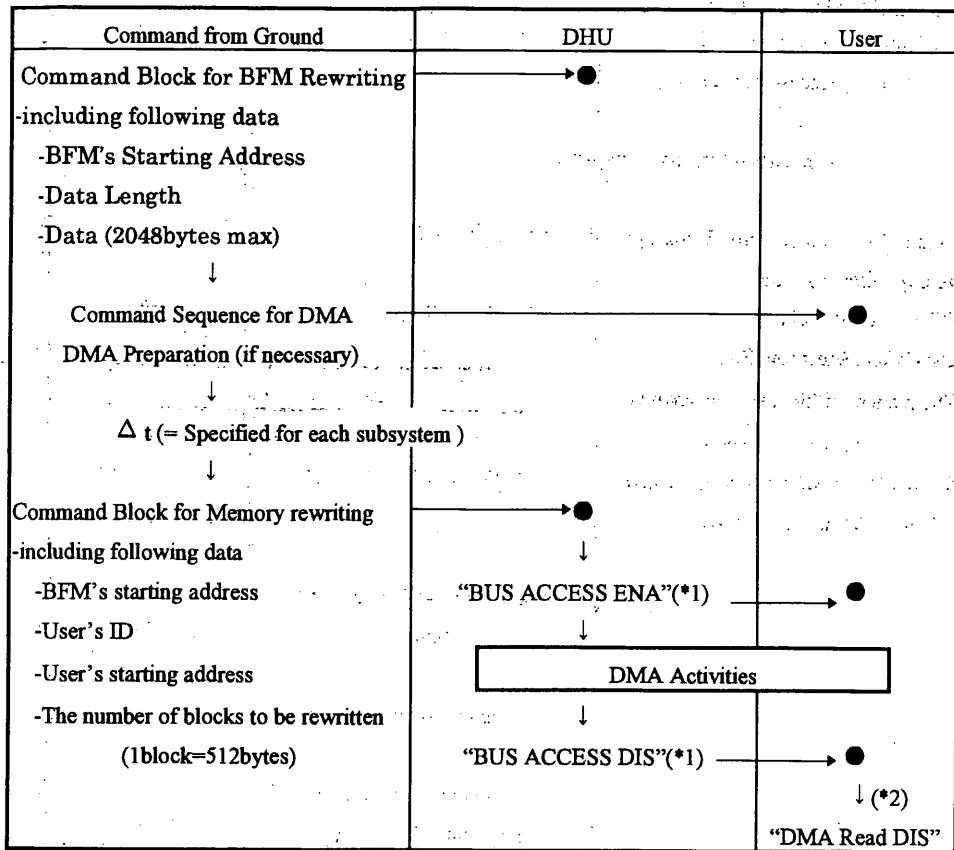
The memory data in the subsystems, which are compatible with the DMA method, can be dumped to the ground by 256bytes/packet. The telemetry edition mode needs to be changed for data dumping. After dumping data, the telemetry edition mode will be automatically changed to the specified mode. The onboard memory dumping is applicable for all the subsystem which complies with DMA method. For dumping the data not supported by BFM, user should insert the data in its mission packet. In this case, unless otherwise specially required, the telemetry edition mode will not be changed. The command sequence for onboard memory dumping is shown in figure 4.1.3-3.



*1-This command is generated by DHU.

*2-This is done by a user.

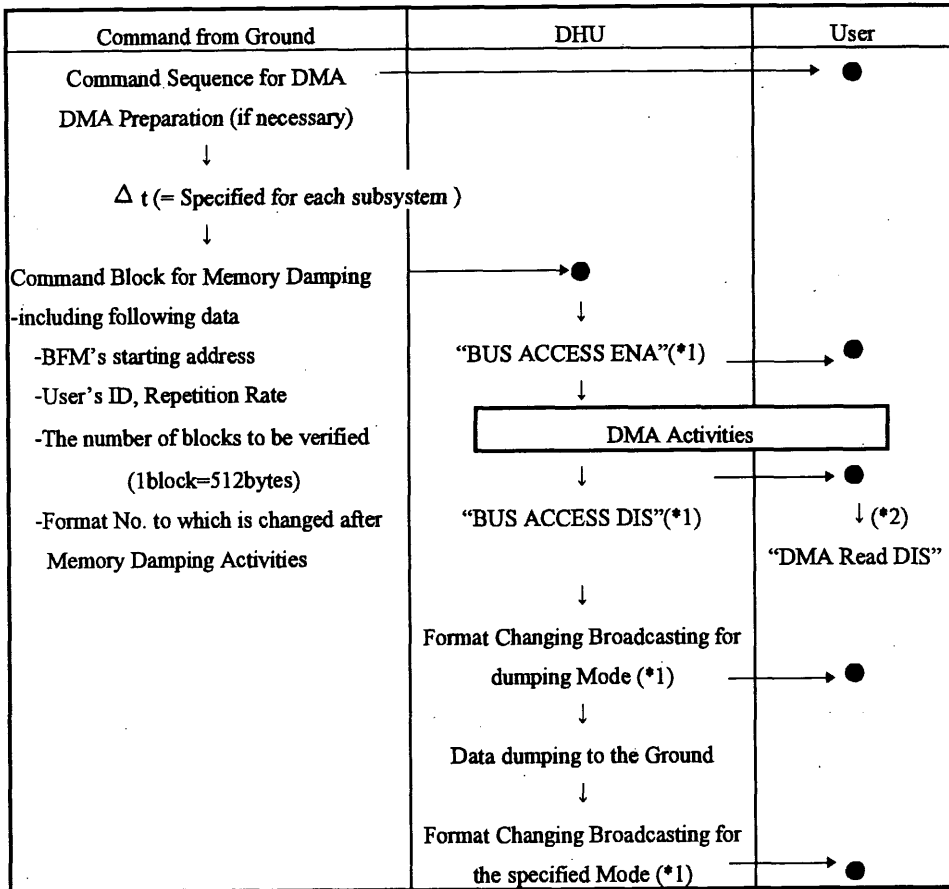
Figure 4.1.3-1 Command Sequence for Onboard Memory Verification



*1-This command is generated by DHU.

*2-This is done by a user.

Figure 4.1.3-2 Command Sequence for Rewriting Onboard Memory



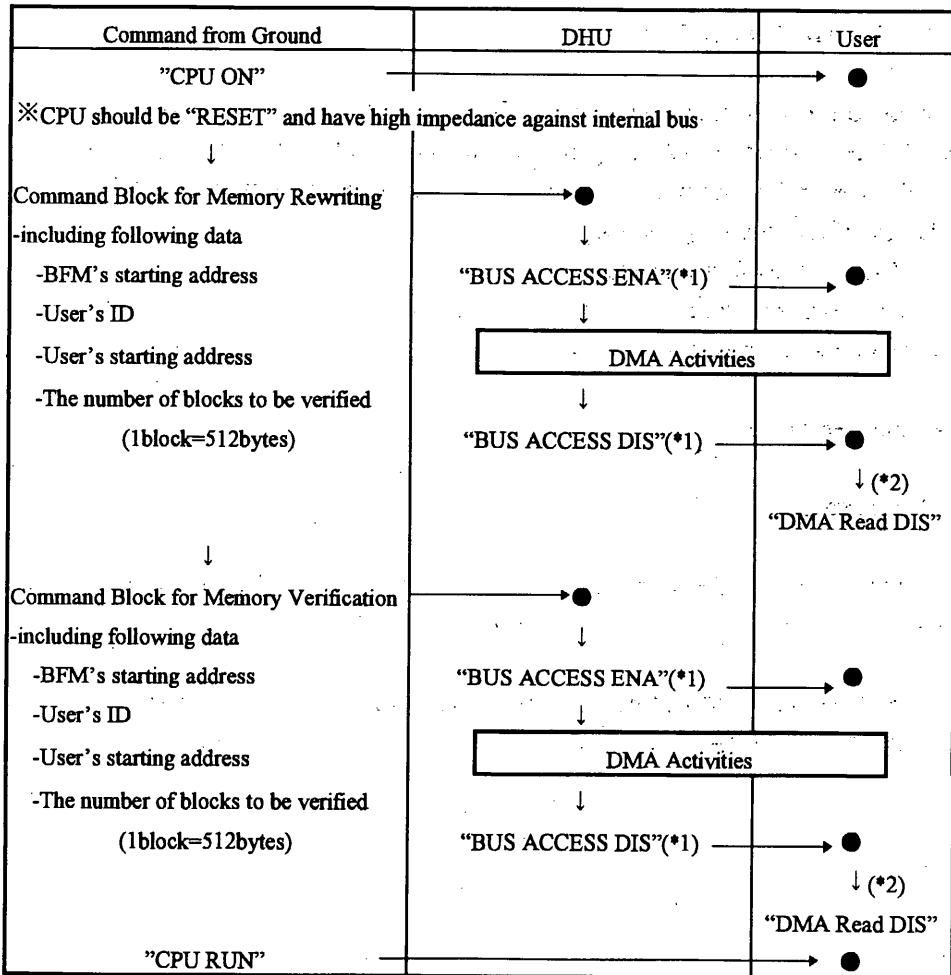
*1-This command is generated by DHU.

*2-This is done by a user.

Figure 4.1.3-3 Command Sequence for Dumping on Onboard Memory

(4) Initial Uploading

The onboard program for the component which has no ROM for it will be initially uploaded from the BFM. The procedure is shown in figure 4.1.3-4.



*1-This command is generated by DHU.

*2-This is done by a user.

Figure 4.1.3-4 Command Sequence for Initial Uploading

4.1.2 Autonomous Control System

The data handling system in PLANET-B has the function of onboard command generation without any requirement from the ground. For each command generated onboard, either of the two states, "ENABLE" or "DISABLE", can be selected.

(1) UVC (Under Voltage Control)

In the case of power shortage (Criteria:TBD), DHU will issue the command sequence for UVC and restrict the onboard power consumption. DHU will send "STAND-BY" or "OFF" command to specified subsystems to curb power consumption. UVC works under any of the following conditions:

- (A) Battery is discharging in sunlit condition.
- (B)Overdischarge of battery is expected in shadow.
- (C)Battery is in overdischarge status.

(2) Other Items (T.B.D.)

(3)Broadcasting

If DHU receives the following command from the ground, DHU will send it to all the PIMs.

- (A) Data Edition Mode Change Information (Bit Rate / Edition Format#)
- (B) TI Counter Reset

4.1.3 Data Handling

The telemetry data prepared with a basic unit (=432bytes =1packet) by each subsystem is sent to DHU through the data bus and DHU adds PIM identification code to each packet. Besides the above-mentioned "mission packet", there is what is called on "HK packet" for monitoring spacecraft housekeeping data on the ground. For HK packet, DHU collects necessary data from each PIM. Each PIM can identify either mission packet or HK packet with its telemetry edition address. The telemetry edition mode is specified by bit rate and packet collection pattern. For changing the mode, DHU sends a broadcasting command to all the PIMs.

One of the following three modes can be selected:

- 1) Transmit the data to the ground on a real time basis.
- 2) Store all the data in the Data Recorder (DR).
- 3) Store all the data in the DR and transmit a part of the data to the ground.

And each mode has two variety whether is simultaneous with reproducing DR or not. The configuration of transfer frame is shown in figure 4.1.3-1.

(1) HK Packet

The HK packet consists of the telemetry data necessary for spacecraft housekeeping. SIs need to prepare the data to be included in HK packet at the HK packet data collection.

(2) Mission Packet

The telemetry packet specified for each SI's PIM is called "Mission Packet". The internal configuration of mission packet can be basically determined freely by SI side. To be concrete, mission packet can consists only of mission data, or includes mission's HK data at SI's convenience for ground data handling. And, of course, mission packet includes time information for mission use.

(3) CLCW (Command Link Control Word)

PLANET-B command operation system has an error correcting code function and uplink information insertion in telemetry packet. The uplink information is called CLCW (Command Link Control Word) including the lock status, retransmission requirement flag and retransmission frame number. Based on the CLCW information, if necessary, the ground station can retransmit command data. But the PLANET-B case, from the view point of transmission time saving, the original command data is transmitted twice.

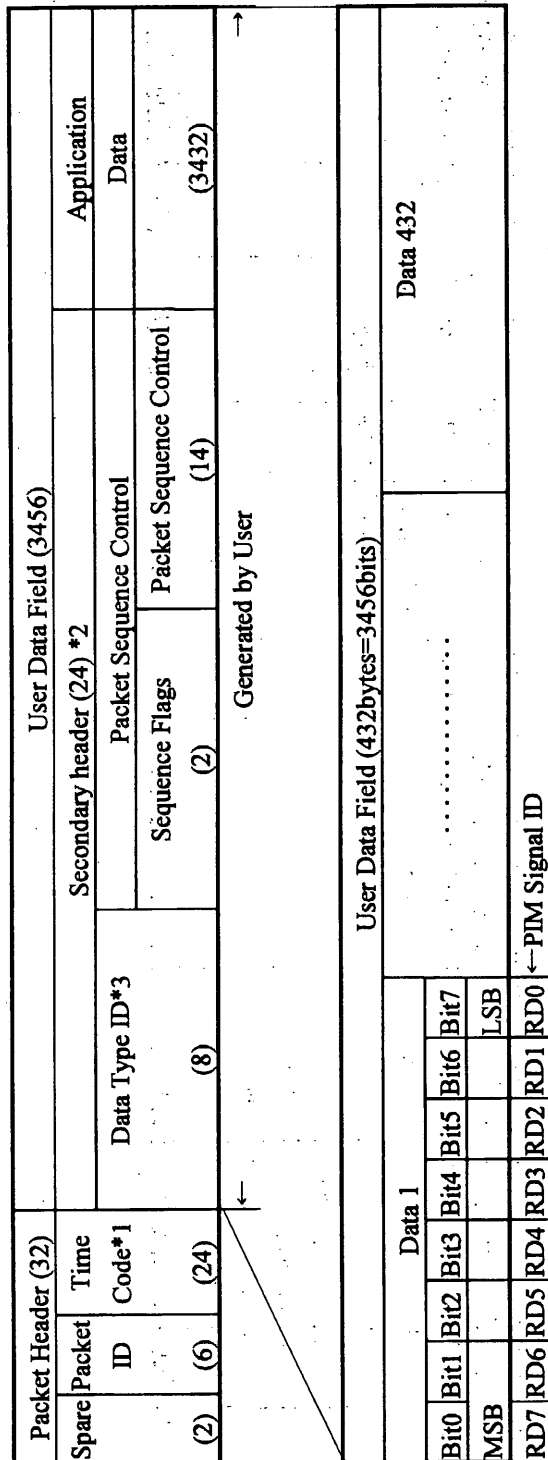
On the other hand, DHU has a memory area for storing command blocks (TBD blocks) and has command execution hysteresis data (sending time, IC and DC/BC data). These data are basically used only for trouble shooting. For transmitting these data, telemetry edition format must be changed.

*(X) : A number of bit in the section.

Sync Marker "1ACFFC1D" h (32)		Channel Access Slot (4064)											

Figure 4.1.3-1 Telemetry Format (1/2)

*(X) : A number of bit in the section.



*1- MSB=524288sec, LSB=31.25msec

*2-Each user can use the secondary header, if necessary. "Use" or "No use" is identified by each packet ID.

*3- The detail of "Data Type ID" is TBD.

Figure 4.1.3-1 Telemetry Format (2/2)

4. 2 Command Decoder (CMD)

4. 2. 1 Overview

A Command Decoder(CMD) consists of a Command Demodulator and a Command Data Decoder. The Command Demodulator selects a command base band signal from the two S band receivers, and demodulates it. The Command Data Decoder decodes the demodulated data and outputs the result to the Data Handling Unit(DHU).

4. 2. 2 Function

The block diagram of Command Decoder is shown in figure 4.2-1. The functions and operation of each instrument are described in the following sections.

4.2.2.1 Command Demodulator

- (1) Receiver Selector has input of the command base band signals from the two S band receivers, and outputs one command base band signal to the Subcarrier Synchronizer by Lock Detector status.
- (2) Subcarrier Synchronizer detects the 8000hz subcarrier from the command base band signal, and regenerates and demodulates the subcarrier.
- (3) Lock Detector watches Subcarrier Synchronizer status and selects a S band receiver by detected 8000hz subcarrier.
- (4) Bit Synchronizer regenerates bit timing from the demodulated subcarrier signal and detects data.
Bit Synchronizer 1 detects 125bps data and Bit Synchronizer 2 detects 15.625bps data.
- (5) Data Detector watches two Bit Synchronizers demodulation status and outputs bitrate selection signal to the Bit Clock Changer.

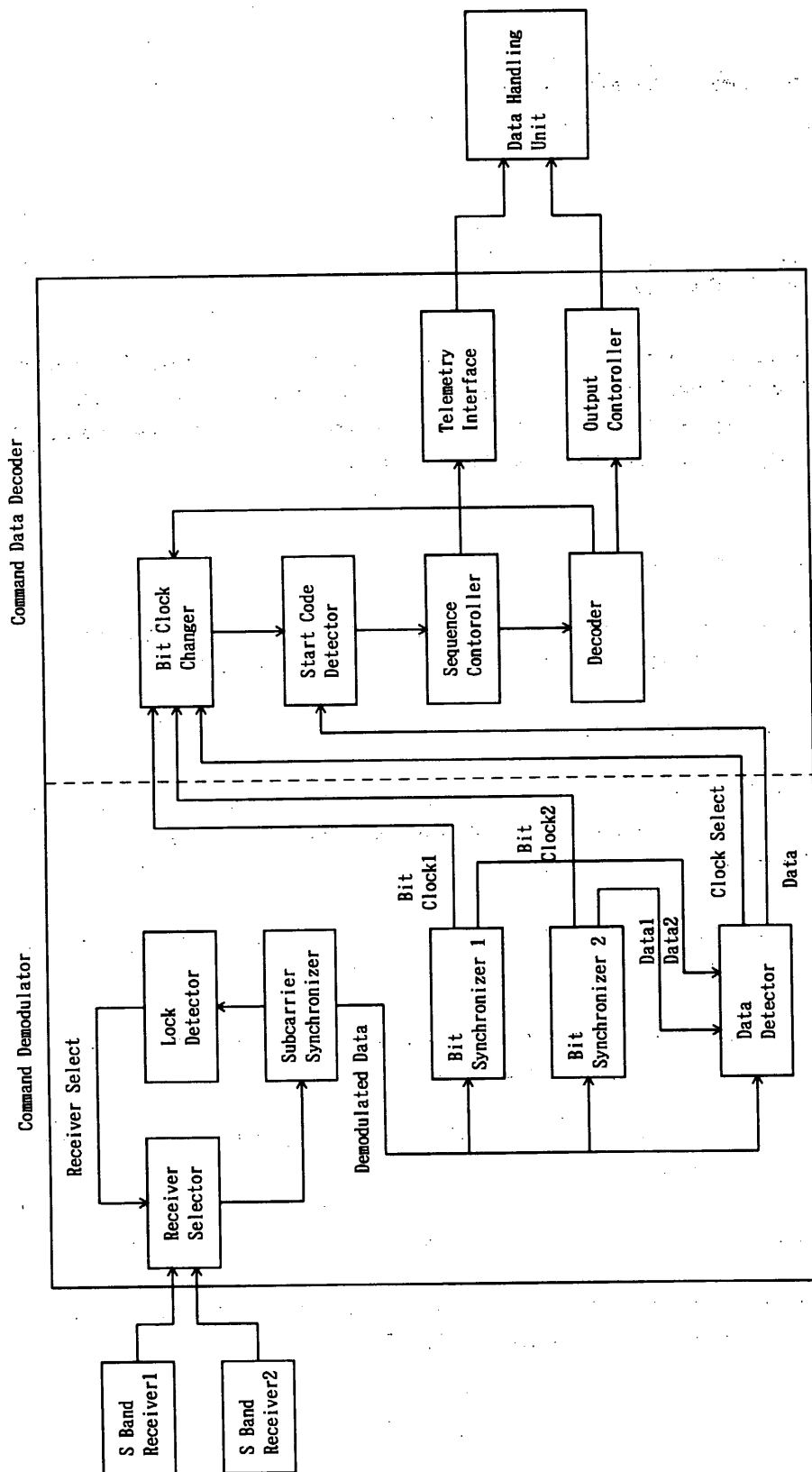


Figure 4.2-1 Command Decoder Block Diagram

4.2.2.2 Command Data Decoder

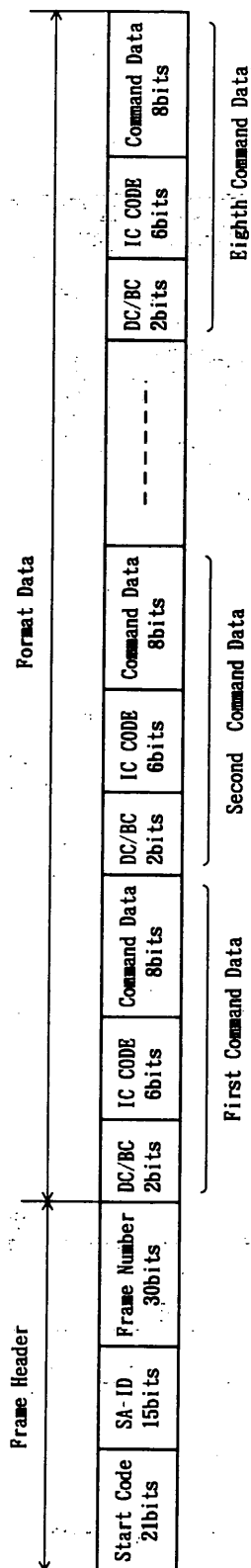
- (1) Bit Clock Changer selects a bit timing using the signal from Data Detector.
- (2) Start Code Detector detects frame Synchronization data and outputs start signal to the Sequence Controller.
- (3) Sequence Controller generates decoding signals for command data and outputs these signals to the Decoder.
- (4) Decoder decodes the PN code, command data, and conducts error detection and error correction.
- (5) Output Controller generates timing signals for the Data Handling Unit and outputs decoded data to the Data Handling Unit.
- (6) Telemetry Interface outputs Command Link Control Word and status to the Data Handling Unit.

4.2.2.3 Performance

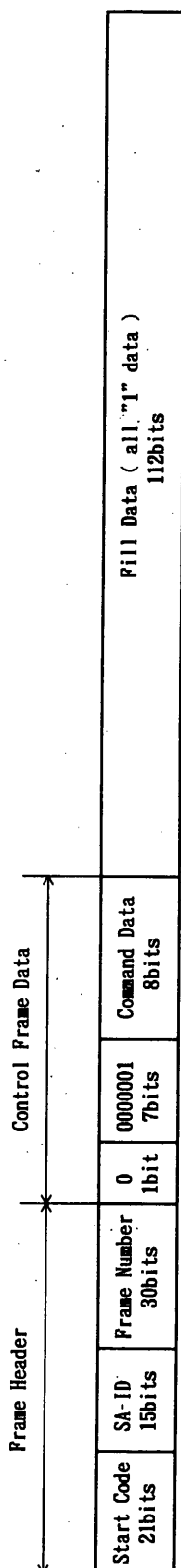
The principal specifications of Command Decoder are shown in table 4.2-1

Table 4.2-1 Principal Specification of Command Decoder

	Item	Specification
Electrical Specification	Subcarrier Modulation	PCM(PN) - NRZ/L - PSK
	Input Signal Level	$2.5V_{rms} \pm 1dB$
	Subcarrier Frequency	8000Hz
	Bit rate	125 bps 15.625bps
	Command Format	See figure 4.2-2
	Output	Command Data 1
		Command Clock 1
		Command Enable 1
Mechanical Specification	External view Weight	Telemetry Data 12 bit
		Lock ON/OFF 1 bit
		Data Error 1 bit
		Request Signal 1 bit
		Receiver Select 1 bit
		Command Link Control Word 8 bit
		Power Consumption $2.5W \pm 0.3W$
		See figure 4.2-3
		$1.7Kg \pm 0.2Kg$



(a) Command Frame



(b) Control Command Frame

Figure 4.2-2 Command Format

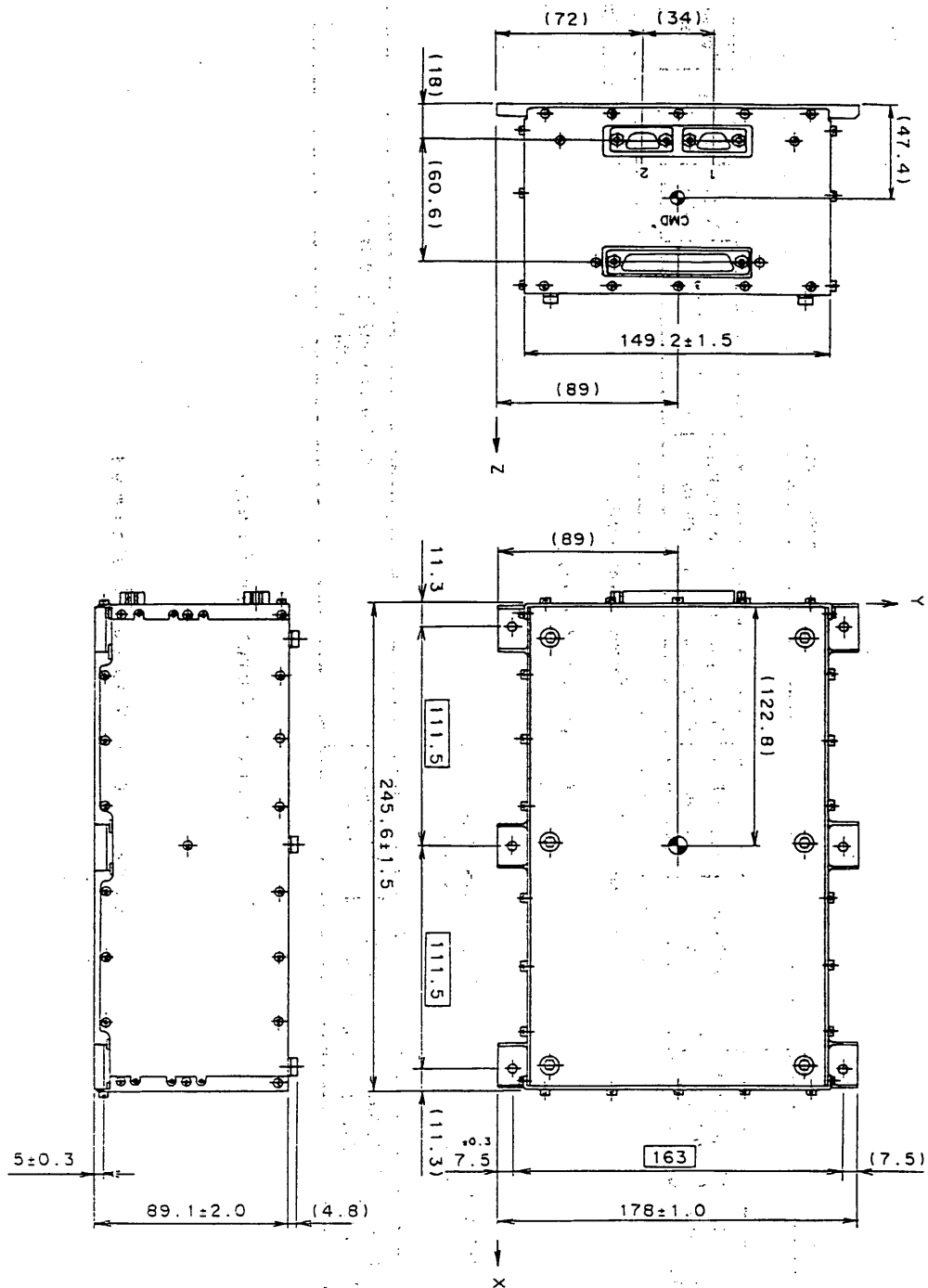


Figure 4. 2-3 External View of CMD

4. 3 Data Handling Unit (DHU)

4.3.1 Overview

DHU manages all subsystems of the spacecraft. Its main functions are decoding and executing the uplink command, and collecting and editing the House Keeping Data and the Mission data via the Data Bus. The Data Bus is used for transferring the command and telemetry data.

DHU adopts surface mount method to realize miniaturization and weight reduction. Its principal features are follows:

- a) DHU has a serial Data Bus which is used for transferring the data between DHU and user system to realize light weight Data Handling subsystem. The Data Bus consists of Bus Master Clock, Supervisory bus (control bus) and Response Bus (Return bus).
- b) The uplink command format is changed from the previous ones to improve uplink command rate. The command data is made of the Command Transmission Track. The Command Transmission Track consists of 2 bytes of header data and 14 bytes of command data.
- c) The downlink telemetry format is conformed to AOS (Advanced Orbiting Systems) Transfer Frame format recommended by the CCSDS (Consultative Committee for Space Data Systems), and adopts RS (Reed Solomon) code as outercode.
- d) The user interface between the data handling system and the user, is PIM (Peripheral Interface Module). This makes it easy to designing the interface between the data handling system and the user.
- e) The data are transmitted through the Data Bus as packet. And the house keeping data and the mission telemetry data are sampled as packets according to programmable packet sequence data in DHU.
- f) For the previous ISAS satellites uplink command is decoded by DHU Hardware. But in PLANET-B it is decoded by Software on 80C86 CPU to realize the high flexible command operation.

4.3.2 Functions

The functional block diagram of DHU is outlined in figure 4.3-1.

DHU consists of modules such as CPU Module (CPM), Command Interface Module (CMDIF), Bus Control Module (BCNT), Status Encoding Module, Telemetry Processor Module (TLMP), Backup File Memory (BFM) and several interfaces including the Data Bus interface.

The functions and operations of each module are described in the following sections.

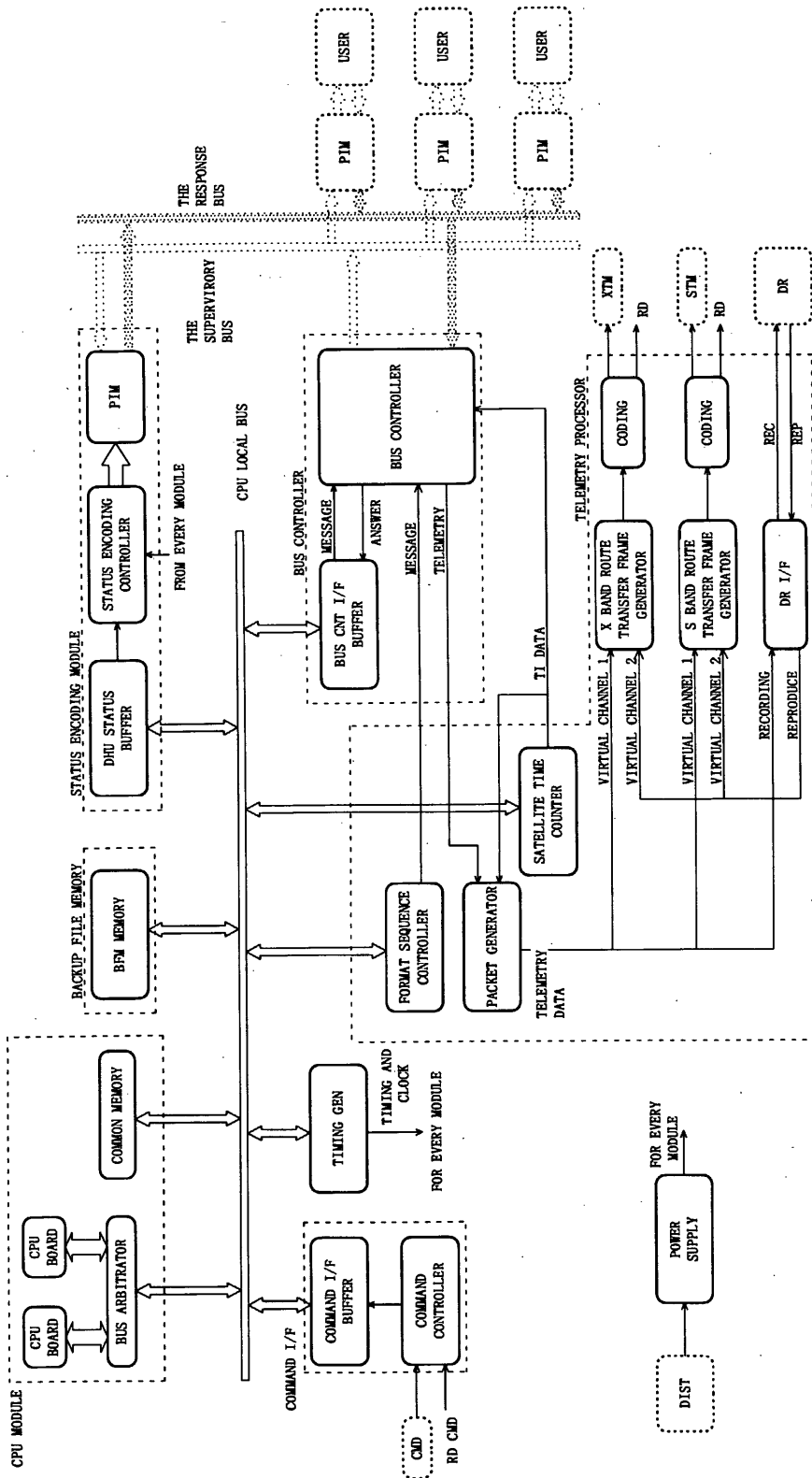


Figure 4.3-1 Block Diagram of Data Handling Unit

4.3.2.1 CPU Module(CPM)

CPM consists of 2 redundant CPU boards, Common Memory and Local Bus arbitrator. Each CPU has Interrupt controller, timer, DMA controller, and Local Memory.

When Power On or CPU Reset command is executed, DHU state turns to IPL mode. In IPL mode, DHU executes redundant CPU switching command and basic DHU's commands, and OS (Operating System) and AP (Application program) can be loaded on CPU.

By "Normal Mode Run" command, DHU status is changed to Normal mode. In Normal mode CPU operates following functions.

- a) Decoding the uplink command.
- b) Generating the time specified command.
- c) Generating and executing automatic commands (OP/OG operation)
- d) Monitoring telemetry and generating autonomous command.
- e) Processing command priority to avoid cross-talk.
- f) Encoding DHU status telemetry.

CPM takes following measures to prevent malfunction and to find anomaly to increase reliability.

- a) Use of SEC-DED (Single Error Correct-Double Error Detect) code in RAM.
- b) Supervision of CPU action W.D.T (Watch Dog Timer).
- c) Supervision of irregular memory address and detection of access error.

4.3.2.2 Command Interface Module(CMDIF)

The commands that is demodulated and coded in CMD, is sent to DHU. The interface between CMD and DHU is serial. In CMDIF, the bit length of the command data is checked and it is stored in command interface buffer.

4.3.2.3 Bus Control Module(BCNT)

BCNT is a bus controller of the data bus protocol, and generates the data bus timing. The data bus timing consists of the Telemetry Window (31.25msec) and the Command Window (31.25msec).

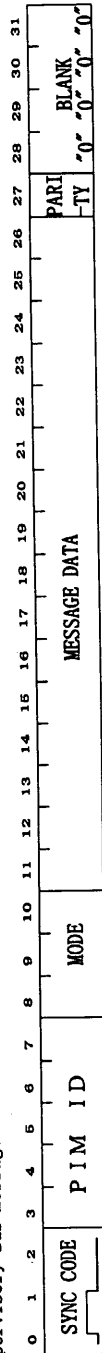
In the Telemetry Window, BCNT reads telemetry collecting message from TLMP (Telemetry Processor Module) and sends it to PIM via the supervisory bus. The sampled telemetry data is returned from PIM via the response bus as the response bus message and sent to TLMP.

In the Command Window, BCNT reads command message from CPM and sends it to PIM via the supervisory bus. The PIM returns the command acknowledge data to BCNT via the response bus, and BCNT sends the command answer to CPM.

ODD parity and PIM ID are included in both bus messages, and checked at the PIM and BCNT. The message format is shown in figure 4.3-2.

If parity error or PIM ID error appears in the supervisory bus or the response bus, BCNT retries to send the message until the right answer is obtained within the

The Supervisory Bus Message



The Response Bus Message

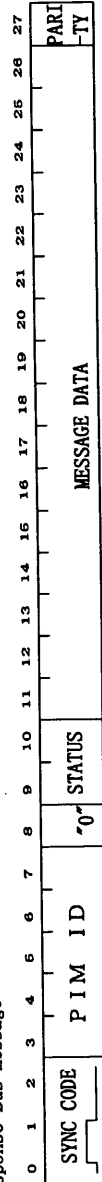


Figure 4.3-2 The Data Bus Message Format

definition time. After the definition time, BCNT rejects the retrying command.

Each window consists of repetition of the polling slot(15.3usec), the control slot (15.3usec) and the Dummy slot(15.3usec). BCNT sends the supervisory bus message in the control slot. In polling slot, BCNT collects the user request code and sends them to CPM. If a user requests programmed operation(commands issue, data transmission, etc) to DHU, the user issues the request code and the request pulse to PIM. DHU reads the request code in polling slot, and the request code triggers the generation of automatic commands and bus operations.

4.3.2.4 Status Encoding Module

Status Encoding Module consists of telemetry collection module and PIM. The telemetry of DHU's telemetry data is collected by the telemetry collection module, and sent to TLMP via PIM of STM and the Data Bus.

4.3.2.5 Telemetry Processor Module(TLMP)

TLMP generates telemetry data. The telemetry data is collected from users, according to the packet sequence data. This packet sequence data has 64 packet formats(MAX) and 32 sampling sequence formats(MAX) that can be reprogrammed after wards. These formats can be set by uplink command from the ground. As DHU has many formats, to flexibly collect telemetry is possible according to requests from SIS. The collected telemetry data via the Data Bus is edited as house keeping packets or as mission data packets. These packets are sent to DR(Data Recorder) as recording telemetry.

In PLANET-B, the downlink telemetry format is conformed to AOS(Advanced Orbiting Systems) Transfer Frame format that recommended by the CCSDS(Consultative Committee for Space Data Systems).

Packet sampling rate and telemetry bit-rate can be set independently by command. When telemetry bit-rate is slower than packet sampling rate, Transfer Frame Generator reduces some frame.

TLMP has two independent Transfer Frame Generators: S band route and the X band route. The X band route and S band route are switched to either real time telemetry or reproduced telemetry from the DR. Each Generator includes RS(255,232) encoder to reduce bit-error-rate.

Satellite time counter maintains relative time as TI(Time indicator) and supplies 2^{26} to 2^5 seconds TI data(1553days at maximum).

4.3.2.6 Backup File Memory(BFM)

BFM consists of EEPROM, that is allocated on CPM local bus. BFM stores user program data and these data can be written through uplink command. In user program writing mode, DHU sends user program data stored in BFM to user and verifies both stored data in BFM and user data.

4.3.2.7 Interface

The main interfaces of DHU are as follows

a) Data Bus Interface

The telemetry and command interface between DHU and each instrument adopts the standard data bus interface, described as follows.

DHU doesn't have the direct user interface, but PIM has one. DHU and PIM are connected with the serial Data Bus, and the Data Bus consists of the Bus Master Clock, the Supervisory bus and the Response Bus.

The Bus Master Clock supplies fundamental clock of PIM and is used for transmitting the Supervisory Bus message. The Supervisory Bus controls the data bus protocol and PIM. PIM writes to or reads from user instrument according to the Supervisory Bus Message. PIM sends user's read data and command acknowledge to DHU via the Response Bus according to the Supervisory Bus Message.

b) Command Interface

The uplink command interface is serial data interface from the CMD(Command Decoder). This interface consists of Enable, Clock and Data Signals, and 128 bits / 1 Command Transmission Track is sent continuously.

c) The telemetry Interface

The Downlink telemetry (the transfer frame) encoded by TLMP is coded as follows

S Band route: NRZ-L $\rightarrow$ NRZ-S $\rightarrow$ CONV. $\rightarrow$ PSK

X Band route: NRZ-L $\rightarrow$ NRZ-S $\rightarrow$ CONV. $\rightarrow$ Bi ϕ -L

The telemetry data is converted into NRZ-S, and then coded by error correction code as inner code. The coding process employs convolution code (NASA-JPL format) with restriction length K=7 and coding rate R=1/2, by Viterbi decoding algorithm. Coded signals are converted into Bi ϕ -L or undergo PSK modulation.

d) Umbilical Command Interface

DHU has umbilical interface. It uses umbilical line for high speed writing of program, etc. The interface receives serial commands same as the uplink command by a differential receiver.

This interface sends downlink telemetry that are converted into Bi ϕ -L by the differential driver.

This interface is only used on the ground, and is turned off just before launch in order to prevent malfunction.

4.3.2.8 Performance

The major specifications of DHU are shown in table 4.3-1 and the external view is shown in figure 4.3-3.

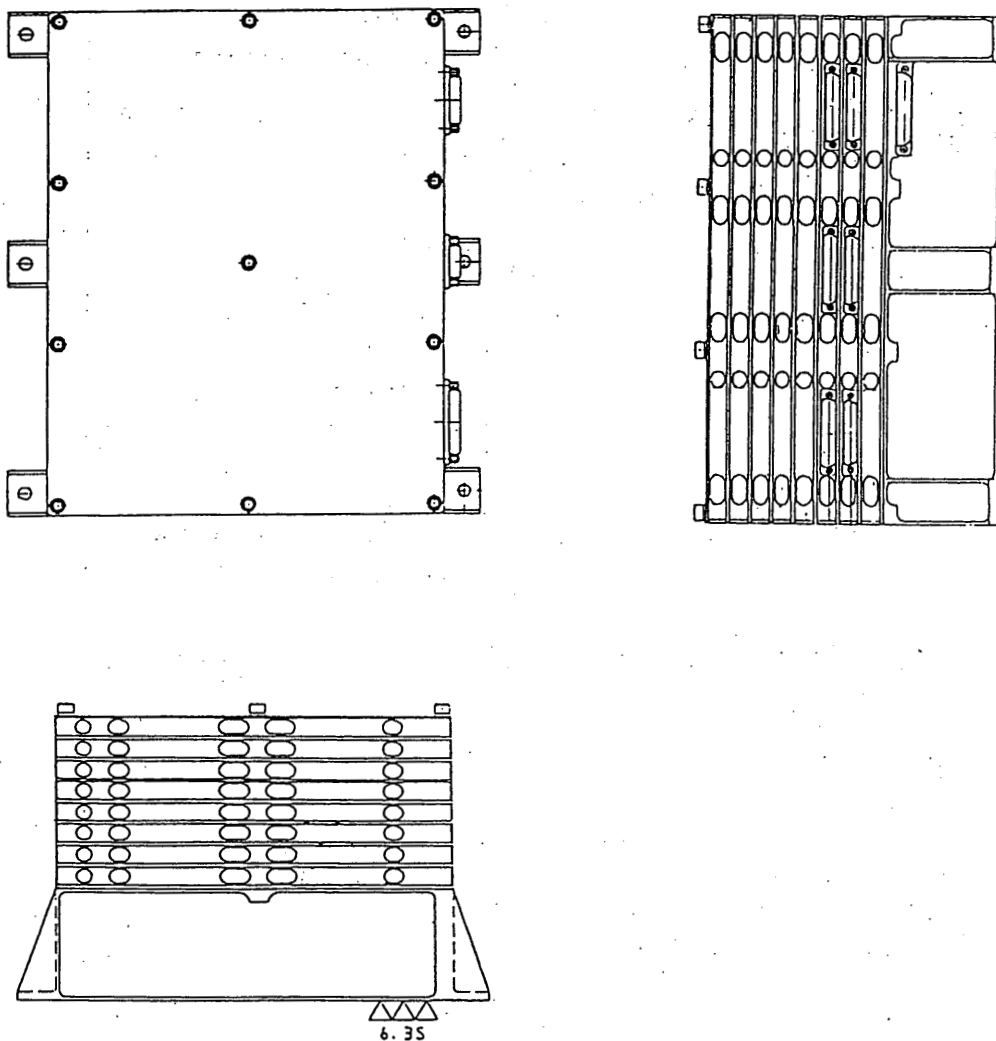


figure 4.3-3 External View of DHU

Table 4.3-1 Principal Specification of DHU

I T E M	D I M E N S I O N
1) REAL TIME COMMAND DATA ORGANIZATION	8 bits/Word. 16 Word/Command Transmission Track
2) PROGRAM COMMAND OPERATION PROGRAM(OP) CONTROL ELEMENT(CE) ORGANIZED COMMAND(OG) INTERVAL TIME	512 CE's/OP 1 CE consists 1 OG and 1 Interval Time 1 OG consists 16 sets of "IC" and "Command Block" 30 sec ~ 65536sec
3) DOWN LINK TELEMETRY FORMAT DATA ORGANIZATION DATA FORMAT VIRTUAL CHANNEL ERROR CORRECTION DATA CONVERSION TELEMETRY SAMPLING RATE	8 bits/Word 512 Word/Transfer Frame CCSDS AOS Transfer Frame Format 2 Transfer Frame Generator 3 Channel (Include FILL Frame) RS(255,232) Encoding (outer code) VERCHAL FILL : 2 SYMBOL/FRAME INTERLEAVE : 2 Convolution Encoding (inner code) S Band Route: 64bps to 1024bps NRZ-L→NRZ-M→CONV→PSK(Subcarrier FREQ. 8192Hz) X Band Route: 2048bps to 32768bps NRZ-L→NRZ-M→CONV→Biφ-L 64bps to 65536bps
4)Data BUS INTERFACE BUS MASTER CLOCK FREQ. SUPERVISORY BUS ORGANIZATION SUPERVISORY BUS MESSAGE LENGTH RESPONSE BUS MESSAGE LENGTH	4194304Hz(nominal) 32 bits/1 slot 2097152bps Differential Interface (RS-485) 32 bits/1 message 28 bits/1 message
5)POWER CONSUMPTION	CPU A ON/BFM OFF : 16.1W CPU A ON/BFM ON : 17.1W CPU A/B ON/BFM OFF : 17.5W CPU A/B ON/BFM ON : 18.6W
6)WEIGHT	4.2kg (nominal)
7)SIZE	220mm × 170mm × 105mm

4. 4 Peripheral Interface Module (PIM)

4.4.1 Overview

PIM is the remote terminal of DHU to connect between the Data Handling Subsystem and the user equipment. PIM's main hardware consists of only 2 IC(FPGA)s and line driver/receiver to realize small and light weight user interface. Its principal features are as follows:

- a)PIM receives and decodes the supervisory bus message, and writes command or reads telemetry according to the supervisory bus message from DHU. PIM sends answer or telemetry data to DHU via the Response Bus. The fundamental clock of PIM is supplied by the Bus Master Clock.
- b)The interface between the data handling subsystem and the user equipment is a unified to standard one. PIM has a standard user interface that is similar to as CPU local bus and several pulse signals.
- c)PIM has a time counter that supplies the TI data for users, and this counter is calibrated by the time calibration command from DHU via the Data Bus.

4.4.2 Functions

The functional block diagram of PIM is outlined in figure 4.4-1.

PIM consists of Supervisory Bus Message Decoder(S-BUS DEC), User Interface(USR I/F), Status Register(STS REG) and Response Bus Message Encoder(R-BUS ENC) and TI counter (TIC).

The functions and operations of each module are described in the following sections.

4.4.2.1 Supervisory Bus Message Decoder(S-BUS DEC)

In this Module, the Supervisory Bus Message is synchronized, and then compared with PIM ID (PIM Identifier Number:this Number is unique and assigned to each PIM) and the parity is checked. PIM responses with the message that is equal to its own PIM ID. When these checks are correct, PIM returns telemetry data or command acknowledge. If the PIM ID in the Message is correct and the message has parity error, PIM returns parity error flag in the message, and then a correct message is decoded.

The message for PIM itself is executed and the message for user is sent to USR I/F.

The command message that has PIM ID = "11111"(bin) means broadcast command, and every PIM response to this message. But when PIM receives the broadcast command, every PIM doesn't return acknowledge.

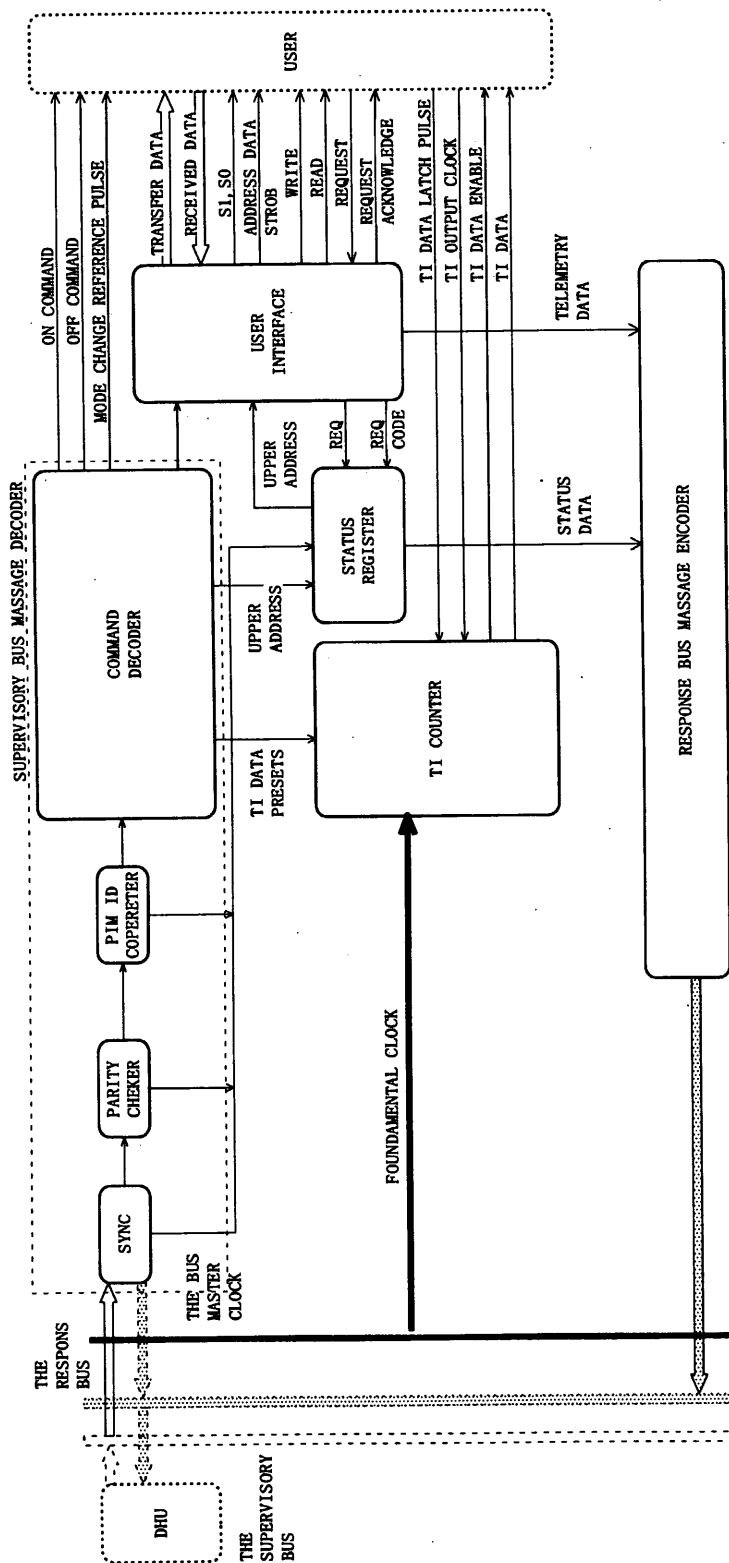


Figure 4.4-1 Block diagram of Peripheral Interface Module

4.4.2.2 User Interface(USR I/F)

The message for the user is decoded and translated for the user interface signals similar to the CPU local bus. USR I/F writes command message for user or reads the user telemetry according to the message from S-BUS DEC. And the telemetry data that is read from user is sent to R-BUS ENC.

4.4.2.3 Response Bus Message Encoder(R-BUS ENC)

In R-BUS ENC, the Response Bus message is generated for the acknowledge and telemetry according to the result of checking in SUPDEC. The output driver is enabled only when its own PIM is selected by the Supervisory Bus Message.

The Response Bus Message has ODD parity to transmit the more reliable data.

4.4.2.4 TI counter(TIC)

TIC has the time counter in each PIM, that is counted by the Bus Master Clock. So each PIM's time is synchronized with the DHU. The time counter is presented to the master satellite time in DHU by the time that is set by the broadcast command from DHU. The time count data is supplied to users as the TI data.

4.4.2.5 Interface

PIM has 2 interfaces, one is the Data Bus interface and the other one is user interface. In the Data Bus interface, PIM has input terminals of the Bus Master Clock and the Supervisory bus, and the Response Bus output terminal. These signals use differential interfaces.

The user interface is described in Figure 4.4-2 and Table 4.4-1. I/O in the table denotes the input to the PIM or the output from the view point of the PIM. The PIM and its user are connected by 51-pin MDM connector.

4.4.2.6 Performance

The major specifications of PIM are shown in table 4.4-2 and the external view is shown in figure 4.3-3.

Table 4.4-1 User Interface Signal Description(1/3)

ABBREV	SIGNAL NAME	I/O	FUNCTION	PIN NO													
TD15	Direct access flag	0	(Transfer Data) This signal shows that the PIM accesses the user's CPU bus with DA (Direct Access)="1" or NDA (Non Direct Access)="0". DA means that the PIM occupies the user's CPU bus and accesses directly to the program memory. In DA the PIM outputs arbitration command (BUS ACCESS ENABLE, DIS). NDA means that the PIM accesses when writing commands and reading telemetry area (ex. exclusive I/O or memory for the PIM).														
TD14~8	High-address data (7bit) MSB: TD14 LSB: TD8	0	(Transfer Data) The higher address of TD14~8 is added to the lower address of TD7~0 to make total 15bits address data.	※1													
TD7~0	Command /low-address data (8bit) MSB: TD7 LSB: TD0	0	(Transfer Data) TD7~0 bus is used to output both command and lower address from the PIM to the users. When the PIM reads the user data, lower address is continuously output in one access. When the PIM writes data to the user, lower address and command data are sequentially output in one access.														
RD7~0	Telemetry data /user request data (8bit) MSB: RD7 LSB: RD0	I	(Received Data) RD7~0 bus is used to input the user telemetry data or the user request data from the user to the PIM.	※2													
S1,0	Status1,0	0	(Status1,0) This shows the status of TD15~0 in combination of S1 and S0. <table border="1"><thead><tr><th>S1</th><th>S0</th><th>STATUS</th></tr></thead><tbody><tr><td rowspan="2">1</td><td>1</td><td>DC command write</td></tr><tr><td>0</td><td>BC command write</td></tr><tr><td rowspan="2">0</td><td>1</td><td>Read from Status register, DPRAM</td></tr><tr><td>0</td><td>INT write (ECW, EMR)</td></tr></tbody></table> DC—Immediately executed after it has been decoded by the user. (first byte of command block) BC—Used to set the user parameters and to load the programs.	S1	S0	STATUS	1	1	DC command write	0	BC command write	0	1	Read from Status register, DPRAM	0	INT write (ECW, EMR)	S1:25 S0:42
S1	S0	STATUS															
1	1	DC command write															
	0	BC command write															
0	1	Read from Status register, DPRAM															
	0	INT write (ECW, EMR)															

Table 4.4-1 User Interface Signal Description(2/3)

ABBREV	SIGNAL NAME	I/O	FUNCTION	PIN NO
ADRS STB	Address data strobe	0	(Address Data Strobe) ADRS STB is the strobe signal for latching the lower address TD7-0. The user should latch the address at a negative edge of ADRS STB.	8
WR	Write	0	(Write) The WR signal is output when the user I/O or memory is written in.	26
RD	Read	0	(Read) The RD signal is output when the data to the user I/O or memory is read out. The PIM latches RD data at a negative edge.	43
REQ	Request	I	(Request) When the user wants to execute the user request processed that has been already registered to DHU, the user writes request code address FF01 and sets the REQ signal to the high level. The user can verify by the REQ ACK signal from the PIM whether the request is accepted or not. The REQ signal should be kept at the high-level until the REQ ACK is set. Before using this function, the user should register the user request code to DHU.	11
REQ ACK	Request acknowledge	0	(Request Acknowledge) The REQ ACK is output when DHU accepts the request and finishes request sequence. The user resets the REQ signal to the low-level by synchronizing REQ ACK (positive edge).	10
TI LCH	TI data latch pulse	I	(TI Data Latch Pulse) The user uses the TI LCH signal to latch the PIM time counter value (TI23-0) at the timing when the user needs to get the data.	29
TI CLK	TI output clock	I	(TI Output Clock) The clock is input from the user in order to output the serial time data latched by the TI LCH. It is no problem that the user always outputs this signal.	46
TI DATA ENA	TI data enable	0	(TI Data Enable) When the TI data (TI23-0) is output from the PIM, the PIM sets this signal in the high-level.	28

Table 4.4-1 User Interface Signal Description(3/3)

ABBREV	SIGNAL NAME	I/O	FUNCTION	PIN NO
TI DATA	TI data	0	(TI Data) When the user requests the time counter data distribution, the TI data (TI23-0) is output to the user serially (MSB first) from the PIM by being synchronized with the clock input from the user.	45
MCRP	Mode change reference pulse	0	(Mode Change Reference Pulse) The DHU outputs this signal at the head of the every telemetry collect sequence. The user should change own observation mode based on format/bit-rate information by synchronizing this signal. The major frame quantity of telemetry collect sequence is variable.	9
ON CMD	On command	0	(On Command) This signal is used for turning on the user main switch (relay) . The pulse width of this signal is 25 ± 5 msec. Since this is CMOS interface, the user should have relay drive circuit.	27
OFF CMD	Off command	0	(Off Command) This signal is used for turning off the user main switch (relay). The pulse width of this signal is 25 ± 5 msec. Since this is CMOS interface, the user should have relay drive circuit.	44
+5V	+5V	I	(+5V) The user provides the PIM with +5V stabilized power.	34
COM(2)	COM(2)	I	(COM(2)) The user provides the PIM with the secondary power ground.	17

※1

SIGNAL NAME	PIN NO	SIGNAL NAME	PIN NO
TD15	2	TD7	39
TD14	20	TD6	5
TD13	37	TD5	23
TD12	3	TD4	40
TD11	21	TD3	6
TD10	38	TD2	24
TD9	4	TD1	41
TD8	22	TD0	7

※2

SIGNAL NAME	PIN NO
RD7	13
RD6	31
RD5	48
RD4	14
RD3	32
RD2	49
RD1	15
RD0	33

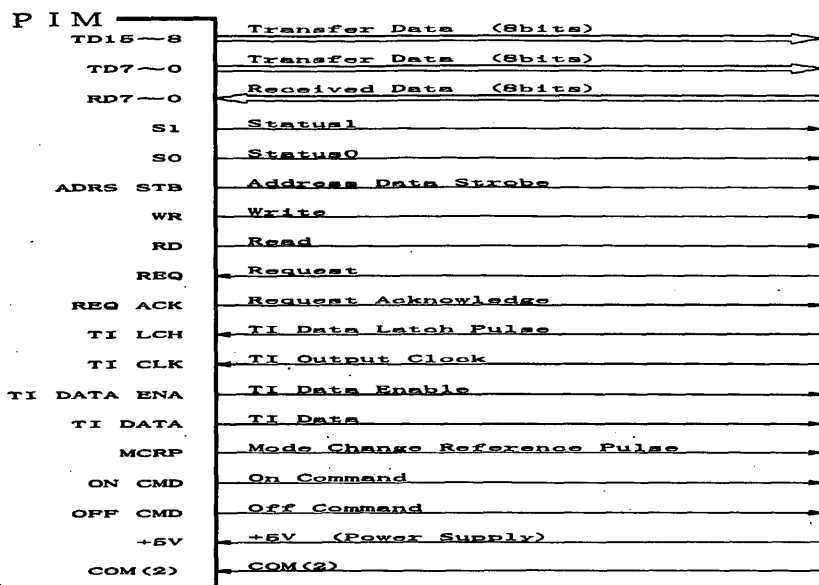


Figure 4.4-2 User Interface Signals

Table 4.4-2 Principal Specification of PIM

ITEM	DIMENSION
1) Data BUS INTERFACE	
BUS MASTER CLOCK FREQ.	4194304Hz(nominal)
SUPERVISORY BUS ORGANIZATION	32 bits/1 slot 2097152bps Differential Interface (RS-485)
SUPERVISORY BUS MESSAGE LENGTH	32 bits/1 message
RESPONSE BUS MESSAGE LENGTH	28 bits/1 message
2) TI DATA	
DATA LENGTH	24 bits
TIME INDICATION	125 msec~12 day
ACCURACY	DEPENDING ON DHU FUNDAMENTAL CLOCK
TI DATA SAMLPIG CLOCK	32768Hz (MAX)
3) USER INTERFACE	
TRANSFER DATA BUS	16BITS (LOWER 8 BITS ARE MULTIPLEXED LOW ADDRESS AND DATA)
RECEIVED DATA BUS	8BITS
CONTROL SIGNALS	5 SIGNALS(S1, S0, ADDRESS DATA STROBE, WRITE, READ)
REQUEST INTERFACE	2 SIGNALS(REQUEST, REQUEST ACKNOWLEDGE)
TI DATA INTERFACE	4 SIGNALS(TI DATA LACH PULSE, TI OUTPUT CLOCK, TI DATA ENABLE, TI DATA)
TIMING SIGNAL INTERFACE	1 SIGNAL(MODE CHANGE REFERENCE PULSE)
PULSE COMMAND CH.	2 CH(ON AND OFF COMMAND)
4) POWER CONSUMPTION (PRELIMINARY)	
	100mA (TYP)
	130mA (MAX)
5) WEIGHT (PRELIMINARY)	170g (nominal)
6) SIZE (PRELIMINARY)	120mm × 96mm × 21mm

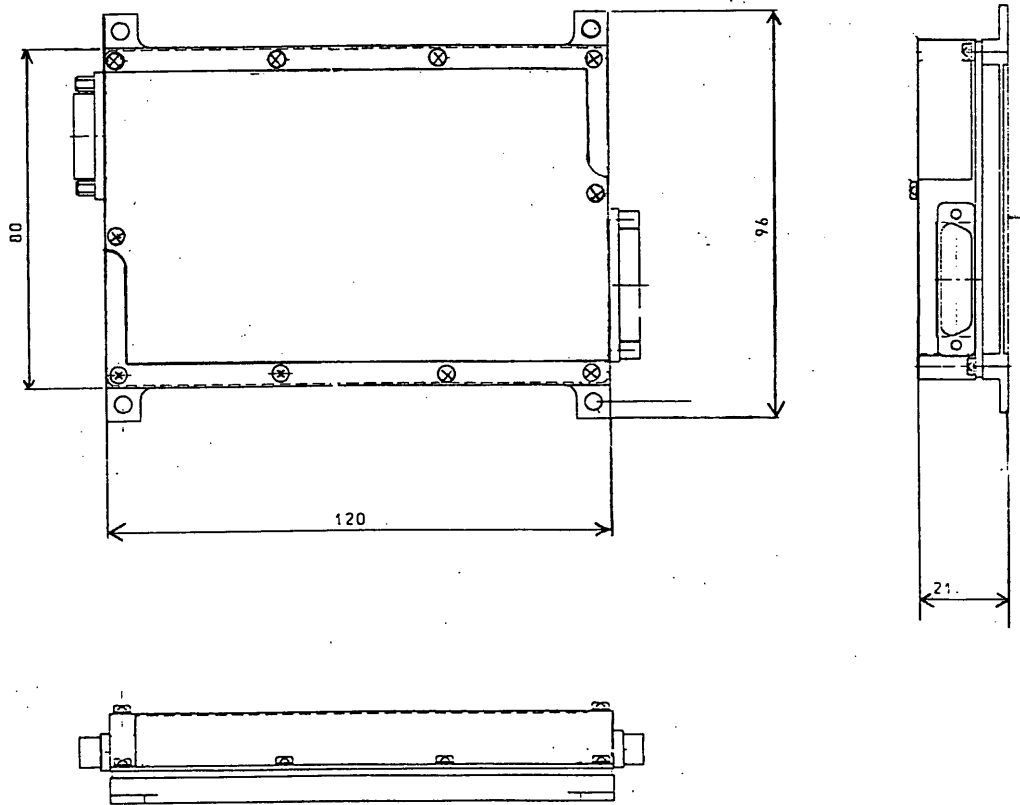


figure 4.4-3 External View of PIM

4.5 Data Recorder (DR)

4.5.1 Overview

A Solid state data recorder using 16Mbits DRAMs as storage devices is used. DR records observation and instrument status data edited by DHU (Data Handling Unit) and reproduces the stored data during the visible periods from the tracking stations. Record data rate is 65kbps (max.) and reproduce data rate is 32kbps (max.) respectively. It stops automatically at the end of reproduction. When an overwrite mode is selected a command, old data is overwritten by newly stored data. DRAMs are divided into four Memory Blocks and each Memory Block is supplied with power independently such that in case of the failure of one of the Memory Blocks, it can be separated from others.

4.5.2 Functions

(1) Architecture

Schematic Diagram of PLANET-B DR is shown in Fig. 1.

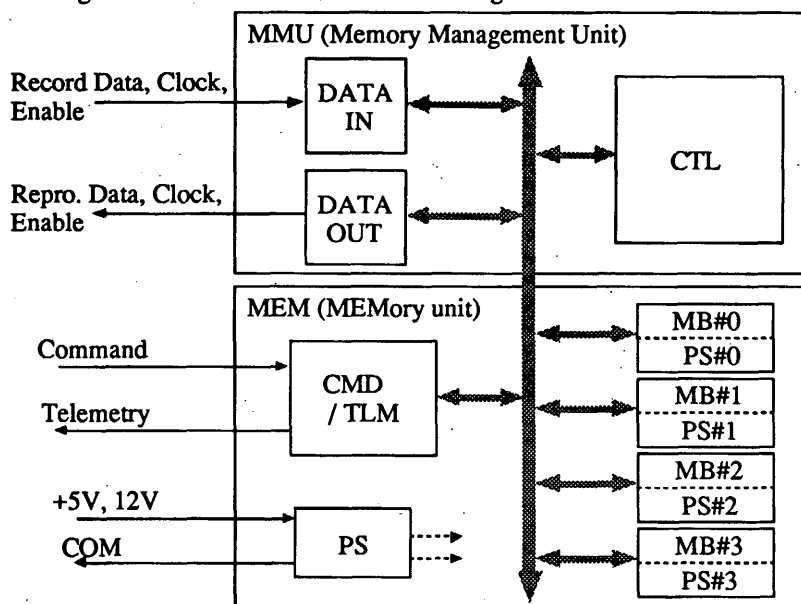


Fig. 1 PLANET-B DR Schematic Diagram

MMU	: DR Controller
DATA IN/OUT	: Data Interface
CTL	: DR Controller, Address Management, Error Correction Encoder / Decoder
MEM	: Memory for User
CMD/TLM	: Command Receiver, Telemetry Buffer
PS	: Power Input Filter, Power Supply
PS#n	: Power Supply for *Memory Block #n
MB#n	: 64Mbits Memory Section (NET)
	* Memory Block #n = PS#n + MB#n

(2) Functions

Status Mode Transition Diagram is shown in Fig. 2.

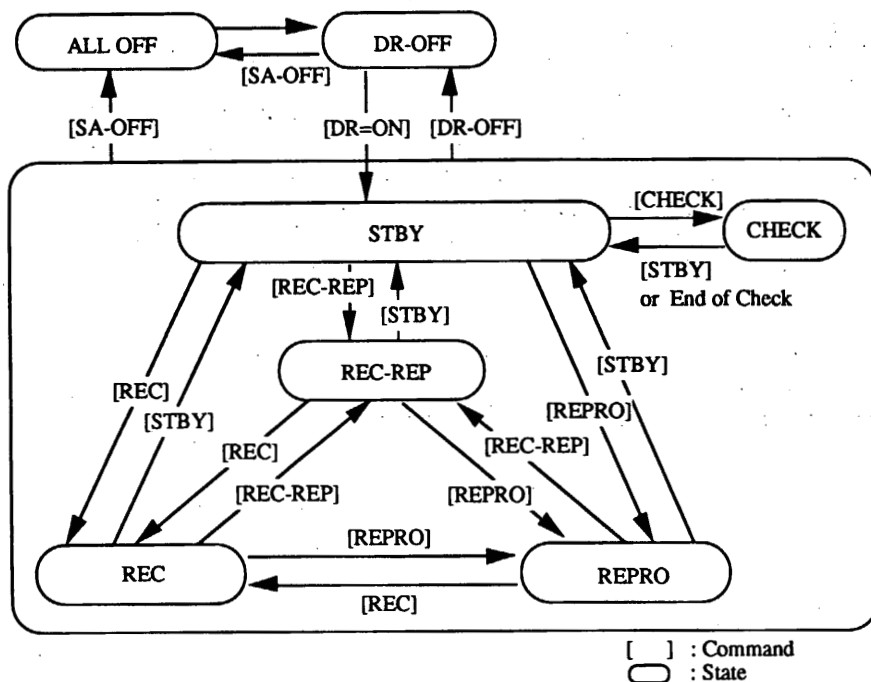


Fig. 2 Status Mode Transition Diagram

DR-OFF : Power off. Data vanishes.

STBY : Stand by. Data is held.

REC : Record data.

REP : Reproduce data.

REC-REP : Record and Reproduce data simultaneously.

CHECK : Self-check memories. Data is broken. Output the results as status telemetry.

(3) Performance

Table. 1 PLANET-B DR SPEC.

		SPEC.	NOTE
Memory Capacity		128 Mbits	For User Use: 128Mbits For Error Correcting: 128Mbits
Record Bit Rate		65 Kbps (max.)	
Repro. Bit Rate		32 Kbps (max.)	
Size		178mm × 205mm × 53mm	
Weight		1.14 Kg	
Power	Rec./ Repro.	2.8W (max.)	
	Standby	1.5W (max.)	Data Hold
	Power Off	≐ 0	Data Vanished
Power Voltage		+ 4.9V to + 5.5V + 12.5V to + 13.2V (for Relay)	

External Appearance of PLANET-B DR is shown in Fig. 3.

4.5.3 Operations

(1) Command

Table. 2 Discreet Commands

No.	Command	X	Y	
1	DR-ON	0	1	Power on.
2	DR-OFF	0	2	Power off forcibly.
3	DR-RST	3	4	Initialize address pointers.
4	DR-REC	3	0	Record data.
5	DR-REP	3	1	Reproduce data.
6	DR-REC-REP	3	2	Record and Reproduce simultaneously.
7	DR-STBY	3	3	Stop REC, REP, REC-REP or CHECK and into standby mode.
8	DR-CHECK-ENA *1	4	0	Prepare to accept SELF-CHK command.
9	DR-SELF-CHK *1	4	1	Begin serf checking.
10	DR-ECC-ON	5	0	Correct data errors by (8,4) Expantion Humming Code.
11	DR-ECC-OFF	5	1	Don't Correct data errors.
12	DR-OVWR-ON	4	2	Overwrite on the data not reproduced.
13	DR-OVWR-OFF	4	3	Don't overwrite.
14	DR-MB-ON	6	1	MBs' power on.
15	DR-MB-OFF	6	2	MBs' power off.

*1 : Double Command

(2) Status

Table. 3 Status Telemetry

No.	Status	bit	
1	DR-RST	1	1: RST command Acknowledge.
2	DR-BC	1	1: Block command Acknowledge
3	DR-REC	1	1: Recording data.
4	DR-REP	1	1: Reproducing data.
5	DR-STBY	1	1: Stand by.
6	DR-CHECK	1	1: Self checking memories.
7	WDT-RST	1	1: DR is reset by Watch Dog Timer.
8	DR-ON/OFF	1	1: Power ON 0: Power OFF
9	DR-OVWR	1	1: Overwrite on data 0: Not Overwrite
10	ECC-ON/OFF	1	1: Error correct 0: Not error correct
11	DR-CHECK-ENA/DSA	1	1: SELF-CHK command enable 0: SELF-CHK command disable
12	WR-ADDRESS	8	Recording address
13	RD-ADDRESS	8	Reproducing address
14	1BIT-ERR	8	1bit error count
15	2BIT-ERR	8	2bits error count
16	MB-ON/OFF	4	Memory Block ON/OFF status
17	LATCH-UP	4	Occurring Latch-Up status each Memory Block
18	MB-ERR	4	Results of Self check each Memory Block

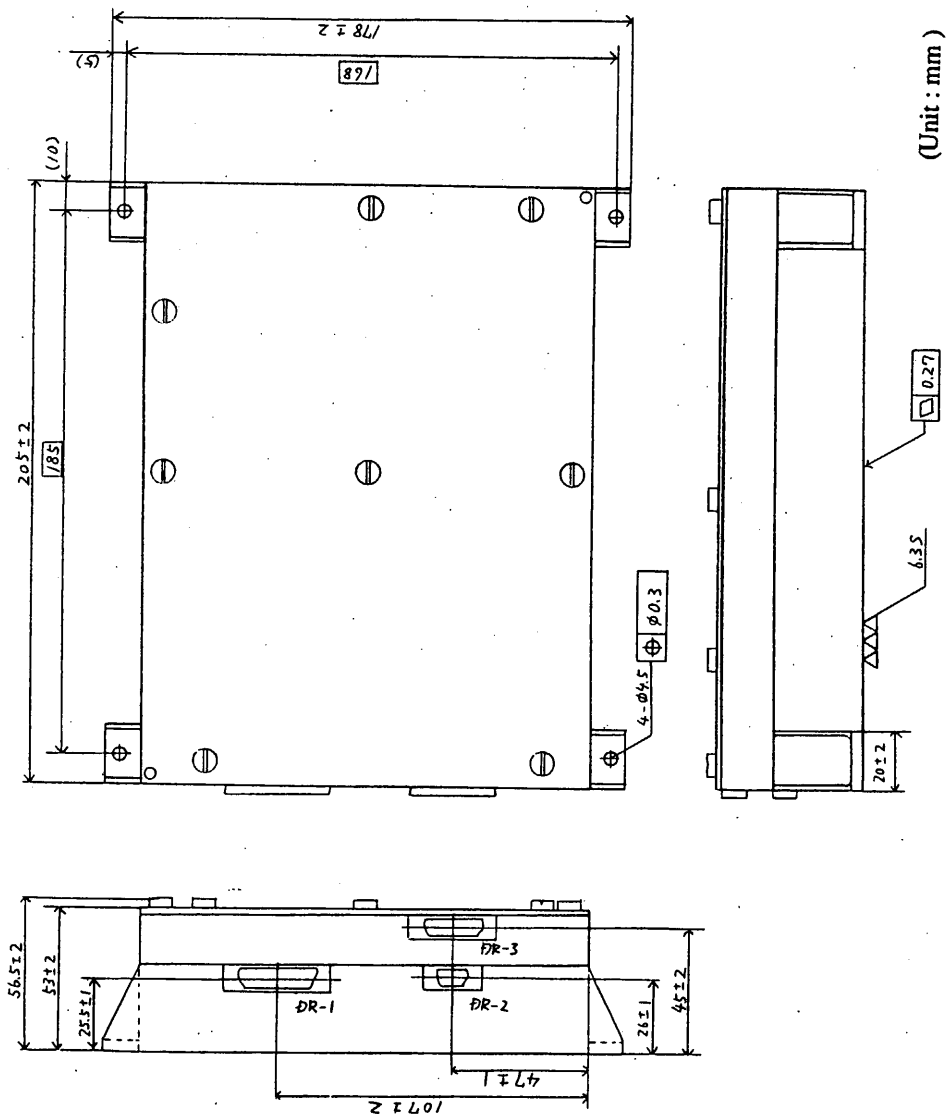


Fig. 3. External Appearance of PLANET-B DR

4. 6 Telemetry Command Interface (TCI)

4.6.1 Overview

TCI supplies PIM Interface to the instruments without PIM Interface.

TCI conditions user telemetry and converts analog data to digital data. Its principal features are as follows:

- a) Connecting with the Data Bus via PIM
- b) Driving discreet commands Pulse.
- c) Receiving bi-level telemetry data and multiplying to 8 bits.
- d) Receiving analog telemetry and converting digital data.
- e) Sending telemetry data to DHU via PIM.
- f) Sampling Command Link Control Word (CLCW: includes the Command Counter, RF Lock Status, etc.) and sending it to DHU.

4.6.2 Functions

The functional block diagram of TCI is outlined in figure 4.6-1. TCI consists of PIM, Command Decoder Module, Telemetry Encoder Module, and CLCW Encoder.

The functions and operations of each module are described in the following sections.

4.6.2.1 Command Decoder Module (CMD-DEC)

CMD-DEC decodes the Command Data received via PIM, and then selects the discreet command output channel according to the command. The Discreet command has two types, one is low level pulse command, the other one is high level pulse command.

4.6.2.2 Telemetry Encoder Module (TLM-ENC)

TLM-ENC supports analog and Bi-level telemetry interfaces. In analog telemetry interface, TLM-ENC selects telemetry input channel and receives analog telemetry. The analog telemetry that is received by TLM-ENC, is converted from analog to digital data. These converted data and Bi-level telemetry data are sampled and encoded according to TCI's timing, and sent to DHU via PIM at DHU sample timing.

4.6.2.3 CLCW Encoder

CLCW Data is monitored to operate command re-send. This data consists of command counter value and RF lock status. These data are sampled by TCI and sent to DHU via the serial interface. In DHU, this CLCW data includes down link transfer frame format.

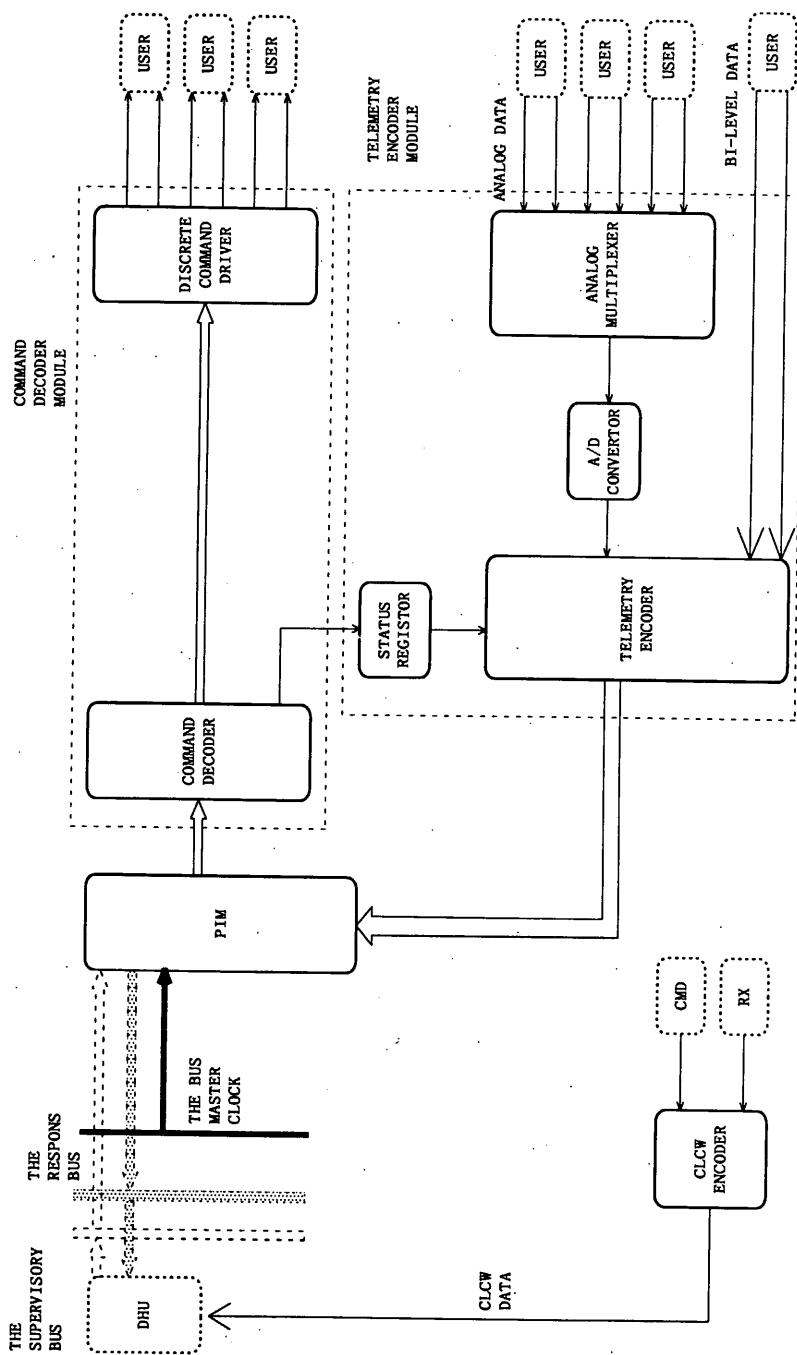


Figure 4.6-1 Block Diagram of Telemetry Command Interface

4.6.2.4 Interface

The user interface has the standard command and telemetry interface. The command interface consists of CMOS level pulse commands and high voltage level pulse commands. Telemetry interface consists the CMOS Bi-level Telemetry, Active Analog Telemetry, and Passive Analog Telemetry. These interfaces' characteristics are described in Table 4.6-1.

4.6.2.4 Specification

The major specifications of TCI are shown in table 4.6-1.

Table 4.6-1 Principal Specification of TCI

I T E M	D I M E N S I O N
1) USER INTERFACE COMMAND INTERFACE TELEMETRY INTERFACE TELEMETRY AND COMMAND CHANNEL NUMBER	DISCREET COMMAND HIGHT LEVEL PULSE COMMAND LOW LEVEL PULSE COMMAND Bi-LEVEL TELEMETRY ACTIVE ANALOG TELEMETRY PASSIVE ANALOG TELEMETRY DISCREET COMMAND :28 CHANNEL Bi-LEVEL TELEMETRY :39 CHANNEL ACTIVE ANALOG TELEMETRY :12 CHANNEL PASSIVE ANALOG TELEMETRY:5 CHANNEL
2) A/D CONVERTER CHARACTERISTICS INPUT VOLTAGE RANGE INPUT IMPEDANCE QUANTIZATION CONVERSION TIME CONVERSION ACCURACY	0~5.11V ABOVE 200k Ω 8 BITS 25 μ sec $\pm 0.8\%$ FOR FULL SCALE
3) POWER CONSUMPTION	4.6W
6) WEIGHT	1.7kg (nominal)
7) SIZE	220mm $\times$ 170mm $\times$ 41mm

5. Attitude and Orbit Control System

**K.Ninomiya, I.Nakatani, T.Hashimoto
NEC Corporation**

5.1 Overview

The attitude and orbit control system (AOCS) performs all the functions required for attitude and orbit control throughout the mission.

The AOCS configuration and components will be described briefly followed by the explanation of AOCS functions.

5.1.1 AOCS configuration and components

The block diagram of AOCS and locations of AOCS components are depicted in Figure 1 and Figure 2 respectively.

Following are the brief description of AOCS component functions. Details of the components are described in Chapter 5.2 and 5.3.

(1) TSAS (Two-dimensional Sun Aspect Sensor)

The TSAS has a 50 degrees $\times$ 50 degrees field of view (FOV) for solar position measurement and two half plane crossing FOV.

The sensor samples the solar position when data request command is put into the sensor. Sun coincidence pulse is generated when the sun crosses the half plane FOV. Solar position is also sampled when the sun coincidence pulse is output.

The pulse and solar position data is the major reference for attitude determination and control.

(2) SSAS (Spin-type Sun Aspect Sensor)

The SSAS is a spin-type sun sensor which outputs sun angle (sun to spin-axis angle) data and sun coincidence pulse.

The sensor covers the sun angle of 5 degrees to 175 degrees.

(3) SSC (Star SCanner)

The SSC is a passive scan type star sensor with "V"-shaped silicone diodes placed on the focal plane of the optical system. When the star image crosses the diodes, the SSC produces

star intensity signal and star coincidence pulse. The center of the field of view is tilted at an angle of 130 degrees from spacecraft spin axis so that the sensor captures bright stars in critical operation phase such as Mars orbit insertion.

(4) ACM (ACceleroMeter)

ACM is an electrical force rebalance type acceleration sensor.

Four ACMs are used on PLANET-B. ACM-A and ACM-B are used to measure the acceleration by reaction control jets during velocity increment maneuver. Outputs of the ACM's are integrated by AOCE to shut-off the jets when the commanded velocity increment is achieved. ACM-C is used to measure the acceleration by OMS. ACM-D is used to measure the acceleration by the fourth stage motor of the launch vehicle.

(5) GRS (Gas Rate Sensor)

The Gas Rate Sensor (GRS) is a sort of rate gyro which detects angular velocity around its "input axis". PLANET-B uses a couple of GRS for spin rate and nutation detection, respectively. They are used for active nutation control of M-V rocket during fourth stage burning.

(6) ND (Nutation Damper)

To attenuate a nutation motion and spin-ripple of the spacecraft, a passive hoop-type damper is used. Silicone oil is filled in the hoop. The motion of the silicone oil, excited by the nutation and spin ripple, dissipates the spacecraft excess energy. The offset and radius of the damper are selected to optimize the damping performance.

(7) Propulsion System

Ten 2.3N hydrazine thrusters are used for attitude and orbit control. The thrusters are categorized to three groups : Axial, Radial, and Tangential. Axial thrusters(A1 - A4) are used for spin axis reorientation and orbit control to axial direction. Radial thrusters(R1,R2) are used for radial direction orbit control. Tangential thrusters(T1 - T4) are used for spin rate control.

A bipropellant Orbit Maneuver System is equipped for large orbit maneuver such as earth departure and Mars orbit insertion.

(8) AOCE (Attitude and Orbit Control Electronics)

AOCE consists of interface electronics (AOCI) and fault tolerant computer system(AOCP). AOCI is a hard-wired electronics which consists of various circuitry to realize interface functions with attitude sensors and propulsion system. AOCP consists of redundant 16bit microprocessor with 128Kbyte RAM and 8Kbyte ROM. The software implemented on the microprocessor performs various jobs in cooperation with AOCI.

5.1.2 AOCS functions

(1) Earth tracking

When the spacecraft is beyond the mid-point of its trans-mars orbit, the communication between the earth and the spacecraft can only be achieved with High Gain Antenna (HGA). In this phase, the spin axis should be oriented to the earth as the HGA is fixed on the spacecraft with its narrow beam aligned with the spin axis. The inertial earth position as seen from the spacecraft moves at the rate of 0.8 deg/day maximum. As the width of the HGA beam is less than 1 degree, the spacecraft spin axis should be adjusted almost once a day to keep the earth within the HGA beam. This earth tracking is realized with a chain of small attitude reorientation that is activated by Operation Program(OP) stored in DHU. The precession is performed so that the sun angle (angle between the spin axis and the sun) keep tracking the predicted sun-spacecraft-earth angle. The prediction angle is computed in AOCE utilizing spacecraft orbit model.

(2) Earth search

If the HGA beam loses the earth due to some failure of above earth tracking, telemetry from the spacecraft can not be received. In such case, the spacecraft will be reoriented to the earth utilizing the following functions. These functions can be activated by ground command because the spacecraft receives the ground command through Low Gain Antenna that has substantially wider FOV than HGA.

(a) Onboard attitude determination and acquisition

The AOCE try to determine the attitude utilizing TSAS,

SSAS and SSC data. To help identify stars, expected star pattern data is uploaded to AOCE. If the attitude is determined with good confidence, AOCE generates and execute precession command to reorient the spacecraft to the earth.

(b) Constant sun angle search

The spin axis is first reoriented so that the sun angle falls into predicted sun-spacecraft-earth angle. After commanding this maneuver, ground operator monitors if the telemetry is reacquired. If the telemetry does not reappear, the spacecraft is commanded to reorient to some other position keeping the sun angle constant. This constant-sun-angle maneuver and dwell for telemetry monitor is repeated until the telemetry is reacquired.

(3) Sun acquisition

If the telemetry can not be recovered through above operations, the spacecraft is commanded to reorient to sun pointing attitude.

The sun pointing attitude is the safest attitude for spacecraft thermal and electrical house keeping. When the spacecraft is on Mars orbit, the earth does not leave beyond 45 degrees from the sun. This assures the spacecraft in solar oriented attitude can receive the ground command.

After achieving this attitude, countermeasure will be thought about on the ground to bring back the spacecraft to normal operation.

(4) Orbit correction maneuver

Orbit correction is achieved by the combination of axial maneuver and radial maneuver. Axial maneuver is performed by the continuous firing of axial thrusters. Radial maneuver is performed by radial thruster firing in pulse mode. The time from the sun pulse to the thruster pulse determines the velocity increment direction. Locations of radial thrusters are carefully chosen so that the attitude change during orbit control is minimized. Radial orbit control has a unique feature called "2 pulses in one spin mode". In this mode, a radial thruster (e.g. R1) is fired half spin period behind the other thruster (e.g. R2) firing. This doubles the time efficiency of the radial orbit control.

The acceleration by the thrusters are sensed by ACM-A and ACM-B. The ACM data is integrated by AOCE to shut off the thruster firing when the commanded velocity increment is accomplished.

(5) Earth departure/Mars Insertion

Large velocity maneuver for earth departure and Mars insertion is performed with OMS. The acceleration by the OMS is detected by ACM-C. The acceleration is integrated in AOCE and stops OMS when the preset velocity increment is achieved.

(6) Orbit insertion velocity measurement/correction

The acceleration by the fourth stage burning of the launch vehicle is sensed by ACM-D. The acceleration is integrated by AOCE. If the error between the integrated velocity and desired velocity exceeds a predetermined value, the error is corrected by spacecraft's reaction jets right after the separation of the spacecraft.

(7) Spin axis reorientation

The spacecraft spin axis is reoriented by the pulse firing of appropriate thrusters. To minimize the disturbance to the spacecraft orbit, pair thrusters are used so that thruster forces cancel each other.

(8) Spin rate control

The spin rate is adjusted by firing the tangential thrusters in pulse or continuous firing mode. AOCP software monitors the spin rate and stops firing when the commanded spin rate is achieved.

(9) Active Nutation Damping

The spacecraft is prolate(spin-unstable) in orbit injection phase in which the fourth motor is attached to the spacecraft. Large amount of fuel can cause the rapid nutation divergence due to the energy dissipation. To keep the nutation small during the injection phase, the ANC function is utilized. GRS is used to detect the spin rate and nutation rate. Radial thruster onboard the spacecraft is activated to reduce the nutation.

(10) Passive Nutation damping

The nutating motion and spin rate ripple is damped out by energy dissipation of fluid enclosed in ND. The damping time constant is approximately 4 minutes.

(11) IP/PC generation

To distribute the sun reference pulse to science instruments, AOCE generates Index Pulse(IP) and Phase Clock(PC). The IP is generated with reference to SSAS or TSAS. During the eclipse, IP is generated with reference to SSC star pulse. PC is generated by dividing IP period utilizing digitally implemented frequency divider.

(12) Attitude sensor data processing

Data from TSAS, SSAS, SSC, GRS, ACM is processed in AOCE and telemetered down to the ground. The telemetered data is used to determine the spacecraft attitude on the ground.

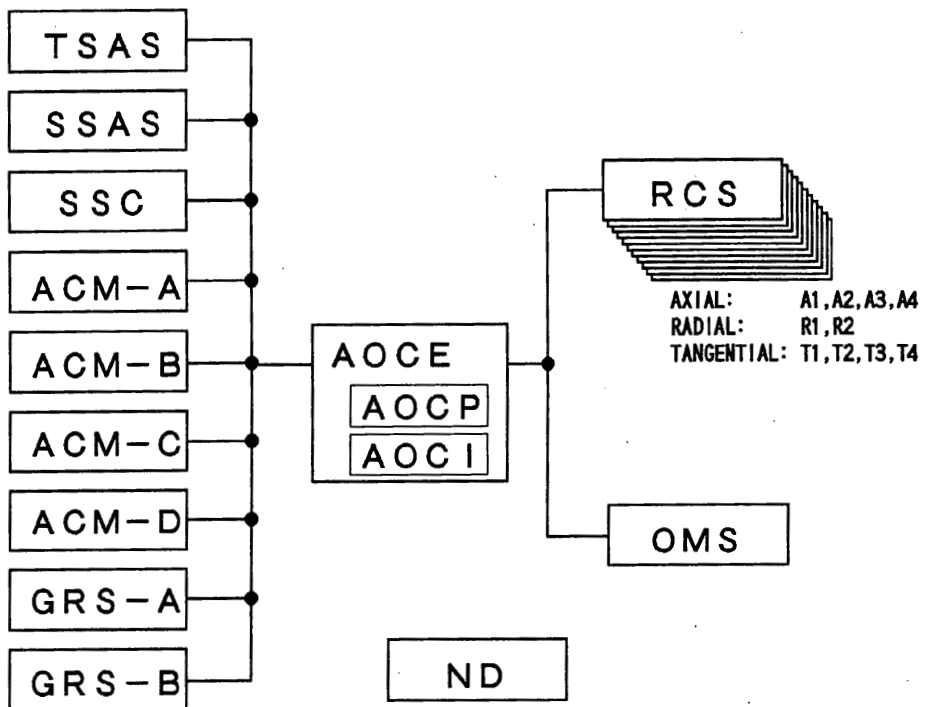


Figure 1 Block diagram of AOCS

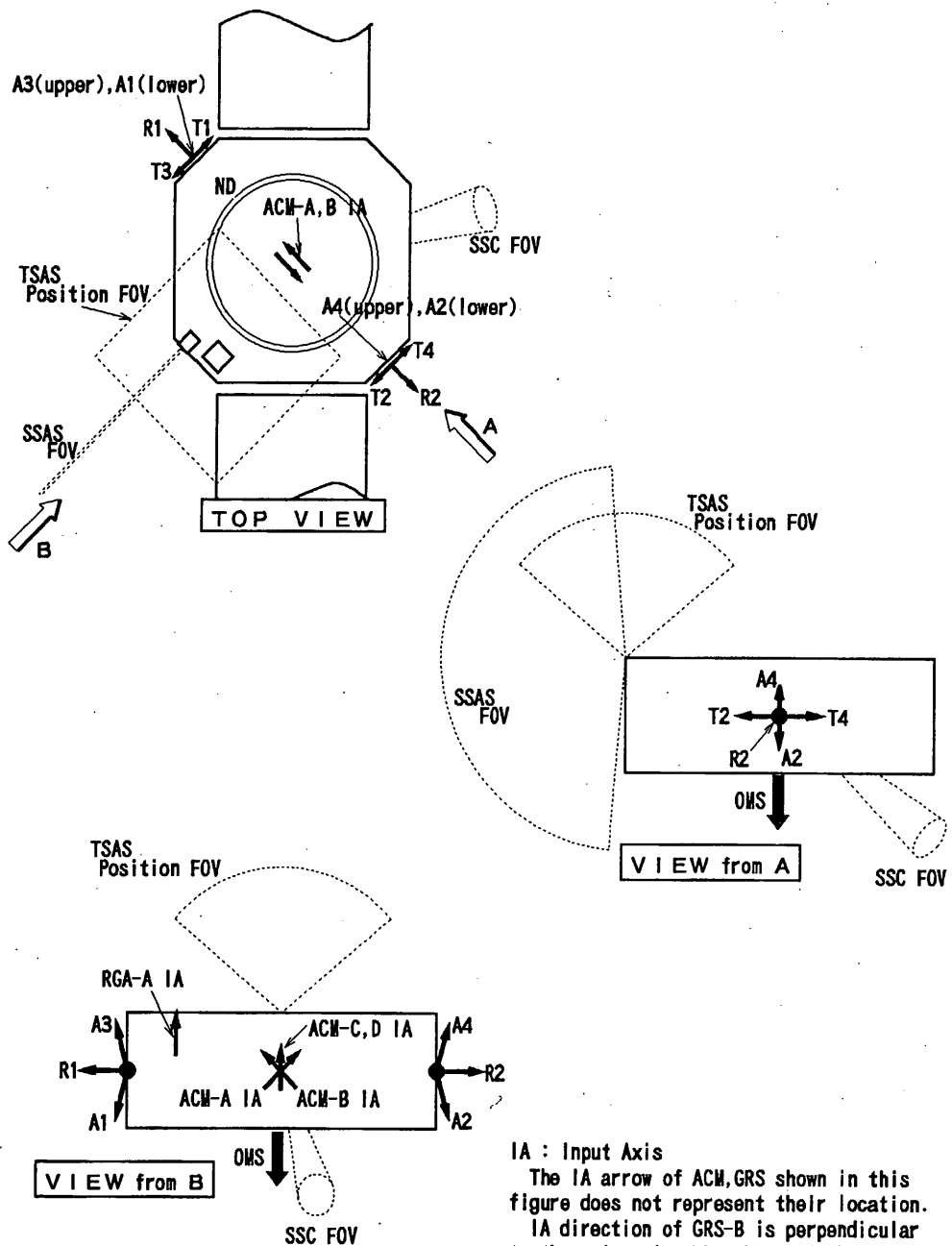


Figure 2 AOCS component location

5.2 Attitude and Orbit Control Electronics (AOCE)

K.Ninomiya T.Hashimoto
NEC Corporation

5.2.1 Scope

The AOCE is divided into two parts --- interface electronics(AOCI) and fault tolerant computer system (AOCP).

AOCI is a hard-wired electronics which consists of various circuitry to perform interface functions with attitude sensors and propulsion system. AOCP consists of redundant 16bit microprocessor with 128Kbyte RAM and 8Kbyte ROM. The onboard software (OBS) implemented on the microprocessor realizes AOCS functions described in 5.2.

The AOCP consists of two CPU modules, two common memories, two common buses, and MRM(Monitor and Reconfiguration Module). The core of the CPU module is a 16 bit word microprocessor implemented on a radiation-hardened latch-up free 9K C-MOS gate array. Peripheral functions such as interrupt controller, serial interface for debugging, programmable timer, watch dog timer, memory controller are implemented on another gate array named IOP(Input/Output Processor). 8Kbyte ROM and up to 128Kbyte RAM are accommodated in CPU module for program and data storage.

RAM is accessed through SEC-DED error correcting processor(ECCP) to avoid the effect of single event upset due to cosmic ray. Data from/to the modules are transferred through redundant common bus. One of the buses is powered at a time.

MRM is responsible for the reconfiguration control of CPU modules. According to the error symptom from the CPU, MRM switches off the faulty CPU and activates stand-by CPU. The AOCP operates in simplex mode or duplex mode. Simplex mode is usually used because, in cruise phase, it is not necessary to maintain normal processing due to the inherent attitude stability of the spin-stabilized spacecraft. During the critical operation, such as initial attitude acquisition and Mars orbit insertion , duplex mode is selected to maximize the possibility to accomplish the required task.

The AOCI is composed of an analog-to-digital converter, counters, and thruster valve drivers and fault detection traps. The fault detection trap monitors the control output of AOCP OBS.

The trap includes:

(1)RCS Watch Dog Timer

In pulse firing mode , the OBS can never command the thruster to fire with width wider than 2 seconds.

(2)Thruster selection parity

The thruster driver circuitry checks the parity bit appended to thruster select command by OBS.

(3)OMS Minimum burn timer

A reliable hard-wired counter is equipped so that OMS firing can be sustained longer than preset period which is enough and minimum to get Mars insertion delta-V.

5.2.2 Main characteristics

External view

Figure 1

Weight

6.7 Kg

Power Consumption

Simplex Mode : 12.4 W

Duplex Mode : 17.7 W

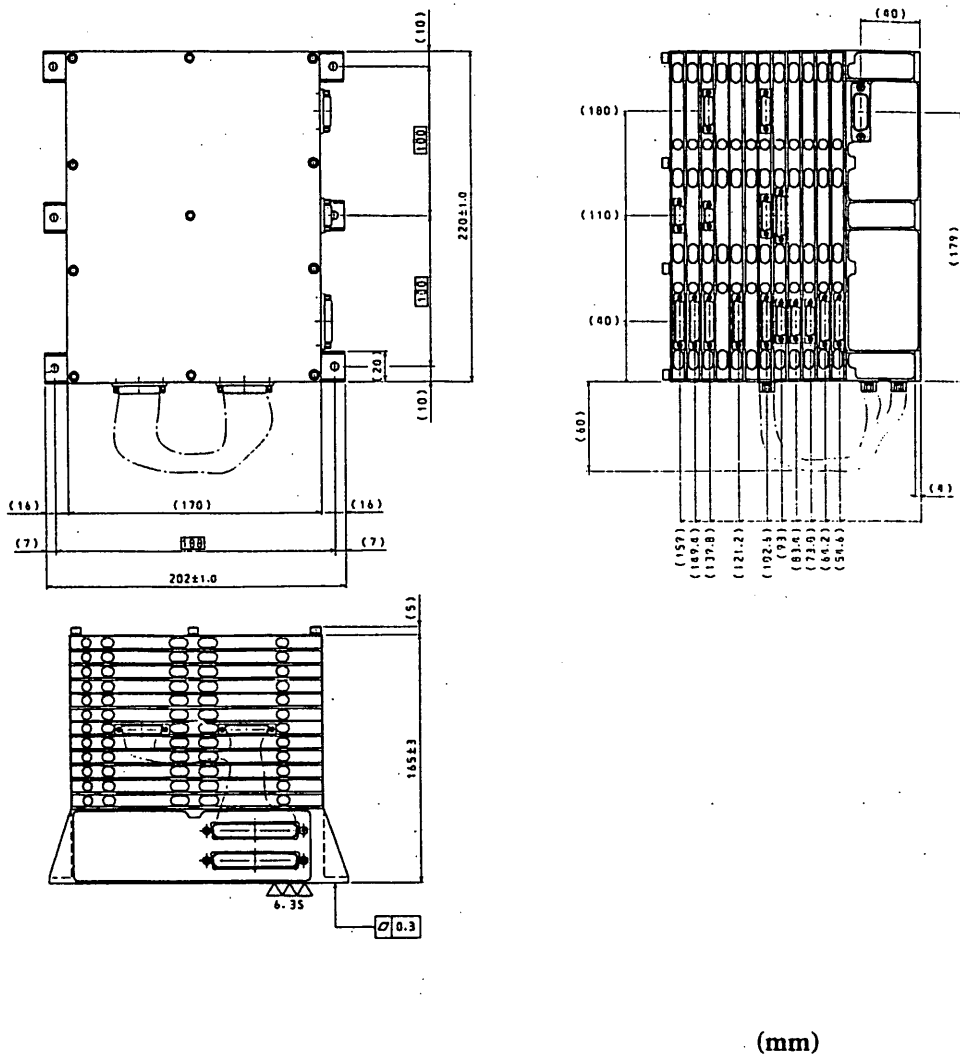


Figure 1 External view of AOCE

5.3 Components for AOCS

5.3.1 SSAS (Spin-type Sun Aspect Sensor)

K.Ninomiya, E.Hirokawa, T.Hashimoto
NEC Corporation

1. Scope

The SSAS is a spin-type sun sensor which outputs sun angle (sun to spin-axis angle) data and sun coincidence pulse. The sensor covers the sun angle of 5 degrees to 175 degrees.

One of four threshold levels shall be properly selected for normal operation on Mars orbit where solar intensity level falls below 40% of the earth orbit.

2. Main characteristics

FOV (measured from the positive spin axis of the spacecraft)

5deg to 175deg

Spin Rate Range

2 to 190 rpm

Operating Solar Intensity level

1.20 to 0.20 Solar Intensity Level.

Accuracy

± 0.1 deg

Resolution

0.003deg

Output data format

Serial 40 bit data for AOCE

Supply voltage

28V $\pm$ 6V DC

Power consumption

less than 3W

Operating Temperature range

-30° C to +60° C

External view

Figure 1

Weight

0.35 Kg

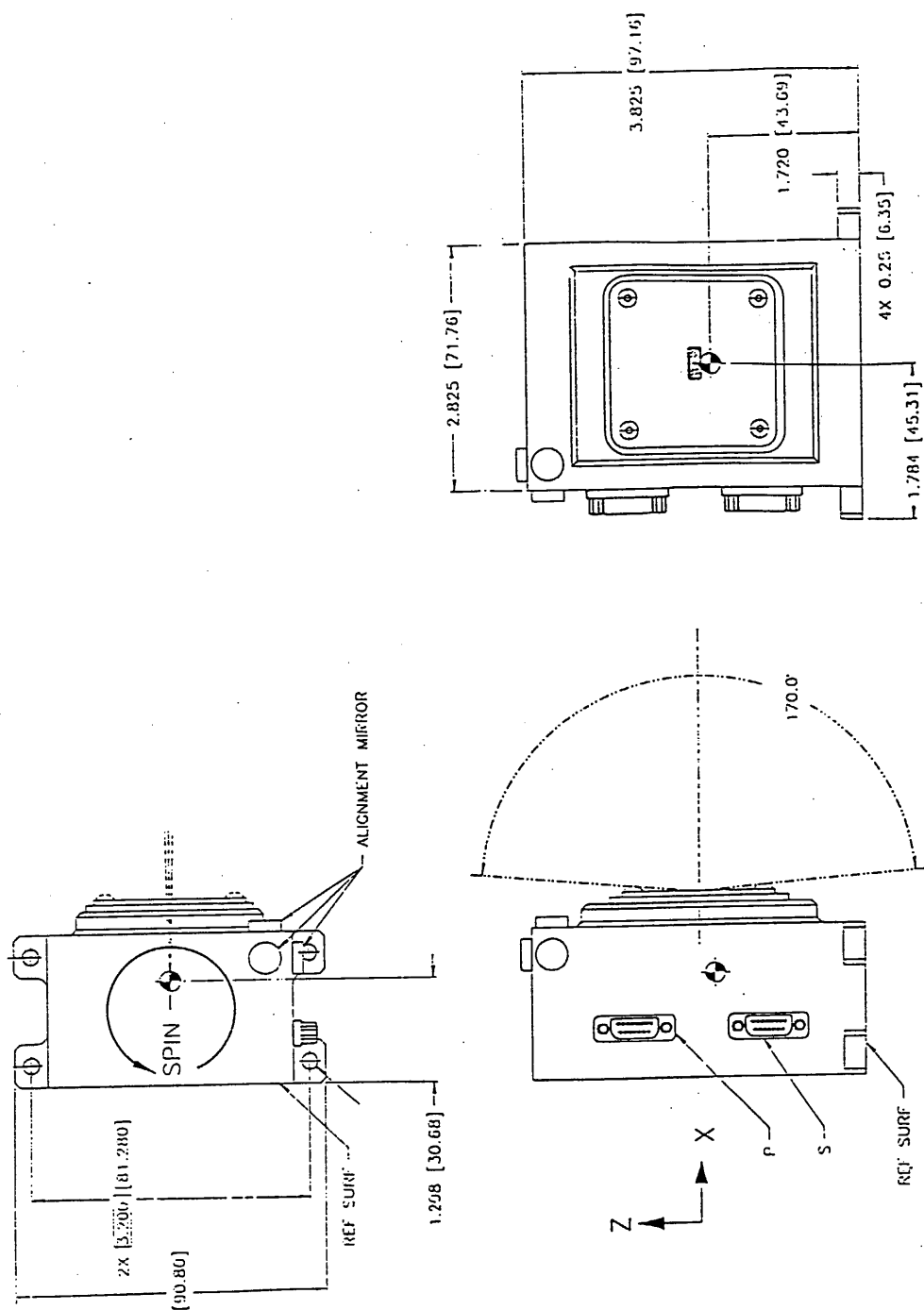


Figure 1 External view of SSAS

(inch [mm])

5.3.2 TSAS (Two-dimensional Sun Aspect Sensor)

K.Ninomiya, E.Hirokawa, T.Hashimoto
NEC Corporation

1. Scope

The TSAS has a field of view (FOV) of ± 50 degrees $\times$ ± 50 degrees for solar position measurement and two half plane crossing FOV (See Figure1). The sensor samples the solar position when data request command from AOCE is put into the sensor. Sun coincidence pulse is generated when the sun crosses the half plane FOV. Solar position is also sampled when the sun coincidence pulse is output.

The pulse and solar position data is the major reference for attitude determination and control.

2. Main characteristics

FOV (measured from the positive spin axis of the spacecraft)
 $\pm 50\text{deg} \times \pm 50\text{deg}$

Spin Rate Range
2 to 35 rpm

Operating Solar Intensity level
1.20 to 0.20 Solar Intensity Level.

Accuracy
 $\pm 0.1\text{deg}$

Resolution
0.003deg

Output data format
Serial 40 bit data for AOCE

Supply voltage
28V $\pm$ 6V DC

Power consumption
less than 3W

Operating Temperature range
 -30°C to $+60^{\circ}\text{C}$

External view
Figure 1

Weight
0.90 Kg

5.3.3 Star Scanner(SSC)

K.Ninomiya ,T.Hashimoto and E.Hirokawa(ISAS)
Toshiba Corporation

5.3.3.1 General Description

The Star Scanner (SSC) is a type of star sensor which determines the star positions in the coordinate system fixed in the body of satellite. SSC has a field of view (FOV) of $14^{\circ} \times 14^{\circ}$ and a sensitivity of 2.0 visual magnitude. To offer a high performance, the SSC employs a photodiode detector consisting of multiple slit-shaped sensitive areas.

5.3.3.2 Functions

SSC block diagram is shown in Figure 1.

(1) Baffle

The two-stage light baffle is mounted on the front of the SSC optics. It attenuates stray lights from outside of the FOV of SSC such as the sunlight, albedo of the Earth, and sunlight reflections by satellite. It is made of CFRP to reduce weight.

(2) Optical System

The lens system is provided to collect light and to focus the star image on the sensitive areas of the photodiode. Within the FOV of SSC and operating temperature range, high light condensing performance is obtained over a wide wavelength range. It consists of 5 lenses, and the front one is a radiation-hardened lens.

(3) Focal Plane

The detector is on the focal plane of the lens system. Four slit-shaped sensitive areas(named "cells") are formed on a photodiode detector. They are divided into two sets to provide redundancy. An LED is installed in the vicinity of the detector in order to calibrate it.

(4) Electronics

This section consists of a preamplifier, a signal processor, an interface and calibration circuit.

The preamplifier has a high sensitivity and high gain, and amplifies low level signal outputs from the photodiode to the level appropriate for signal processing.

The signal processor consists of the filter, discriminator, peak holding, and other circuits. It provides the star detection timing and the signal amplitude which is proportional to star brightness for AOCE. Two signal processing systems are provided. Normally, two cell outputs are processed independently, but they can be added together for other processing modes. The interface section is composed of command receivers from AOCE, telemetry and power circuit.

5.3.3.3 Specification and Performance

SSC performance is indicated in Table 1. Commands and telemetry data are listed in Tables 2 through 4. SSC external views are shown in Figure 2.

Table 1. SSC Performance Characteristics

Item	Description
Detector	Silicon photodiode V-shaped type×2(redundancy)
Optical system	Refractive system $f=60\text{mm}$, F 1.0
Wavelength range	$0.5 - 1.1 \mu\text{m}$
Lens transmittance	>0.85
FOV	$14^\circ \times 14^\circ$
Sensitivity	>2.0 Visual magnitude(at 7.5rpm)
Angular accuracy	Elevation:10 arc min Azimuth :10 arc min
Operating temperature range	$-30^\circ\text{C} - +20^\circ\text{C}$
Power consumption	0.37W

Table 2. Discrete Commands(Processed by AOCE)

Code		Command name	Description	Related telemetry
X	Y			
4	6	SSC ON	SSC PS ON	8000H B2
4	8	SSC OFF	SSC PS OFF	8000H B2
4	9	SSC CAL ON	SSC CAL ON	8000H B3
4	A	SSC CAL OFF	SSC CAL OFF	8000H B3
C	2,3	BC EXE	BC execute	—

* When the pseudo-star light due to a ON/OFF switching of a built in LED irradiates photodiode section, the pseudo-pulses are generated at about 150 ms intervals corresponding to a spin rate of 7.5 rpm. The system returns to the normal measurement mode upon a SSC CAL OFF command execution.

Table 3. Block Commands(from AOCE)

Bit	Function	Description				
0	Redundant photodiode system selection	0	Photodiode A select			
		1	Photodiode B select			
1	Circuit selection	B1	B2	Circuit A output	Circuit B output	
		0	0	Cell 1	Cell 2	
		0	1	Cell 1 + Cell 2	N/A	
2		1	0	N/A	Cell 1 + Cell 2	
		1	1	Cell 1	Cell 2	
3	Gain selection	0	High			
		1	Low			
4	Discrimination Level selection	B4	B5	Discrimination Level		
		0	0	3.3V High		
		0	1	2.2V Medium High		
5		1	0	1.5V Medium Low		
		1	1	1.0V Low		
6	Time constant selection	No	B6	B7	Applicable spin rate(rpm)	
		1	1	0	7.0	
1		0	1	7.5	nominal	
7		2	1	0	8.0	
		3	1	1	9.5	

Normally SSC is used BC= 0D (H)

- Photodiode : 0 : Photodiode A
- Circuit : 00 : Circuit A output=cell 1,Circuit B output=cell 2
- Gain : 0 : High
- Discrimination Level : 11 : Low
- Filter time constant : 01 : 7.5rpm

Table 4. Status

Bit.	Function	Description					
1	SSC ON/OFF	0	OFF				
		1	ON				
2	SSC CAL/MES	0	Measure				
		1	Calibrate				
3	SSC A/B	0	A				
		1	B				
4	Signal processing circuit system selection	B3	B4	Circuit A output		Circuit B output	
		0	0	Cell 1		Cell 2	
		0	1	Cell 1 + Cell 2		N/A	
5		1	0	N/A		Cell 1 + Cell 2	
		1	1	Cell 1		Cell 2	
6	Gain	0	High				
		1	Low				
7	Discrimination Level	No	B7	B8	Discrimination Level		
		0	0	0	High		
		1	0	1	Medium High		
8		2	1	0	Medium Low		
		3	1	1	Low		
9	Time Constant	No	B9	B10	Applicable spin rate(rpm)		
		0	0	0	7.0		
		1	0	1	7.5	Nominal	
10		2	1	0	8.0		
		3	1	1	9.5		

Table 5. Data

Name	A/D	Description
STH 1	A	Star magnitude signal(cell A),0-5V
STP 1	D	Star detection timing signal(cell A)
STH 2	A	Star magnitude signal(cell B),0-5V
STP 2	D	Star detection timing signal(cell B)
Status signal	D	See Table 4.

A:Analog /D:Digital

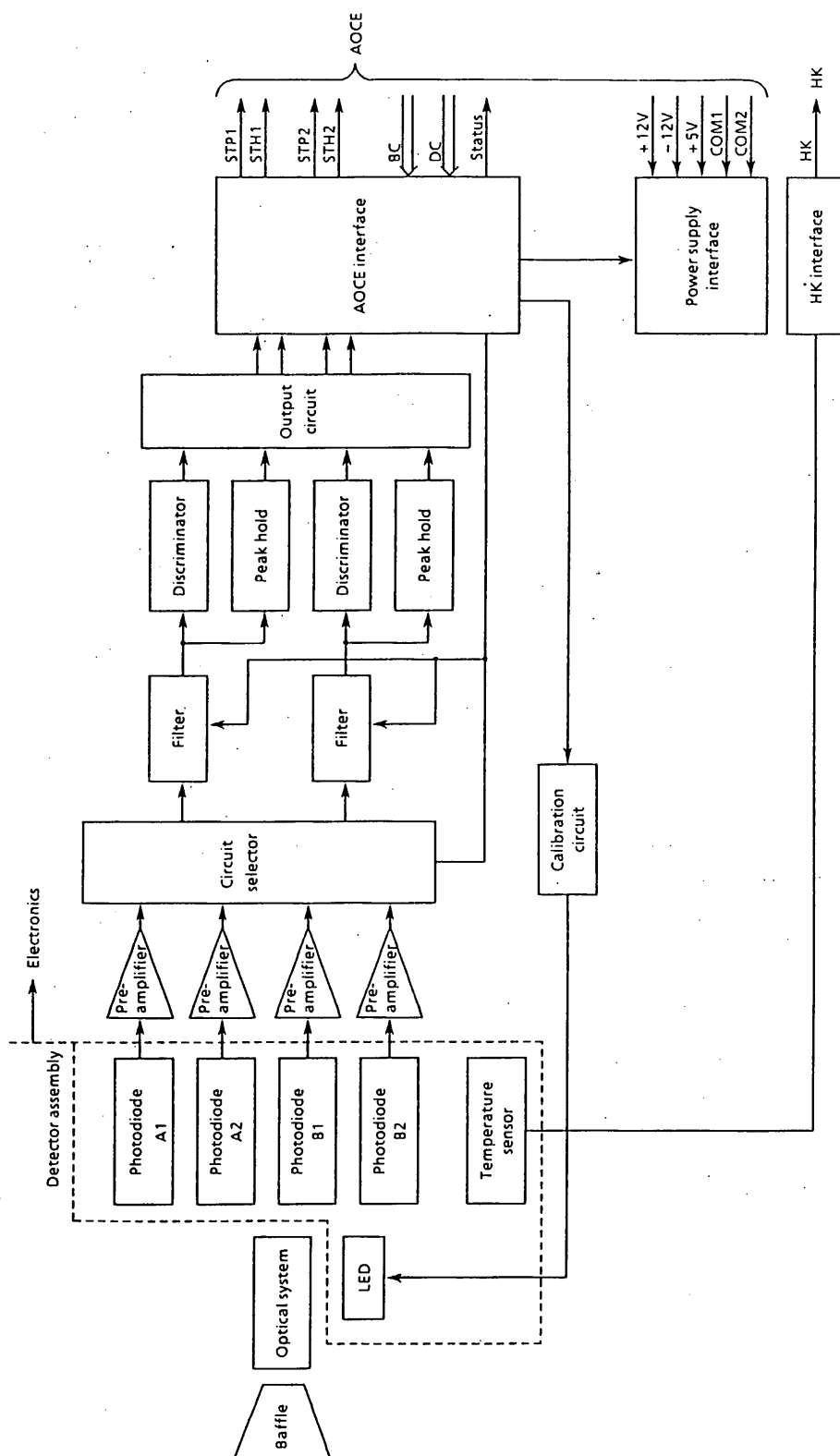


Fig. 1. SSC Block Diagram

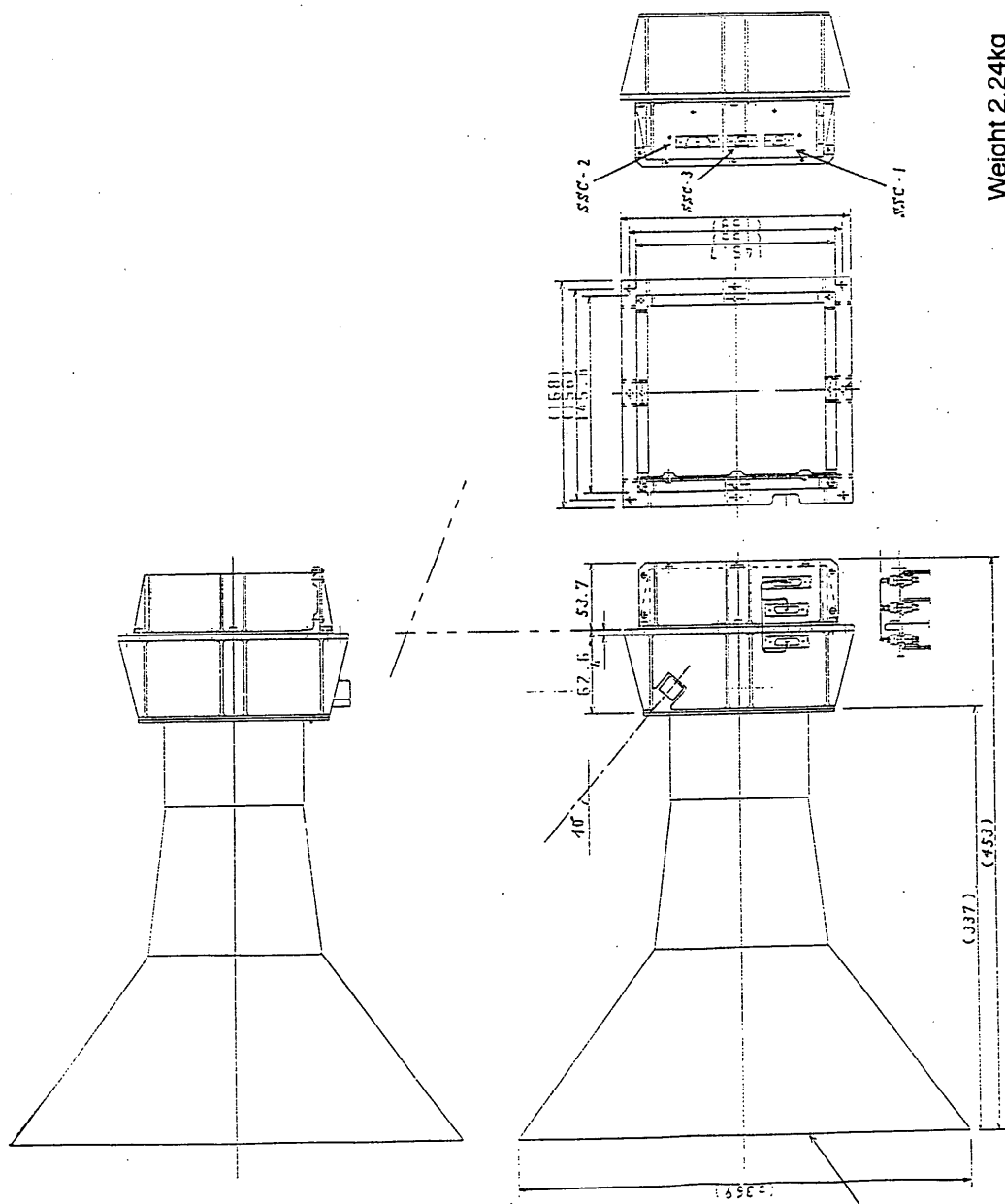


Fig. 2. Star Scanner External Views

5.3.4 Gas Rate Sensor (GRS)

K.Ninomiya, J.Kawaguchi and T.Hashimoto
Tamagawa Seiki Co. Ltd.

5.3.4.1 General

The Gas Rate Sensor (GRS) is a sort of rate gyro which detects angular velocity around its "input axis". PLANET-B uses a couple of GRS for spin rate and nutation detection, respectively. They are used for active nutation control of M-V rocket before, during and after fourth stage burning.

5.3.4.2 Specification and Performance

GRS-A detects angular velocity around X-axis of PLANET-B and GRS-B detects that around Z-axis of it. Specification of them are listed in Table 5.4.3.2-1.

Table 5.3.4.2-1 Specification of GRS

	GRS-A	GRS-B
Model Number	TA7298N1	TA7298N2
Detection range	$\pm 100[\text{deg/sec}]$	$\pm 1000[\text{deg/sec}]$
Output voltage	$\pm 5[\text{V}] \pm 10\%$	$\pm 5[\text{V}] \pm 10\%$
Sensitivity	$50[\text{mV}/(\text{deg/sec})]$ $\pm 10\%$	$5[\text{mV}/(\text{deg/sec})]$ $\pm 10\%$
Offset voltage	$\pm 500[\text{mV}]$ MAX	$\pm 500[\text{mV}]$ MAX
Noise voltage	$10[\text{mV}]_{\text{rms}}$ MAX	$10[\text{mV}]_{\text{rms}}$ MAX
Linearity	$\pm 1[\%]$ MAX	$\pm 2[\%]$ MAX
Hysteresis	$\pm 0.5 [\text{deg/sec}]$ MAX	$\pm 0.5 [\text{deg/sec}]$ MAX
Threshold	$\pm 0.5 [\text{deg/sec}]$ MAX	$\pm 0.5 [\text{deg/sec}]$ MAX
Frequency response	20 [Hz]	50 [Hz]
Start-up time	100 [msec] MAX	100 [msec] MAX
Load impedance	5 [k Ω] MIN	5 [k Ω] MIN
Life time	10000 [hour] MIN	10000 [hour] MIN

5.3.4.3 Size, Weight, and Power Consumption

External views of GRS-A and GRS-B are shown in Fig.5.3.4.3-1 and Fig.5.3.4.3-2, respectively. Size, weight and power consumption of them are listed in Table 5.3.4.3-1.

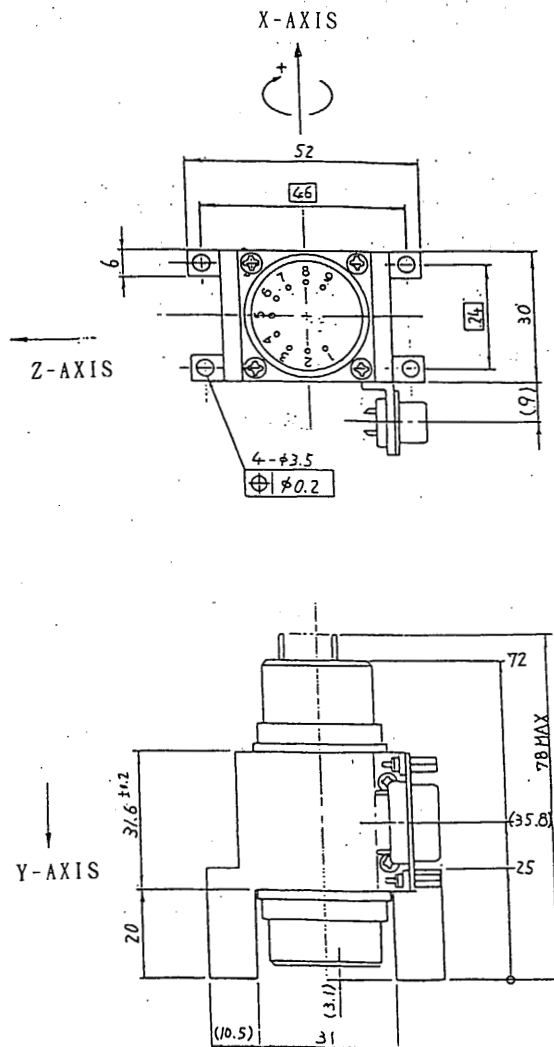


Fig.5.3.4.3-1 External view of GRS-A

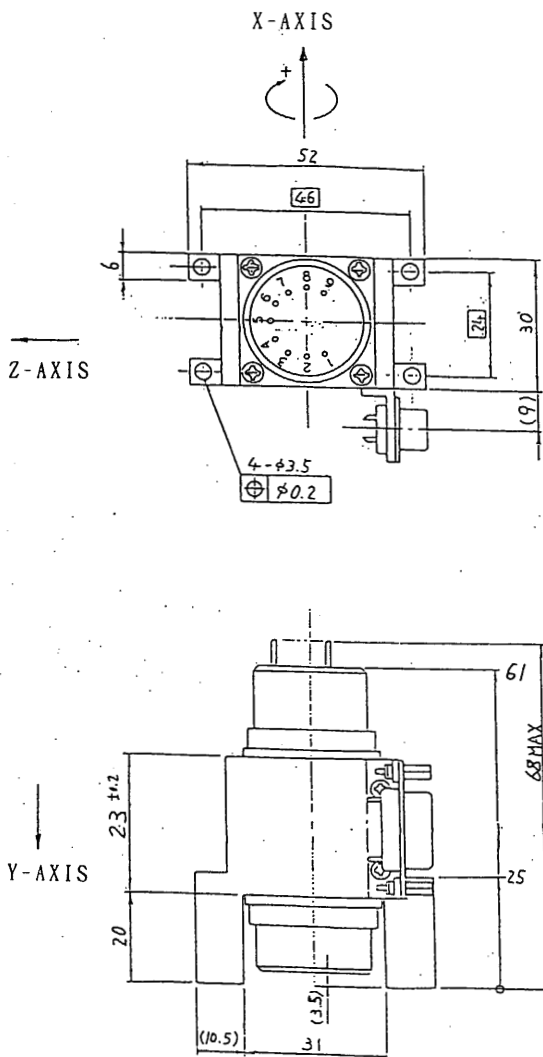


Fig.5.3.4.3-2 External view of GRS-B

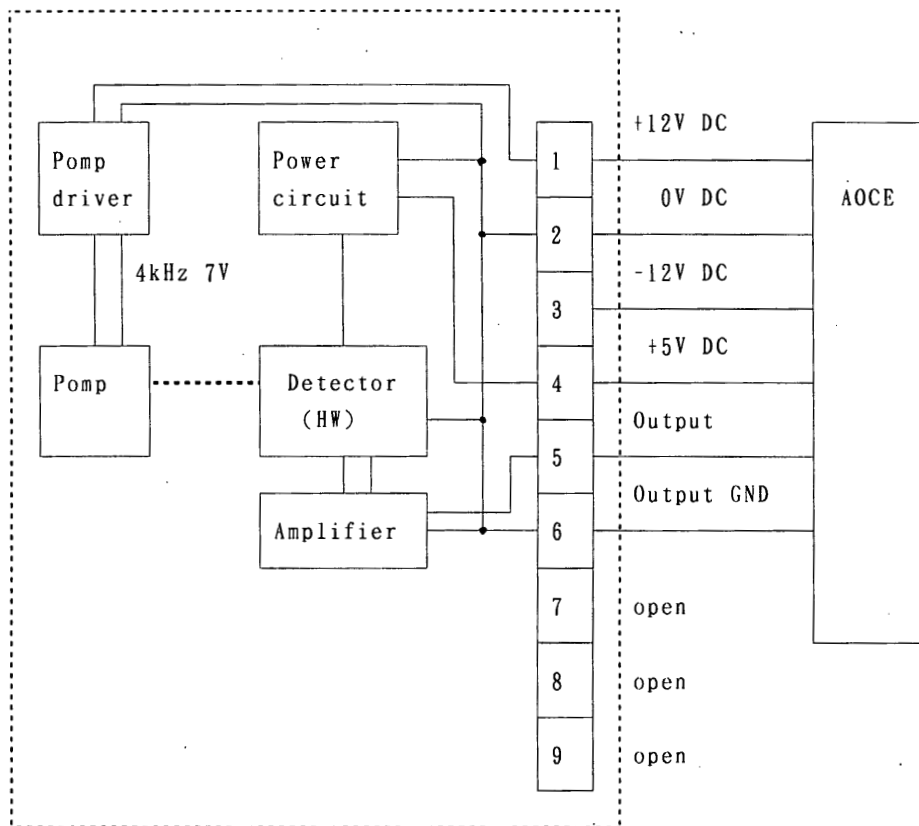
Table 5.3.4.3-1 Size, weight and power consumption

	GRS-A	GRS-B
Size	$\phi 25.12 \times 75$ [mm]	$\phi 25.12 \times 65$ [mm]
Weight	61 [g] TYP	55 [g] TYP
Power	0.5 [W]	0.5 [W]

5.3.4.4 Electrical and Mechanical Interface

Electrical interface of GRS is shown in Fig. 5.3.4.4-1. All lines including power supply are connected with AOCE.

Sensor coordinates of GRS-A and GRS-B are drawn in Fig.5.3.4.3-1 and Fig.5.3.4.3-2, respectively. Relation between sensor coordinates of both sensors and that of spacecraft is shown in Table 5.3.4.4-1



Power supply $\pm 12[V] \pm 0.5[V]$ 20[mA] MAX
 $+ 5[V]^{+1.0}_{-0.5}[V]$ 60[mA] MAX

Fig. 5.3.4.4-1 Electrical interface of GRS

Table 5.3.4.4-1 Sensor alignment

GRS coordinate	PLANET-B coordinate	
	GRS-A	GRS-B
X (Input) Axis	Z	X
Y (Gas flow) Axis	X (TBD)	-Z (TBD)
Z (Colioris) Axis	Y (TBD)	Y (TBD)

5.3.4.5 Command Items

Commands for both GRS are listed in Table 5.3.4.5-1. All of commands are sent via AOCE.

Table 5.3.4.5-1 Command items of GRS

CODE		COMMAND NAME	FUNCTION
X	Y		
3	C	GRS-A_ON	GRS-A on
3	D	GRS-B_ON	GRS-B on
3	E	GRS_OFF_ENA	GRS off enable
3	F	GRS_OFF	both GRS off

5.3.4.6 Telemetry Items

Status of both GRS can be seen in HK packet telemetry. Table 5.3.4.6-1 shows the list of bilevel data concerning GRS.

Output voltages of both GRS can be seen in AOCS packet while LAUNCH mode. Detail of telemetry format is TBD.

Table 5.3.4.6-1 Bilevel data of GRS

Address (Hex)	S/S NAME	Bit	ITEMS	STATUS	
				1	0
8001	AOCE2	B6	GRS OFF ENA/DIS	ENA	DIS
8007	AOCE8	B2	GRS-A ON/OFF	ON	OFF
		B3	GRS-B ON/OFF	ON	OFF

5.3.5 Accelerometer (ACM)

K.Ninomiya, T.Hashimoto and E.Hirokawa (ISAS)
Japan Aviation Electronics Industry, Ltd.

5.3.5.1 General

The ACM is an electrical force rebalance type of acceleration sensor.

Four ACM's are divided into two groups. One group (ACM-A, ACM-B and ACM-D) is used to measure the velocity increment generated by thruster firing of reaction control system or orbit maneuvering system during the trajectory control maneuver. The outputs of ACM's are integrated in AOCP to shut off the thrusters when the commanded velocity increment is achieved. The other (ACM-C) is used to measure the acceleration due to the fourth stage motor of the launch vehicle. The output of ACM-C is also integrated in AOCP to obtain the indication of ΔV to be telemetered to the ground.

Each ACM has a temperature sensor to provide an analog current signal which is proportional to the ambient temperature.

Power-ON and -OFF of ACM's is controlled by AOCE through ground commands.

A functional block diagram of ACM is depicted in Figure 1.

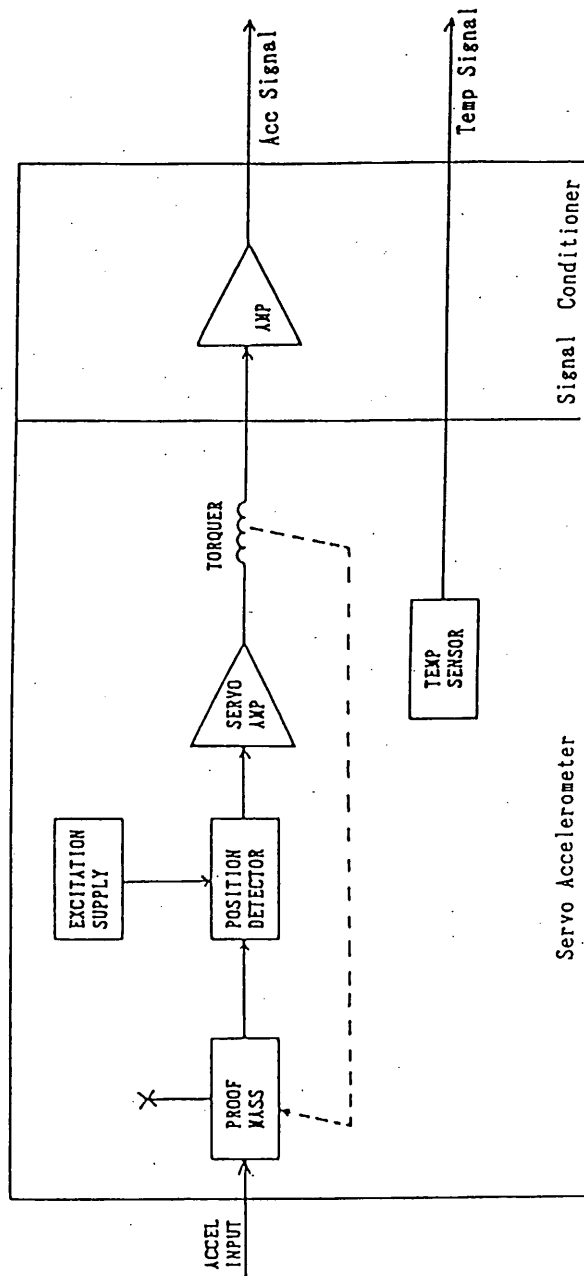


Figure 1. Functional Block Diagram of ACM

5.3.5.2 Specification and Performance

Performance and characteristics of ACM's are shown in Table 1.

Table 1 Performance and characteristics of ACM's

No	I T E M	ACM-A, B	ACM-C, D
1	Range (Full Scale)	$\geq \pm 40\text{mG}$	$\geq \pm 20\text{G}$
2	Sensitivity (Scale Factor)	$5\text{V}/40\text{mG} \pm 5\%$	$5\text{V}/20\text{G} \pm 5\%$
3	Offset (Bias) (@25℃)	$\leq \pm 200\mu\text{G}$	$\leq \pm 2\text{mG}$
4	Offset Temp Coef (B T C)	$\leq \pm 30\mu\text{G}/^\circ\text{C}$	$\leq \pm 100\mu\text{G}/^\circ\text{C}$
5	Offset Stability (B S T)	$\leq \pm 100\mu\text{G}/\text{Yr}$	$\leq \pm 100\mu\text{G}/\text{Yr}$
6	Non-Linearity	$\leq \pm 0.1\% \text{F.S}$	$\leq \pm 0.1\% \text{F.S}$
7	Resolution	$\leq 20\mu\text{Grms} (=2.5\text{mVrms})$	$\leq 4\text{mG} (=1.0\text{mV})$
8	Noise Level	$\leq 32.1\mu\text{G} (=3.9\text{mV})$	$\leq 1.25\text{mVrms}$ (5mG相当)
9	Frequency Responce ($\pm 3\text{dB}$)	$\geq 0 \sim 200 \text{ Hz}$	$\geq 0 \sim 20 \text{ Hz}$
10	Temp-Sensor	$-1 \mu\text{A}/^\circ\text{K}$	$-1 \mu\text{A}/^\circ\text{K}$
11	Power-Supply Voltage (dc)	$\pm (12.2 \sim 12.8) \text{ v}$	$\pm (12.2 \sim 12.8) \text{ v}$
12	Current-Consumption	$\leq \pm 25\text{mA}$	$\leq +50\text{mA}, \leq -30\text{mA}$
13	Seal	lasar weld /glass hermetic	lasar weld /glass hermetic
14	EMC/EMI	As specified in PLANET-B CS,CE,RS,RE	

5.3.5.3 Interface Condition & Thermal Characteristics

(1) . Mechanical Interface Condition of ACM's are shown in Table 2.

Table 2 Mechanical Interface Condition of ACM's

Unit Name : ACM-A,B,C,D			
No	ITEM	CONTENTS	REMARKS
1	WEIGHT	0.1 Kg $\pm$ 0.01 Kg	EACH ACM
2	DIMENSION	53 mm $\times$ 38 ϕ mm	SEE FIGURE 2
3	CENTER OF GRAVITY	SEE FIGURE 2	
4	MOMENT OF INERTIA	IX 0.09 Kg $\cdot$ cm ²	EACH ACM
		IY 0.19 Kg $\cdot$ cm ²	
		IZ 0.19 Kg $\cdot$ cm ²	
5	CASE MATERIAL	PC PERMALLOY (CONFORM TO JIS C 2531)	
6	DIAMETER OF MOUNTING HOLE	SEE FIGURE 2	
7	ACCURACY OF MOUNT-HOLE POSITION	SEE FIGURE 2	
8	THICKNESS & WIDTH OF MOUNTING FLANGE	SEE FIGURE 2	
9	FLATNESS OF MOUNT-SURFACE	SEE FIGURE 2	
10	SMOOTHNESS OF MOUNT-SURFACE	3.2S ▽▽▽	
11	CONTACT AREA OF MOUNT-SURFACE	0.8 cm ²	
12	MOUNTING PROVISIONS	M3 Screw to be used (length=8~10mm) Recommended Torque is 5kg $\cdot$ cm $\pm$ 10%.	

(2) . Electrical Interface Condition

Electrical Interface Condition of ACM's are shown in Table 3.

Table 3 Electrical Interface Condition of ACM's

Unit Name : ACM-A,B,C,D				
No	ITEM	CONTENTS		REMARKS
1	Electrical Interface	Pin Assignment of Accelerometer	1 Signal Out(Hi)	Thru Signal Conditioner Output.
		※2	Accel Out(Hi)	Direct Servo Loop Signal Output.
		※2	Current Self-Test (Lo)	Self-Test Input.
		3	+12.5Vdc	Power Input.
		4	±12.5Vdc Return	Power Input.
		4	Signal Out(Lo)	Signal Output.
		※4	Accel Out(Lo)	Signal Output.
		※4	Temp Out (Lo)	Signal Output.
		5	-12.5Vdc	Power Input.
		※6	Current Self-Test (Hi)	Self-Test Input.
		※7	Temp Out (Hi)	External Resister 10kΩ is necessary between pin 7 & 4.
		GND	GRN Terminal	Case GND Insulation Resistance 200MΩ(50Vdc) Insulation Break down 100 Vdc
		Note ※: Maker's Use Only		

(3) . Thermal Characteristics

Thermal Characteristics of ACM's are shown in Table 4.

Table 4 Thermal Characteristics of ACM's

Unit Name ; ACM-A,B,C,D				
No	ITEM	CONTENTS		REMARKS
1	PERFORMED TEMP.	-30 ℃	+60 ℃	Heating Rate and Cooling Rate shall be less than 3℃/minute.
2	FUNCTIONAL TEMP.	-30 ℃	+60 ℃	
3	STORAGE TEMP.	-50 ℃	+60 ℃	
4	TURN OFF TEMP.	-50 ℃	+60 ℃	
5	TURN ON TEMP.	-50 ℃	+60 ℃	
6	TEMP MONITOR POINT	SEE FIGURE 2		
7	MOUNTING SURFACE TREATMENT	NO TREATMENT PC PERMALLOY (CONFORM TO JIS C 2531)		
8	EXTERNAL SURFACE TREATMENT	NO TREATMENT PC PERMALLOY (CONFORM TO JIS C 2531)		
9	THERMAL OPTICAL CHARACTERISTICS FOR EXTERNAL	$\epsilon_H = 0.116$		
	SURFACE(EXCEPT MOUNT-SURFACE)	α_s _____		
10	HEAT CAPACITY	67.9 J/℃		
11	HEAT DISSIPATION (✓EACH ACM)	OPERATE MODE	POWER CONSUMPTION	
		OFF	0.00 W± 0.00 W	
		_____	W± W	
		ON(0G~40mG)	0.64 W± W	Max
		"	0.50 W± 0.08 W	Nominal
		_____	W± W	
		ON (20G)	1.02 W± W	Max
		"	0.88 W± 0.10 W	Nominal

5.3.5.4 External View

External View of each ACM is shown in Figure 2.

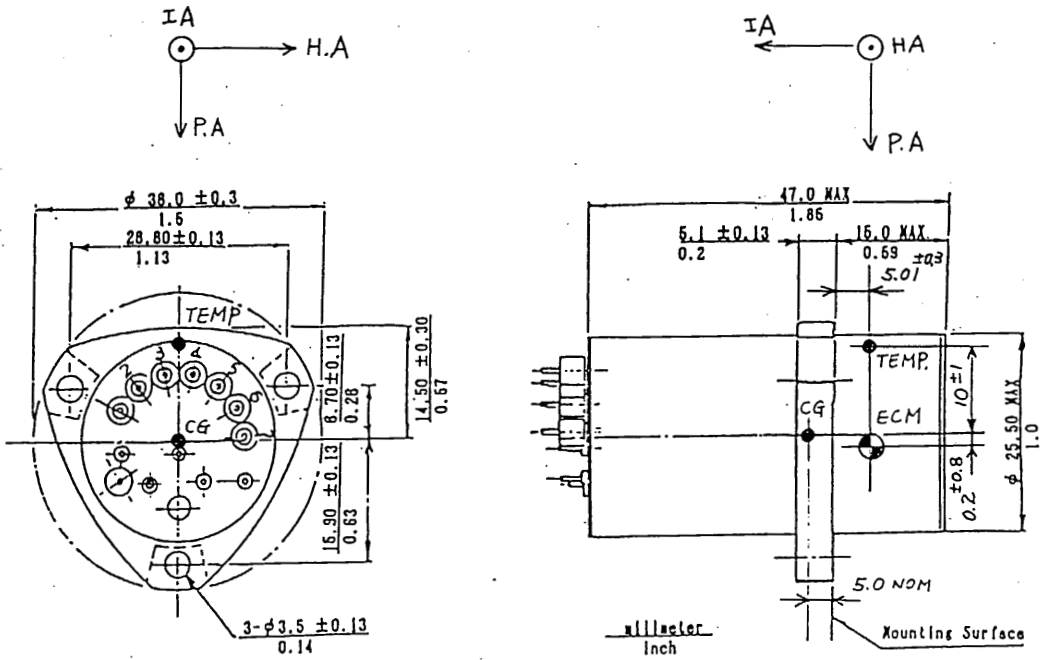


Figure 2. External View of ACM

5.3.6 Nutation Damper

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To attenuate nutational motion and spin rate ripple of the spin-stabilized spacecraft, a hoop-type damper is to be aboard (Fig. 1).

About 1/3 in volume of the annular tube is filled with silicone oil. Oil's relative motion to the tube wall dissipates spacecraft's excess energy through its dynamical coupling with the nutation and spin ripple.

The characteristic parameters of ND, such as hoop radius, offset from spin axis, and mass of silicone oil, are selected carefully so that the excitations of the oil motion by nutation and spin ripple are maximized. Essential characteristics of the damper are listed below.

Hoop material :	aluminum alloy
Mean radius of hoop :	0.4m
Radius of tube :	0.015m
Offset of hoop center from spin axis :	0.017m
Offset height from c.g.:	0.5m
Mounting block material :	glass epoxy
Density of silicone oil :	0.915Kg/m
Kinematic viscosity of silicone oil :	5.0centi-stokes
Filling percentage:	33.3%
Leak estimated :	<1.0atm cc/year
Damping time constant:	220 seconds at 7.5rpm
Total weight :	1.2Kg

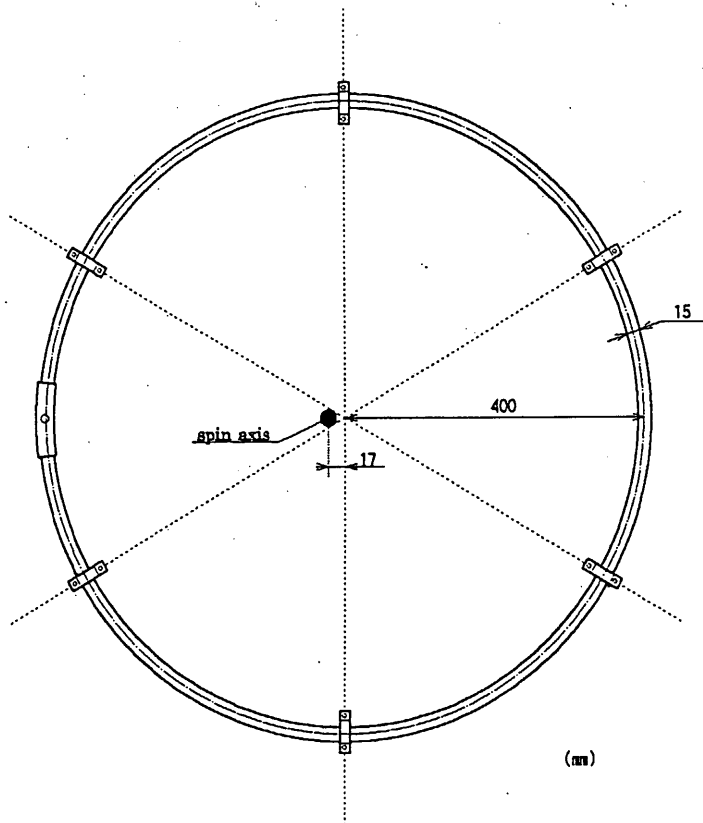


Figure 1 Schematic diagram of ND

5.4 Propulsion System

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5.4.1 Overview

The PLANET-B propulsion system is required not only to control the attitude of the spacecraft but also to correct trajectory on the course to Mars, and to insert the spacecraft into an orbit around Mars. The total delta-V required is extremely large, that is, 1965 m/sec.

To comply with such requirements, a dual mode bipropellant propulsion system is adopted to the PLANET-B. This propulsion system has one 500N bipropellant (NTO/N₂H₄) thruster for the Trajectory Control Maneuvers (TCM's) and ten 3N mono-propellant (N₂H₄) thrusters for the attitude control maneuvers.

5.4.2 System Description

(1) General

The propulsion system consists of four propellant tanks, one pressurant tank, ten 3N mono-propellant thrusters, one 500N bipropellant thruster, pipings, valves, filters, and heaters. Both kinds of the thruster work under the regulated pressure. Heaters and temperature sensors are attached to the thrusters, valves, tanks and pipings. A system block diagram of the propulsion system is shown in Fig. 1.

The 3N thrusters are installed in two thruster modules (five thrusters in each module) and the latching valves, filters and a pressurant gas regulator are separately installed in three valve modules. All connecting points along the pipe lines from the tanks to the thrusters are completely welded to preclude any possibilities of leakage of the propellant and pressurant gas.

As illustrated in Fig. 2, each component of the propulsion system is allocated symmetrically so as to make its center of gravity (CG) drop on the spin axis of the spacecraft.

(2) Tank Module

The propulsion system has three kinds of tank: a pressurant (Helium gas) tank, two fuel (N₂H₄) tanks, and two oxidizer (NTO) tanks. All these tanks are supported by the base panel and the truss structures, and this configuration gives a symmetry of the allocation, an effective utilization of space in the spacecraft, and consequently contributes to reduce weight of the spacecraft.

Fuel and oxidizer are loaded in the teardrop shaped tanks made of titanium alloy (Ti-6Al-4V). The tank shell is formed by the super-plastic forming process and fabricated by the electron beam welding. Each fuel tank is 569 mm in diameter and 706 mm long, and its volume is about 99 liters. About 87 liters of fuel is loaded in each tank. The size of an oxidizer tank is 421 mm D x 525 mm L, and its volume is about 40 liters. In this tank, about 35 liters of oxidizer is loaded. Propellant in the tank is separated from the pressurant gas by the centrifugal force caused by spinning of the spacecraft after launch so that no bladder nor diaphragm is necessary inside the tank.

The pressurant tank has a spherical shape of which shell is made of titanium alloy wrapped with carbon fiber. This composite structure has been newly developed to decrease its weight and adopted to PLANET-B as the first time. The outline of the pressurant tank is shown in Fig. 3.

(3) Thruster Module

The RCS has two thruster modules; Thruster Module -A and -B. Both modules have the same structures and are installed on the opposite sides of the spacecraft base panel respectively. Each of these thruster modules is equipped with five 3N mono-propellant thrusters; two axial, one radial, and two tangential thrusters.

Though the RCS thruster can generate 3 to 1.4 Newton thrust in the blowdown mode, it is fixed to 2.3 Newton in the PLANET-B mission in which the regulated pressure is provided. Every thruster consists of hydrazine decomposition chamber (catalyst bed), a nozzle, a thruster valve etc. Typical materials are Haynes alloy 25 and SUS 304, and Shell 405 catalyst is used for the hydrazine decomposition. A heater and a temperature sensor are equipped to every chamber so as to heat the catalyst up to 100 degree centigrade prior to firing. A space proven reliable double seated valve is adopted for the thruster valve.

The fill and drain valves are installed on the thruster modules to ensure accessibility from the outside of the spacecraft and to make the ground operations easier.

(4) Orbit Maneuver Engine

An orbit maneuver engine is installed under the bottom of the spacecraft through the truss structure which is also supporting the tanks mentioned above. Bipropellant (NTO/ N_2H_4) thruster which can produce 500 Newton thrust has been newly developed for the orbit maneuvers in the PLANET-B mission. This thruster consists of an injector, a combustion chamber, a nozzle, and thruster valves for fuel and oxidizer, as shown in Fig. 4. Material of the chamber is Niobium alloy with silicide coating and the nozzle is made of titanium. The present status of the development of this orbit maneuver engine and the results of its ground firing tests are mentioned in the section 4.2.3.4.

The heaters and a temperature sensor are attached to the injector to heat it up before its firing in orbit.

(5) Valve Module

Propellant and pressurant control valves except for the fill and drain valves are assembled into three valve modules; pressurant control valves in the valve module-A and propellant control valves in the valve module -B and -C. These modules are installed on the base plate.

A regulator (RG) installed in the gas feed line in the valve module-A regulates primary gas pressure of upperstream (250 kg/cm^2 at beginning of the mission) to the secondary pressure of downstream (14 kg/cm^2 throughout the mission). Each pressure is monitored with the pressure transducers (P1, P2, P3 and P4). A relief valve (RV) is equipped in the gas feed line under the secondary pressure in order to prevent over pressurization of the downstream and the propellant tanks. Also equipped with each gas feed line after it branches to the lines to the fuel and oxidizer tanks is a check valve (CV1 and CV2) which prevents any unexpected mixture of the vapors of NTO and N_2H_4 . Three latch valves (HLV, LV1 and LV2) are installed for safety during the ground operations and the launch phase. Another latch valve (LVm) is installed in the gas feed line connecting two fuel tanks in order to prevent the fuel migration on the launch pad, because the M-V launch vehicle is launched not vertically but with some elevation angle.

The propellant feed lines in the valve module -B and -C have four latch valves (LV3, LV4, LV5 and LV6) to ensure safety of the ground operations and launch phase. The latch valves in the hydrazine feed lines to RCS (LV3 and LV4) would be closed in the contingency or degradation mode caused by malfunction of the RCS thruster(s) in one of the thruster modules.

(6) Thermal Control

Temperature of hydrazine fuel has to be maintained at any time within the range from +5 to +70 degree centigrade. Especially in the thermal design of the spacecraft for Mars mission, the fact that solar power at the distance of Martian orbit is a half of it at Earth distance should be taken account. Thus the thermal blankets (Multi-layer thermal insulation film) and electrical heaters are applied for the thermal control of the propulsion system.

The heaters and temperature sensors are connected to the Heater Control Electronics (HCE) to control ON/OFF of the power supply to the heaters autonomously. As for the preheating of the monopropellant and bipropellant thrusters prior to firing, ON/OFF of each heater is operated manually by a command sent from the ground station and temperature is monitored through the House Keeping (HK) system.

The pressurant tank is also equipped with a heater and a temperature sensor. This heater is turned on manually only before firing of the bipropellant thruster in order to provide highest primary pressure available. Temperature of the tank is also monitored through the HK system.

5.4.3 Performance

The specification and planned performance of the propulsion are listed in Table 1. They are estimated on the assumption of the following characteristics of the spacecraft:

Dry weight of the spacecraft : 258 kg

Weight of propellant initially loaded : 278 kg

Moment of Inertia around the spin axis of the spacecraft : 294 kg m² (dry)

5.4.4 Development Status

(1) Bipropellant Thruster

The ground firing tests of the 500 N bipropellant thruster have been conducted to verify and demonstrate its performance by use of the experimental thrusters of which nozzle expansion ratio was low, and we have obtained a lot of valuable data concerning temperature, burning pressure, effective exhaust velocity, O/F ratio, film cooling, stability of firing, and so on.

The stable firing for 300 seconds was attained and we confirmed that the specific impulse of 310 seconds would be available with the nozzle with a high expansion ratio of 150. Some examples of the test results are shown in Fig. 5.

Table 1 Performance of Propulsion System

Item		Initial capability (nominal)	Remarks
1. Thrust	Radial & Tangential Thruster	2.3 N	
	Axial Thruster	2.2 N	canted thruster
		500 N	OME
2. Total Impulse		783100 N·s	W _{p1} =32kg, I _{sp1} =180sec(pulse) W _{p2} =239kg, I _{sp2} =310sec
3. Propellant Weight		278 kg	
4. Precession Torque		4.3 N·m (2.2 N·m)	r=1m 2 axial thrusters operation ()shows 1 thruster operation
5. Spin Torque		4.6 N·m	r=1m 2 tangential thrusters operation
6. Acceleration		0.93 m/s ²	OME operation W _{s/c} =536kg
7. Angular Velocity of Precession		0.33 deg/s (0.17deg/s)	Same as Para.5 N=20rpm, I _z =352kg·m ²
8. Spin acceleration		0.13 (rpm)/s	
9. Minimum Pulse Width		100 msec	RCS thruster
10. Precession Angle per Pulse		0.033 deg (0.017 deg)	Same as Para.5
11. Spin per Pulse		0.013 rpm	
12. Propulsion System Weight		343.6 kg (wet) 66.5 kg (dry)	

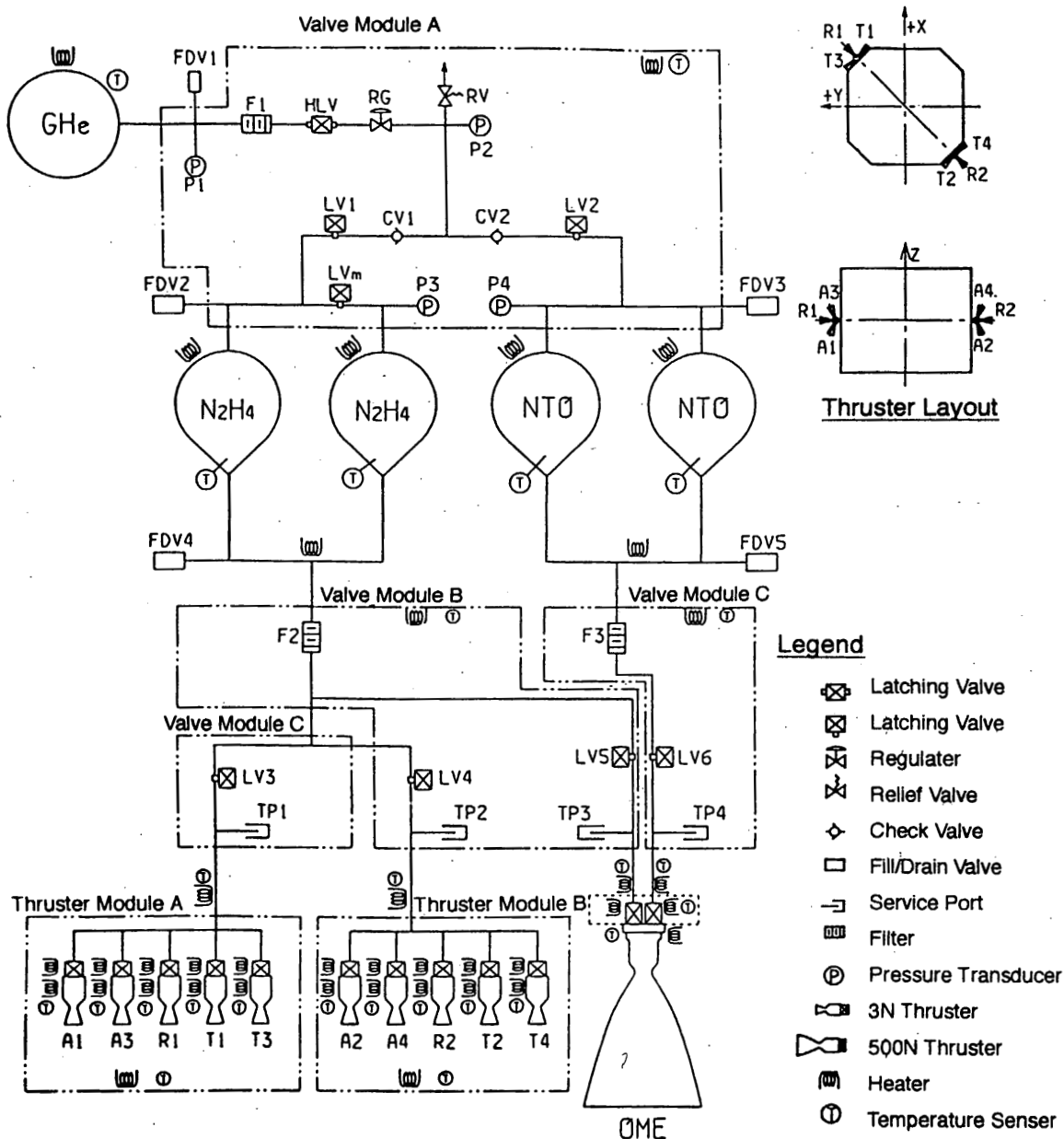


Fig.1 Flow Diagram of Propulsion System

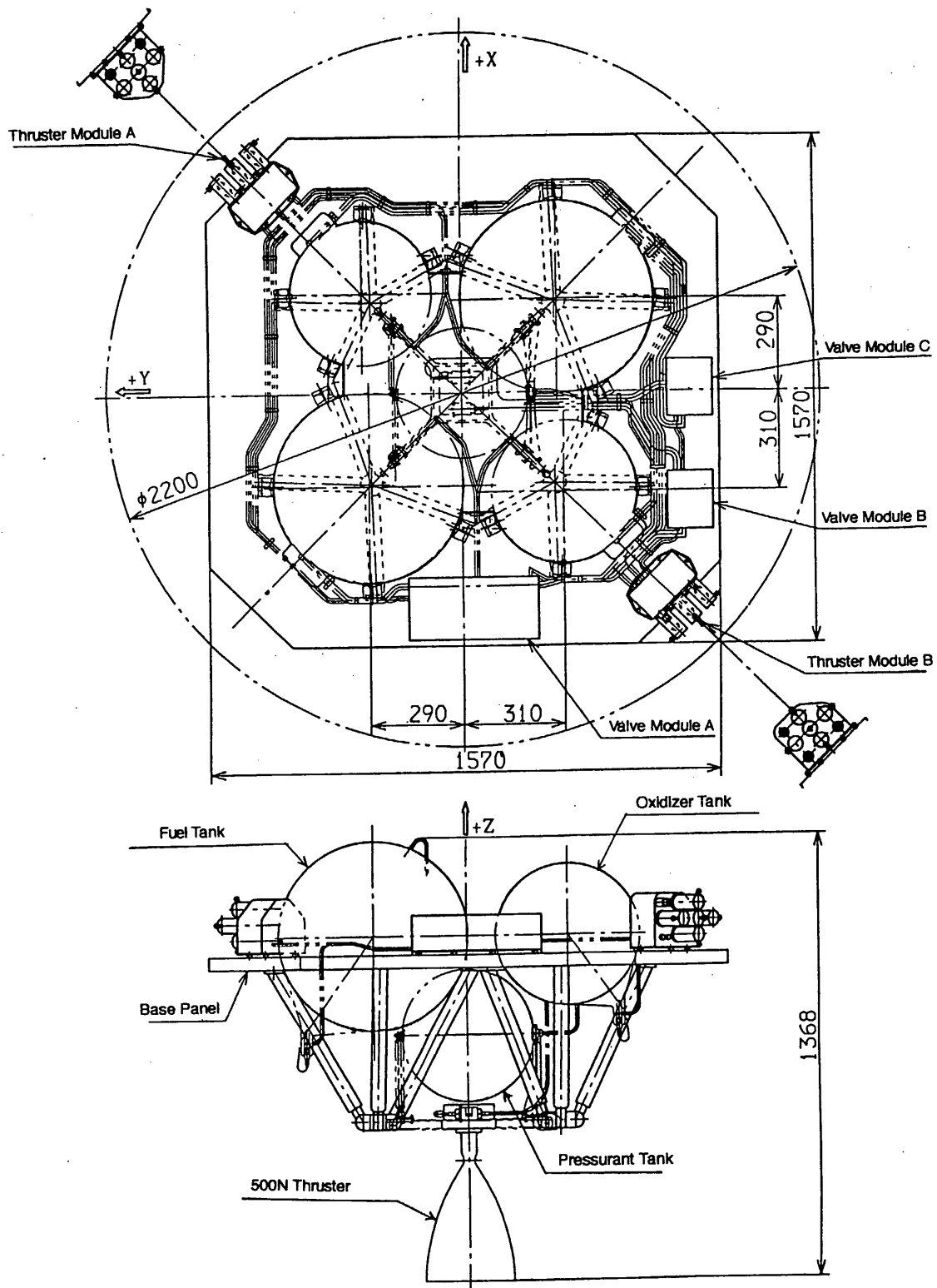


Fig.2 Arrangement of Propulsion System

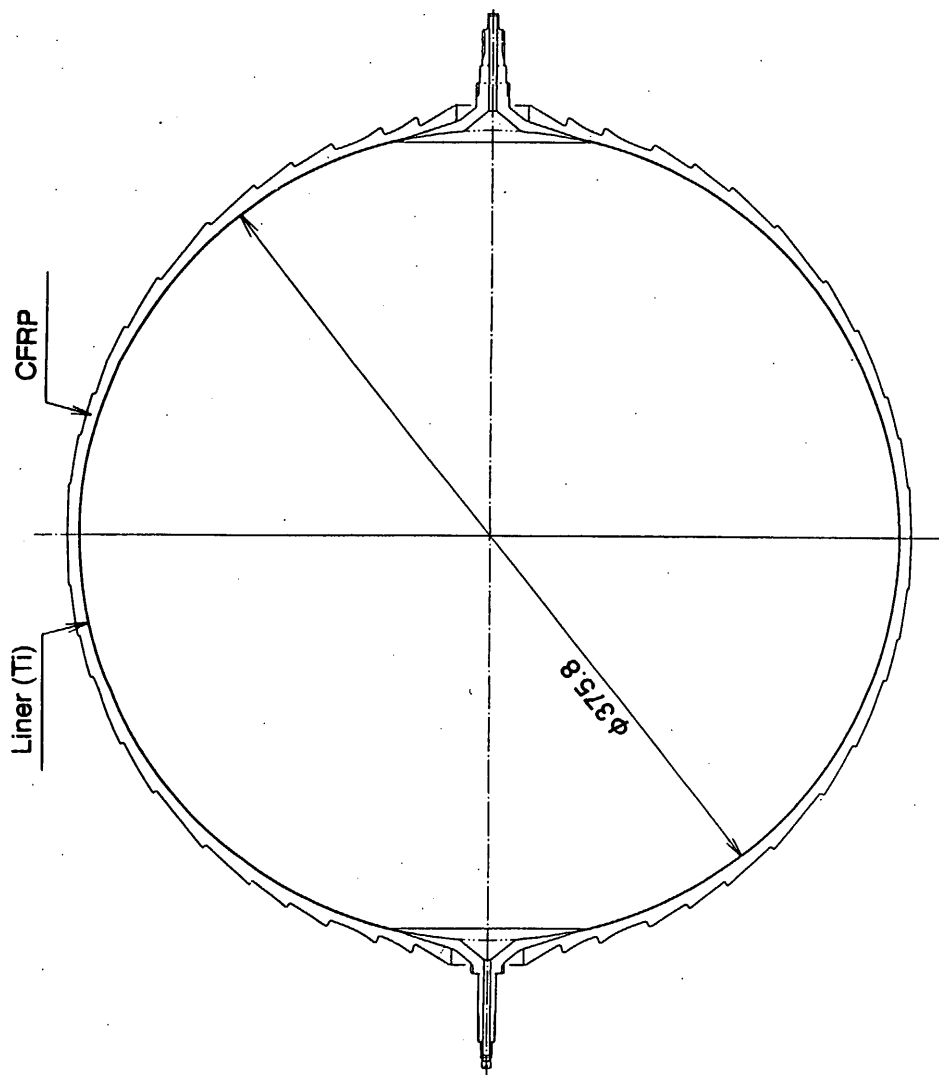


Fig.3 Outline of Pressurant Tank

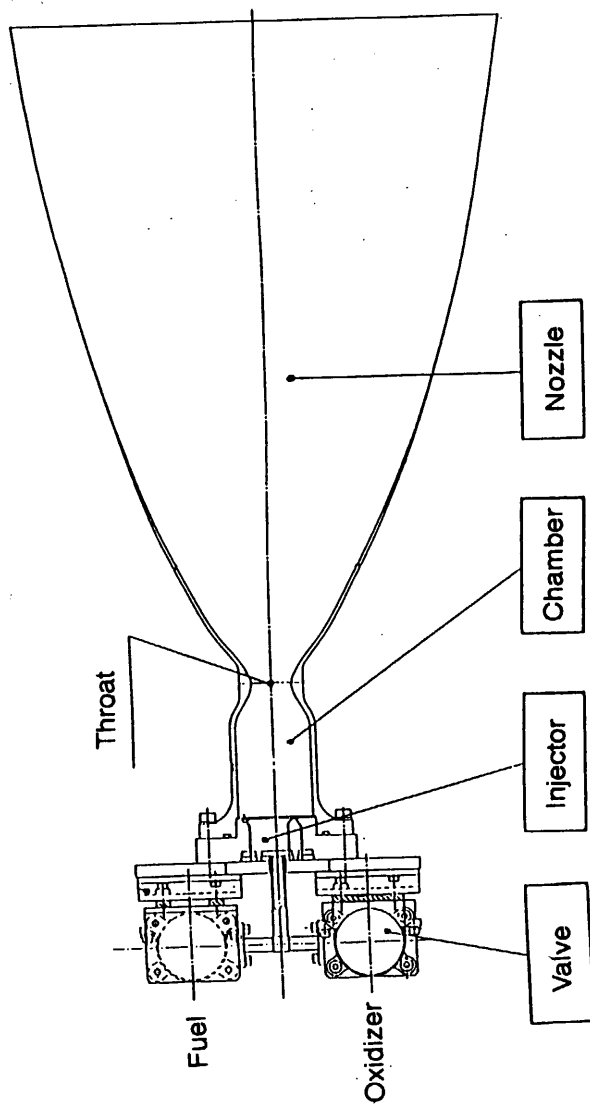


Fig.4 Outline of 500N Bipropellant Thruster

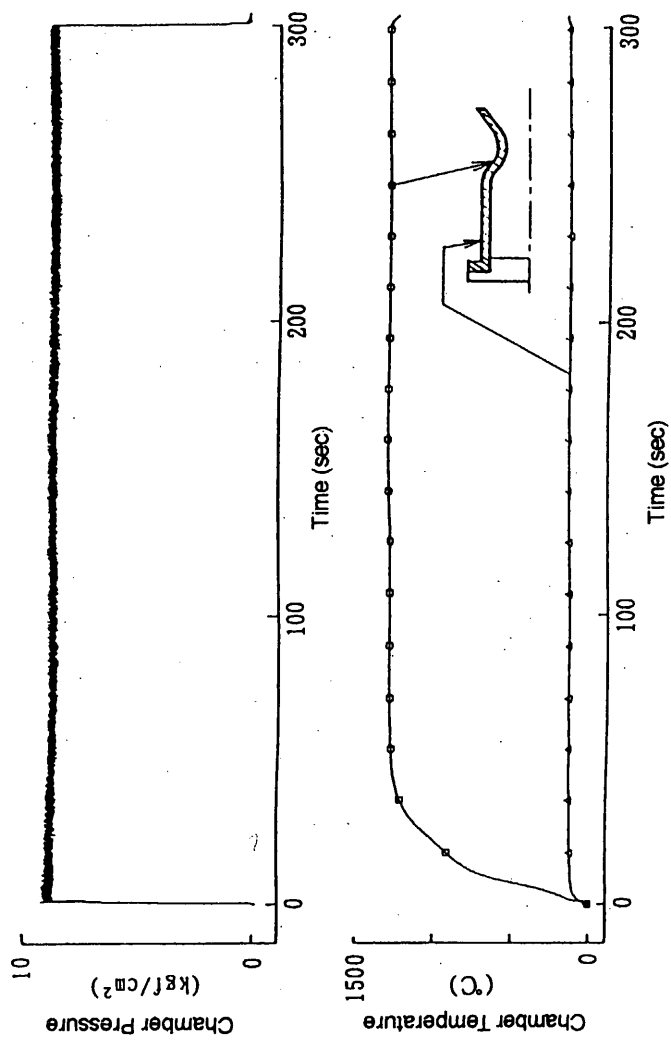


Fig.5 Firing Test Data of Bipropellant Thruster

5.5 Commands and Telemetry Items

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5.5.1 Command Items

Discrete commands for AOCS are summarized in chapter 1.4.6.

Block commands are not shown in this report as they are currently yet under detailed assignment phase.

5.5.2 Telemetry Items

(1) AOCS packet sequence

Telemetry format and packet sequence of the spacecraft is summarized in chapter 1.4.4. Shown in Table 1 are more detailed packet sequence related to AOCS.

(2) Secondary header for AOCS packets

Nine types of AOCS packets are used. They are identified by secondary header embedded in the top of user area of each packet.

Packet Header	Secondary Header
05H : AOCS DMP	10011000B(98H) : CPU-A MEMORY DUMP
	10011001B(99H) : CPU-B MEMORY DUMP
	10011010B(9AH) : EEPROM MEMORY DUMP
07H : AOCS	00000001B(01H) : AOCS-L1
	00000010B(02H) : AOCS-L2
	00000011B(03H) : AOCS-L3
	00000100B(04H) : AOCS-M1
	00000101B(05H) : AOCS-M2
	00000110B(06H) : AOCS-M3

Table 1 AOCs packet sequence

Format-01:Launch

PS No	0	1	2	3	4	5	6	7
0	HK		AOCs-L2		AOCs-L3		AOCs-L3	
8			AOCs-L2		AOCs-L3		AOCs-L3	
16			AOCs-L2		AOCs-L3		AOCs-L3	
24	AOCs-L1		AOCs-L2		AOCs-L3		AOCs-L3	
32	HK		AOCs-L2		AOCs-L3		AOCs-L3	
40			AOCs-L2		AOCs-L3		AOCs-L3	
48			AOCs-L2		AOCs-L3		AOCs-L3	
56	AOCs-L1		AOCs-L2		AOCs-L3		AOCs-L3	

Format-02:AOCs (Maneuver)

PS No	0	1	2	3	4	5	6	7
0	HK	AOCs-M1	AOCs-M2	AOCs-M3	AOCs-M3	AOCs-M3	AOCs-M3	AOCs-M3
8	HK	AOCs-M1	AOCs-M2	AOCs-M3	AOCs-M3	AOCs-M3	AOCs-M3	AOCs-M3
16	HK	AOCs-M1	AOCs-M2	AOCs-M3	AOCs-M3	AOCs-M3	AOCs-M3	AOCs-M3
24	HK	AOCs-M1	AOCs-M2	AOCs-M3	AOCs-M3	AOCs-M3	AOCs-M3	AOCs-M3
32	HK	AOCs-M1	AOCs-M2	AOCs-M3	AOCs-M3	AOCs-M3	AOCs-M3	AOCs-M3
40	HK	AOCs-M1	AOCs-M2	AOCs-M3	AOCs-M3	AOCs-M3	AOCs-M3	AOCs-M3
48	HK	AOCs-M1	AOCs-M2	AOCs-M3	AOCs-M3	AOCs-M3	AOCs-M3	AOCs-M3
56	HK	AOCs-M1	AOCs-M2	AOCs-M3	AOCs-M3	AOCs-M3	AOCs-M3	AOCs-M3

Format-03,04,05,11:Extension (MST, WANT, TPA), Emergency_1

PS No	0	1	2	3	4	5	6	7
0	HK	AOCs-M1		AOCs-M1		AOCs-M1		AOCs-M1
8	HK	AOCs-M1		AOCs-M1		AOCs-M1		AOCs-M1
16	HK	AOCs-M1		AOCs-M1		AOCs-M1		AOCs-M1
24	HK	AOCs-M1		AOCs-M1		AOCs-M1		AOCs-M1
32	HK	AOCs-M1		AOCs-M1		AOCs-M1		AOCs-M1
40	HK	AOCs-M1		AOCs-M1		AOCs-M1		AOCs-M1
48	HK	AOCs-M1		AOCs-M1		AOCs-M1		AOCs-M1
56	HK	AOCs-M1		AOCs-M1		AOCs-M1		AOCs-M1

Format-08:AOCe Program Dump

PS No	0	1	2	3	4	5	6	7
0	HK	AOCSDMP		AOCSDMP		AOCSDMP		AOCSDMP
8	HK	AOCSDMP		AOCSDMP		AOCSDMP		AOCSDMP
16	HK	AOCSDMP		AOCSDMP		AOCSDMP		AOCSDMP
24	HK	AOCSDMP		AOCSDMP		AOCSDMP		AOCSDMP
32	HK	AOCSDMP		AOCSDMP		AOCSDMP		AOCSDMP
40	HK	AOCSDMP		AOCSDMP		AOCSDMP		AOCSDMP
48	HK	AOCSDMP		AOCSDMP		AOCSDMP		AOCSDMP
56	HK	AOCSDMP		AOCSDMP		AOCSDMP		AOCSDMP

Format-10:Analysis(Common)

PS No	0	1	2	3	4	5	6	7
0	HK		AOCs-M2		HK		AOCs-M2	
8	HK		AOCs-M2		HK		AOCs-M2	
16	HK		AOCs-M2		HK		AOCs-M2	
24	HK		AOCs-M2		HK		AOCs-M2	
32	HK		AOCs-M2		HK		AOCs-M2	
40	HK		AOCs-M2		HK		AOCs-M2	
48	HK		AOCs-M2		HK		AOCs-M2	
56	HK		AOCs-M2		HK		AOCs-M2	

(3) AOCS telemetry

(a) HK packet

AOCS telemetry in HK packet consists of:

- Hardware status of AOCE
- Attitude sensor(SSAS,TSAS,SSC) data
- Onboard software status

The data is carefully selected so that cruise phase operation, such as attitude determination and AOCE monitoring, is possible with very limited telemetry capability.

Hardware status of AOCE in HK packet is summarized in chapter 1.4.5 .

(b) AOCS DMP packet

AOCS DMP packet dumps program and data of memory in CPU modules. The dump data has following three sources:

- main memory of CPU module-A
- main memory of CPU module-B
- EEPROM for non-volatile program storage

The source is designated with command before dumping.

Detailed dump format is omitted here.

(c) AOCS-Launch packets

AOCS-L1, AOCS-L2, and AOCS-L3 are used in launch phase where GRS and ACM-D takes major part in AOCS operation.

The packets are almost filled with high rate sample data of these sensors. Detailed dump format is omitted here.

(d) AOCS-Monitor/Maneuver packets

Major contents of AOCS-M1 packet is data of SSAS, TSAS and SSC. These data are used for attitude determination. AOCS-M2 packet is dedicated for operating and monitoring AOCE onboard software (OBS). AOCS-M3 packet is dedicated for dumping high rate sample data of ACM-A, ACM-B and ACM-C.

Contents of the packets are shown in Table 2. OBS status is currently under detailed assignment phase and is not included in this report.

Table 2 AOCs-Monitor/Maneuver packet

Table 2-1 AOCs-M1 packet

No.	Bytes	
0	1	Secondary Header(04H)
1	1	Packet Counter
2	4	Reference TI
6	12	Sensor Status
18	88	Sun pulse data
106	136	SSC pulse data
242	96	BC parameter list
338	92	OBS data and status

Sun pulse data format

No.	Bytes		
18	1	Number of SAS data included in this packet	
19	1	Number of SSAS data out of packet area limit	
20	1	Number of TSAS-X data out of packet area limit	
21	1	Number of TSAS-Y data out of packet area limit	
22	4	Spare	
26	3	Sun	Sun pulse phase
29	1	sensor	SAS(SSASorTSAS) status
30	2	data set	Sun angle
32	2	1	Spin rate
98	3	Sun	Sun pulse phase
101	1	sensor	SAS(SSASorTSAS) status
102	2	data set	Sun angle
104	2	10	Spin rate

SSC pulse data format

No.	Bytes		
106	1	Number of SSC-#1 data included in this packet	
107	1	Number of SSC-#1 data out of packet area limit	
108	1	Number of SSC-#1 data omitted by phase rejection	
109	1	Number of SSC-#1 data omitted by level rejection	
110	1	Number of SSC-#1 data included in this packet	
111	1	Number of SSC-#1 data out of packet area limit	
112	1	Number of SSC-#1 data omitted by phase rejection	
113	1	Number of SSC-#1 data omitted by level rejection	
114	3	SSC data	Star pulse phase
117	1	1	Star pulse intensity level
238	3	SSC data	Star pulse phase
241	1	32	Star pulse intensity level

Table 2-2 AOCS-M2 packet

No.	Bytes	
0	1	Secondary Header(05H)
1	1	Packet Counter
2	4	Reference Tl
6	422	OBS data and status

Table 2-2 AOCS-M3 packet

No.	Bytes	
0	1	Secondary Header(06H)
1	1	Packet Counter
2	4	Reference Tl
6	8	ACM data phase
14	390	ACM-A/ACM-B/ACM-C data
404	28	Spare

ACM-A/ACM-B/ACM-C data format

No.	Bytes	contents	
14	1	ACM data 1	ACM-A upper 8bits
15	1		ACM-A lower 4bits | ACM-B upper 4bits
16	1		ACM-B lower 8bits
401	1	ACM data 130	ACM-A upper 8bits
402	1		ACM-A lower 4bits | ACM-B upper 4bits
403	1		ACM-B lower 8bits

ACM-A data is replaced with ACM-C data when commanded

6. Electrical Power System (EPS)

6.1 Overview

The EPS for PLANET-B is required to provide the unregulated bus power and the regulated secondary power to all subsystems continuously during the mission life.

The conventional bus power control method for scientific satellites was to produce all of the regulated secondary voltages in EPS and provide the voltages to all subsystems.

In PLANET-B, a distributed power conversion method is adopted for the purpose of the minimization of the weight and EMI, and the failure mode separation of instruments.

This method is to set power supply unit (PSU) in each subsystem and to distribute the secondary power conversion function at each PSU.

The EPS for PLANET-B consists of two solar cell paddles(SCP), two batteries (BAT), a power controller and a distributor (PCD), shunt dissipators (SHNT), and nine power supply units (PSU).

An EPS block diagram is shown in Figure 6.1-1. The main function of EPS is as follows:

- (1)To convert solar energy to electrical energy by SCP in sunlight.
- (2)To provide the generated power straightly to each subsystem through the primary bus power line and at the same time store part of power into BAT.
- (3)To provide the BAT stored power to each subsystem in eclipse.
- (4)To control the bus voltage under the upper limit by SHNT.
- (5)To control and manage the charge current, the voltage, the temperature, and the capacity of BAT.
- (6)To control and monitor the status of EPS by command and telemetry.
- (7)To convert the primary bus voltage to the secondary voltages by the respective PSU for each subsystem.

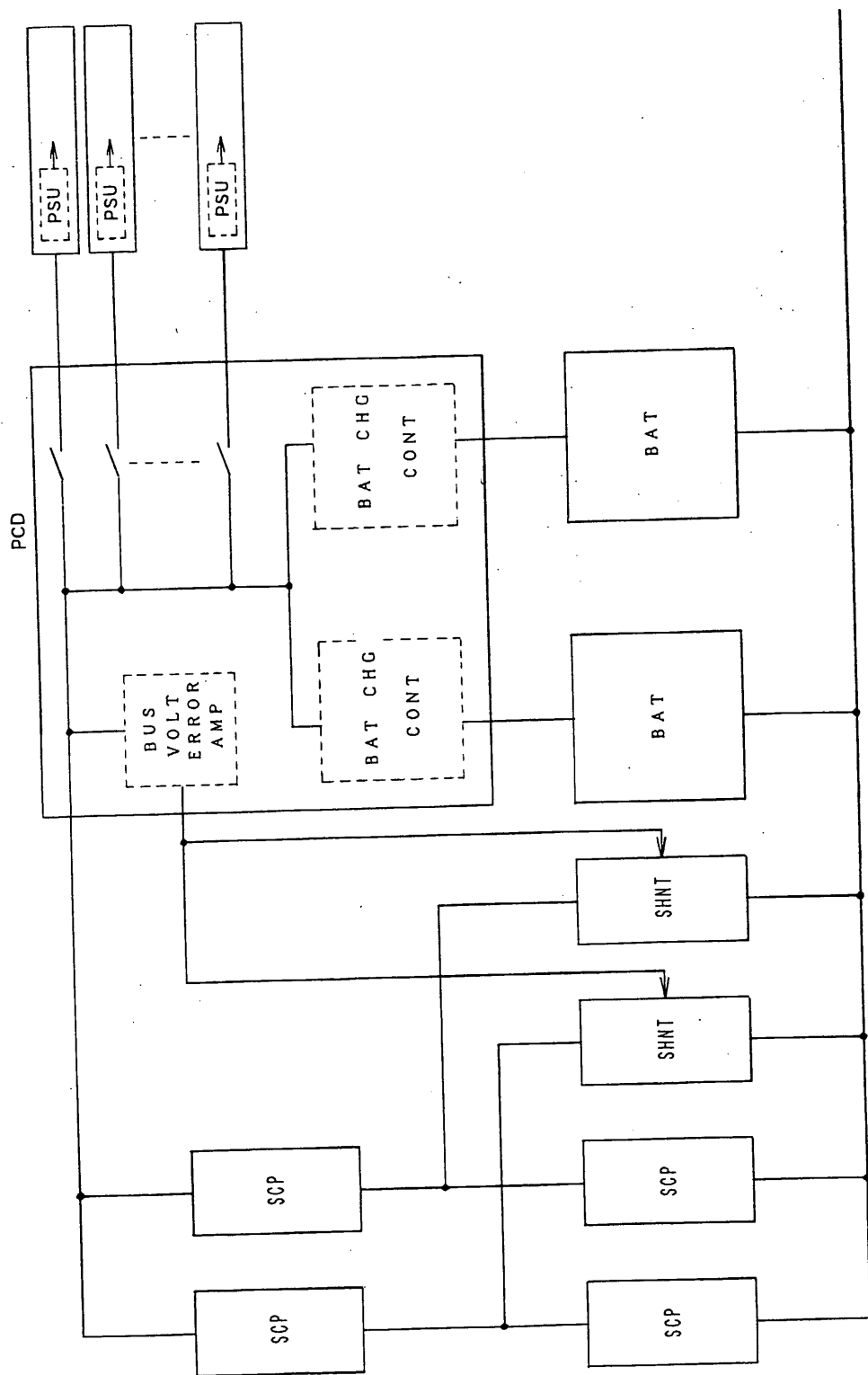


Figure 6. 1-1 EPS Block Diagram

6. 2 S o l a r C e l l P a d d l e (S C P)

6. 2. 1 O v e r v i e w

The solar cell paddle(SCP) converts solar energy into electrical energy and supplies it to electrical equipments of PLANET-B. The PLANET-B is equipped with two solar array wings, each of which consists of three solar cell panels. The solar cell paddle can generate power of 200 W min. and support the PLANET-B mission for more than 3 years. The weight of SCP is shown in Table 1.

Table 1 Weight of SCP

UNIT NAME	TARGET
Solar cell assembly	7.2 kg
structures and mechanisms	13.4 kg
TOTAL AMOUNT	20.6 kg

(1) Components

The solar cell paddle is equipped with solar panels and mechanisms. The solar panel consists of a solar cell assembly and structures. The mechanisms consist of clamp release mechanisms and deployment mechanisms.

(2) Performance

The performance of SCP is as follows:

- a) the power supply to electrical equipments of PLANET-B.
- b) the fold and release of the solar panels.

(3) Magnetic Cleanliness

To minimize the effects of current loops, the following are considered.

- a) To design the solar cell circuit direction for decrease in the magnetic noise.
- b) To keep the panel surface and coverglass of the solar cells equipotential.

6. 2. 2 Functions

6. 2. 2. 1 Electrical Functions

The solar cells for the PLANET-B solar panel are high efficiency silicon cells. The cell string layout of PLANET-B is designed for maximum panel performance. Functions of the solar cell panel are as follows.

(1) SOLAR CELL

PLANET-B uses Non-Reflective Surface(NRS)/Localized Back Surface Field(LBSF) Silicon cells with an average efficiency of 17.6%. The solar cell characteristics are shown in Table 2.

Table 2. Solar cell characteristics summary

Type	NRS/LBSF Silicon
Cell size	2cm × 4cm
Thickness (μm)	100
Resistance ($\Omega\text{-cm}$)	2
Anti Reflective coating	TiO ₂ -Al ₂ O ₃
Grid Number	37/2cm
Cell Efficiency (%)	17.6 (TPY)
Voc (V)	0.630
Isc (A)	0.384
Vmp (V)	0.520
Imp (A)	0.366
Radiation Analysis	
Equivalent 1MeV Electrons	
For Isc (e/cm ²)	1.706×10^{18}
For Voc, Pmax (e/cm ²)	6.853×10^{12}
Cell strings	TBD

(2) COVER GLASS (CG)

The PLANET-B solar cell has conductive coating cover glass(CCCG). This CCCG is covered with Blue Red Reflective(BRR) coating, decreasing greatly the solar absorptance of the covered cell. The CCCG characteristics are listed in Table 3.

Table 3. CCCG characteristics summary

Material	BRR
Thickness (μm)	100
UV Reflectance 50% Cut off (nm)	355 ± 15
IR Reflectance 50% Cut on (nm)	1165 ± 50
IR Reflectance 50% Cut off (nm)	1520 ± 50
Anti Reflecting	MgF ₂
Conductive Coating	ITO

6.2.2.2 Mechanical Functions

Structures and mechanisms of solar cell paddles consist of ;

- 1) Substrate on which solar cells are mounted
- 2) Clamp Release Mechanism (CRM) that restrains and releases the folded solar panels.
- 3) Deployment Mechanism (DLM) that deploys the released solar panels and maintains them in the deployed position under on-orbit environments including RCS/OMS firings.

(1) Configuration

The stowed and deployed solar array configuration are presented in Figures 6.2.2.2-1 and -2. PLANET-B spacecraft is equipped with two solar array wings, each of which consists of three solar panels. Two clamp cables, as shown in Figure 6.2.2.2-1, restrain the stowed solar panels. Firing of wire cutters severs the clamp cables, enabling the solar panels to deploy.

In addition to the electrical power supply, the wing provides the mounting interface of a scientific sensor (PET-S).

(2) Substrate

Substrates provide the required solar cell mounting area or 4.28 m² per two wings. Dimensions of a wing are shown in Figure 6.2.2.2-3. The substrate is made of honeycomb sandwich panel with CFRP facesheets, reinforced with CFRP stiffeners. Design requirements for the substrate are ;

a) Strength

quasi-static loads during launch :	TBS
random vibration environments :	TBS
acoustic environments :	TBS
end-of-travel deployment latch impact loads :	TBD
quasi-static loads during OMS burn :	approx. 0.4G (tentative) for deployed configuration

b) Stiffness

stowed :	greater than 25 Hz (tentative)
deployed :	greater than 0.5 Hz (tentative)

c) Interfaces

- To accommodate the M-V launch vehicle nose fairing constraints
- To accommodate the spacecraft structures mechanical interfaces
- To provide the mounting interface of PET-S on the outermost panel

(3) Clamp Release Mechanism (CRM)

CRMs are pyrotechnically actuated mechanisms that restrain and release the stowed solar panels. The wings are wrapped around the spacecraft by two, pre-tensioned clamp cables to withstand mechanical environments during launch. Two wire cutters (primary and back-up cutters) are installed on each clamp cable, thus enabling the mechanisms to be fully redundant in both electrical and mechanical senses.

(4) Deployment Mechanism (DLM)

Once solar panels released, the spring-actuated DLMs deploy them. Deployment is initiated while the spacecraft is spinning at approximately 4-rpm spin rate, which will decrease to approximately 2 rpm after deployment completion.

DLM consists of a hinge assembly, springs, a lock mechanism, and a microswitch. Each hinge assembly joins the adjacent solar panels and deploys them to the latched position with constant-force springs. Once in the latched position, the lock mechanism engages with the hinge assembly to maintain the deployed configuration against on-orbit inertial loads induced by the spacecraft spinning, attitude control maneuvers and OMS burn.

Latch status of each panel can be monitored via a microswitch provided on the hinge assembly.

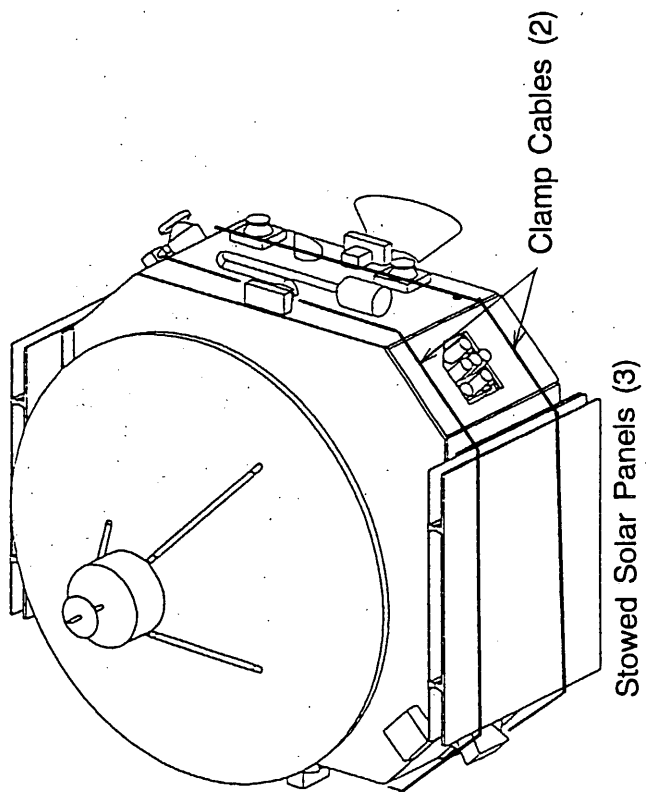


Figure 6.2.2.2-1 Stowed Configuration

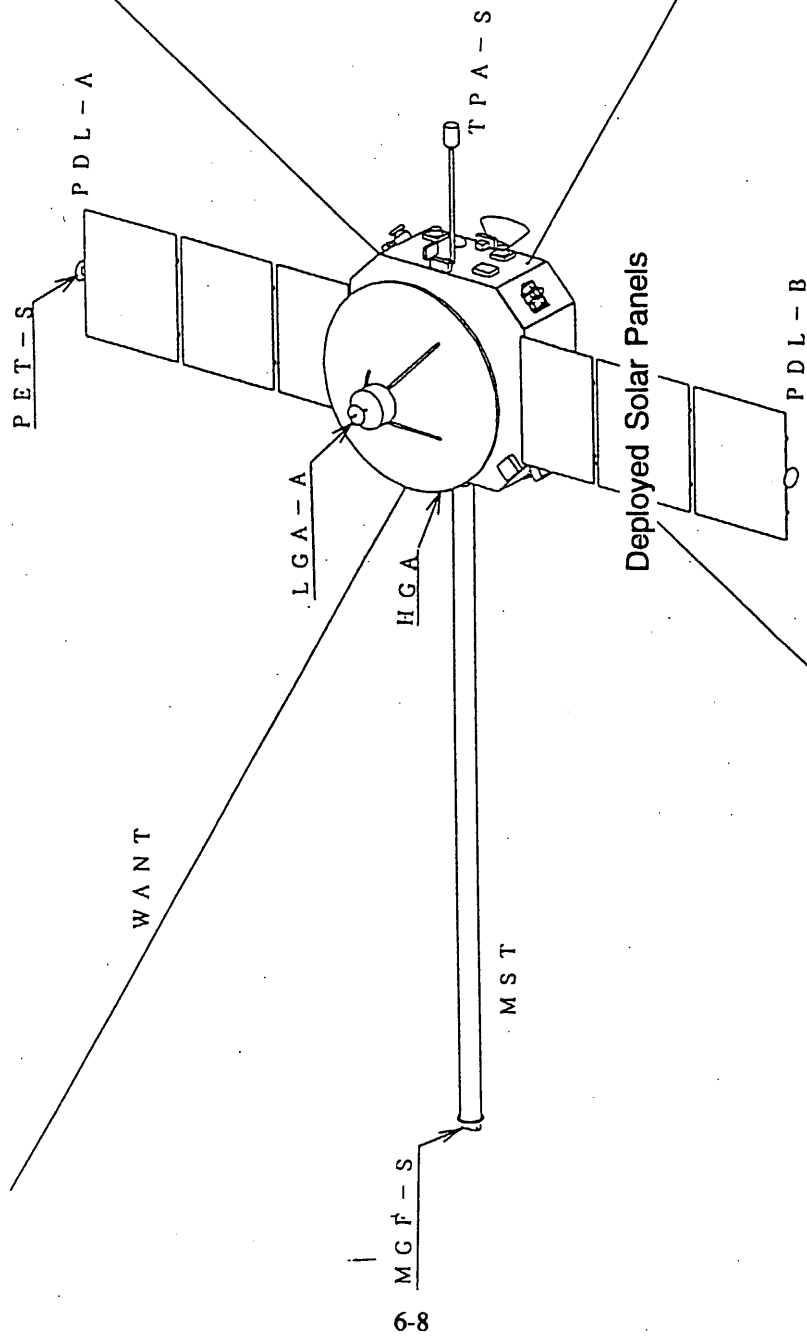


Figure 6.2.2.2-2 Deployed Configuration

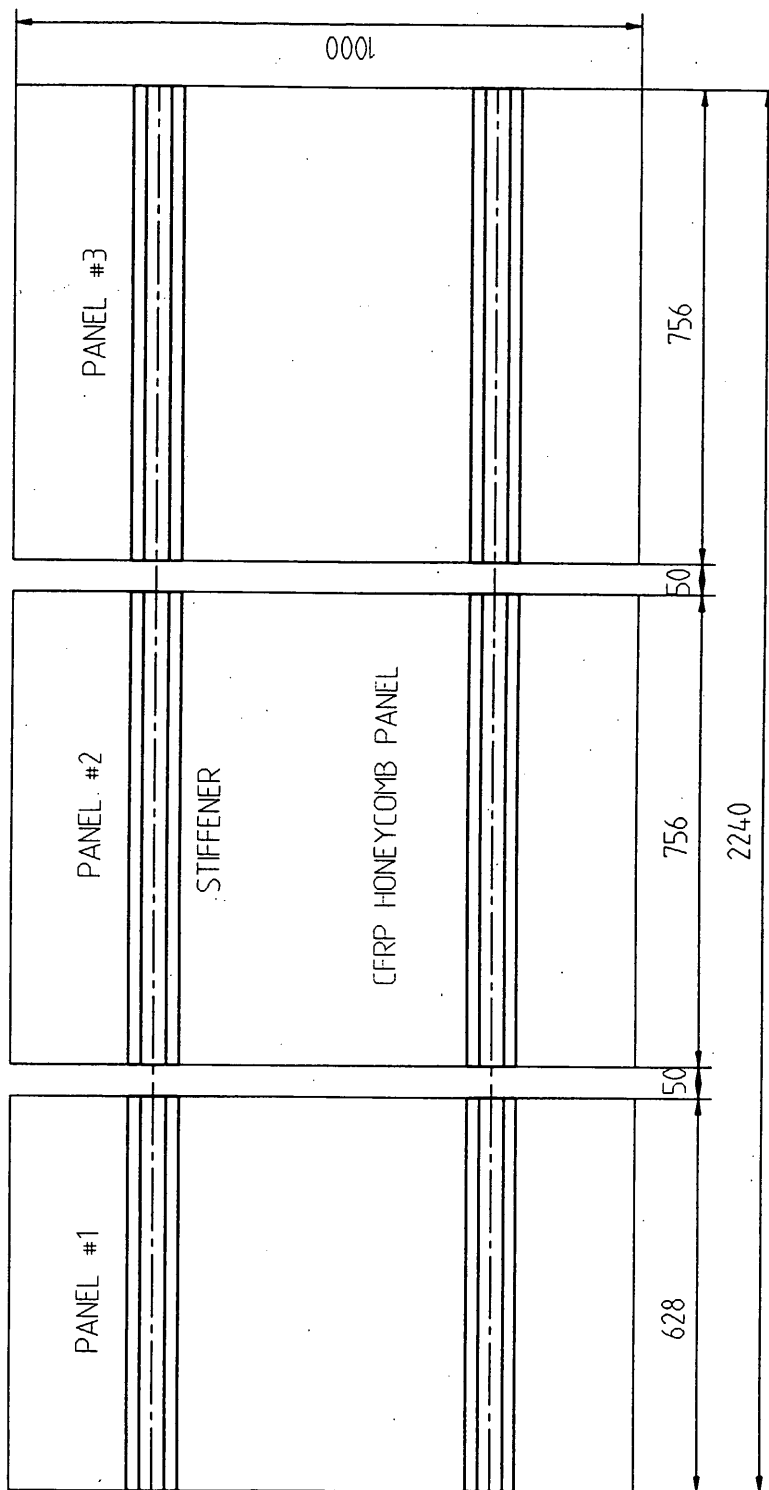


Figure 6.2.2.2-3 Wing Configuration (Deployed)

6.3 Battery (BAT)

6.3.1 Overview

BAT stores part of the SCP generated power in sunlight and provides the stored power to each subsystem in eclipse.

BAT subsystem consists of two battery units, each of which involves 16 series-connected cells.

Ni-MH (Nickel-Metal Hydride) battery cells are used for PLANET-B to minimize the BAT weight. They are superior to Ni-Cd (Nickel-Cadmium) cells in specific energy, weight or volume.

The rated capacity of the PLANET-B battery cell is 15AH, and the total BAT capacity is 30AH.

A block diagram of BAT is shown in Figure 6.3-1.

The main characteristics of BAT are as follows.

(1) Battery Cell Type

15AH Ni-MH Cell

(2) BAT Configuration

16 Cells $\times$ 2 Units

(3) Output Voltage

16.0V $\sim$ 24.8V

(4) DOD Limitation

50%

(5) Size

250 $\times$ 200 $\times$ 130mm/Unit

(6) Weight(BAT Subsystem)

17.5Kg in Total

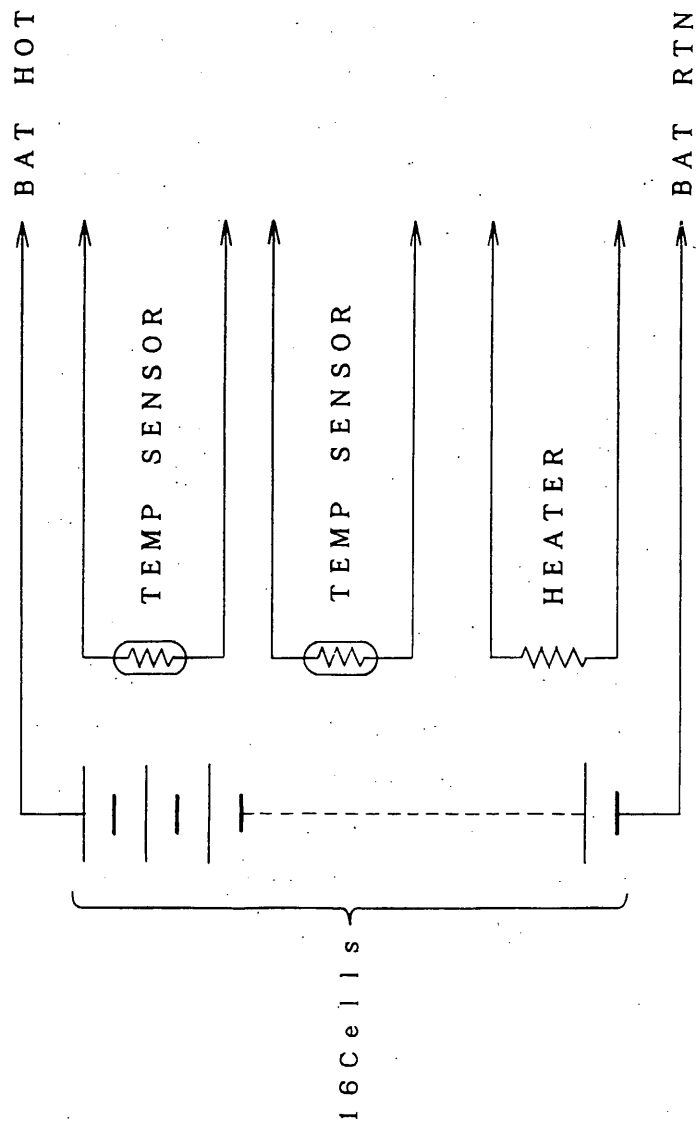


Figure 6. 3-1 BAT Block Diagram

6.3.2 Functions

The main functions of BAT are to store the SCP generated power in itself in sunlight and to provide the stored power to each subsystem through PCD in eclipse.

BAT subsystem consists of two battery units, and two units are connected in parallel in PCD to have the total capacity of 30AH.

The control and management of the battery charge/discharge current, voltage, and capacity of BAT is conducted by PCD.

The temperatures of each battery unit are controlled by HCE.

6.3.3 Operations

In sunlight, part of the SCP generated power is stored in parallel into the two battery units at the high rate charge level (1/10C).

When charge is completed, the charge rate is automatically changed to the low charge rate (1/50C).

In eclipse, the stored power is straightly provided in parallel from the two battery units to each subsystem through PCD. To protect overdischarge, each battery unit outputs the battery voltage signal to PCD.

An under voltage control (UVC) signal is outputted from PCD when either of the battery unit voltage signals reaches a lower voltage limit.

Each battery unit has also a temperature sensor and heaters so that its temperature is controlled by HCE.

6.4 Power Controller and distributor (PCD)

6.4.1 Overview

In PLANET-B, the distributed power conversion method is adopted.

Among the components of EPS, PCD has the function to distribute the unregulated primary bus power to each instrument. The PCD has also switches to turn on/off PSU for each subsystem.

Besides the primary bus power distribution function, PCD has the BAT charge/discharge control function. So far, EPS has employed battery charge control unit (BCCU) as a separate unit.

In PLANET-B, BCCU is eliminated for the purpose of minimization of EPS weight and the BAT charge control function is carried out by PCD.

A block diagram of PCD is shown in Figure 6.4-1.

The main characteristics of PCD are as follows.

(1)Bus Voltage

16.3V~27.5V

(2)Under Voltage Control (UVC)

T.B.D. levels

(3)Over Voltage Control (OVC)

$27.5 \pm 0.5V$

(4)Power Bus Distribution

13 Lines

(5)Each Line Current Monitor

(6)Each Line ON/OFF Control with Circuit Breaker

(7)Each Line Current limitation

(8)Charge/Discharge Control(2 Batteries in Total): High Rate Charge 3.0A (1/10C)

Trickle Charge 0.6A (1/50C)

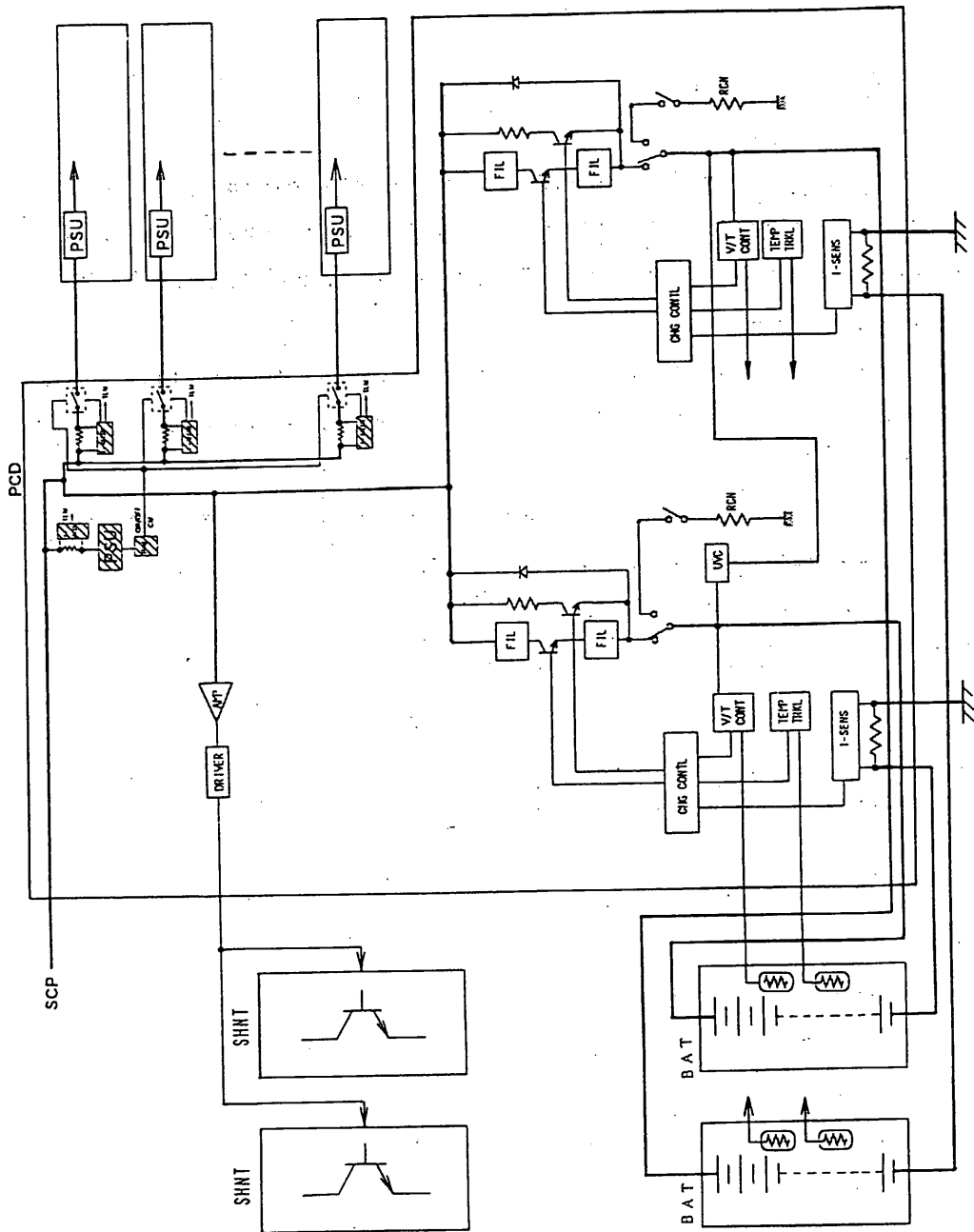


Figure 6.4-1 PCD Block Diagram

- (9) Battery Reconditioning
- (10) C/D Counter
- (11) Battery Charge/Discharge Current Monitor
- (12) Battery Voltage Monitor

6.4.2 Functions

The PCD is the key component that controls the EPS operation centrally. The main functions of PCD are the primary bus power distribution and the BAT charge/discharge control.

The detailed functions of PCD are as follows.

- (1) To distribute the unregulated primary bus power to each subsystem.
- (2) To turn on/off PSU by command signals with the switches inserted in the bus line.
- (3) To control the upper bus voltage limit by driving SHNT according to the bus voltage.
- (4) To charge BAT at the controlled charge rate in sunlight.
- (5) To provide the BAT stored power to each subsystem through the bus line.
- (6) To control and manage the current/voltage/temperature/capacity of BAT to protect the stress or degradation of BAT.
- (7) To monitor the bus current of each subsystem and separate a broken-down subsystem from the bus line with a circuit breaker.

6.4.3 Operations

The PCD receives the SCP generated power and straightly distributes it to each subsystem in sunlight. A power on/off switch is inserted in each distributed bus line in PCD, and PSU is turned on/off with the switch driven by command signals.

The part of the SCP generated power is stored into BAT at the controlled charge rates. A C/D counter in PCD always monitors the capacity of BAT and switches the high charge rate to the trickle charge rate when the recharge quantity reaches the designated level according to the discharge quantity.

The BAT stored power is straightly provided to the bus line in eclipse. Thus, the bus voltage in eclipse remains unregulated.

In sunlight, PCD controls the upper bus voltage limit to prevent bad affects to load subsystems.

The bus voltage error amp. in PCD sends out to SHNT the amplified signal corresponding to the bus voltage. The SHNT dissipates the output current corresponding to this control signal and the SCP output voltage is controlled under the upper limit.

The PCD also monitors currents/voltages/temperatures of EPS components to manage the EPS operating status.

6.5 Power Supply Unit (PSU)

6.5.1 Overview

In PLANET-B, the distributed power conversion method is adopted. Thus, each subsystem has PSU respectively and each PSU produces the secondary voltages that the corresponding subsystem needs.

A standard type of small-sized, lightweight PSU is now being developed for PLANET-B to minimize EPS weight.

There are 4 types of PSU corresponding to its power and output voltages.

The main characteristics of PSU are as follows.

(1)Type

4 Types (PSU 1~4)

(2)Output Power

PSU-1 20W

PSU-2 35W

PSU-3 80W

PSU-4 103W

(3)Output Voltage

+5V, $\pm 12V$, +29V

6.5.2 Function

Each PSU receives the unregulated primary bus voltage from PCD, and produces the regulated secondary voltages that the corresponding subsystem needs.

Each PSU must keep the secondary voltages within designated ranges under all operation modes of the corresponding subsystem.

Only one PSU with the highest power consumption is installed straightly on the satellite structure, and each of the other PSU's is installed inside the corresponding subsystem chassis.

6.5.3 Operations

A signal forward or pushpull type of switching regulator is used for PSU. Thus, PSU emits EMI noise as conducted emission and radiated emission. But this EMC between PSU and the other components is controlled by specifying and meeting the respective permitted level allocated to each PSU or component.

The PSU is turned on/off by the command control of a switch in PCD.

6.6 Shunt Dissipator (SHNT)

6.6.1 Overview

The SHNT dissipates the SCP output current according to the bus voltage error amp. signal from PCD, and keeps the SCP output voltage under the upper limit.

The SHNT uses the analog sequential partial shunt type to reduce SHNT power dissipation.

The main characteristics of SHNT are as follows.

(1)Type

Analog Sequential Partial Shunt

(2)SHNT Configuration

2 Units

(3)Shunt Capacity

T.B.D(W) (full shunt)

6.6.2 Functions

The SHNT receives the bus voltage error amp. signal from PCD, and dissipates a current according to this signal.

The SCP output voltage is shut off by dissipating the SCP output current and the bus voltage is kept under the upper limit.

6.6.3 Operations

The SHNT consists of two Units. Each unit has several shunt elements each of which is respectively connected to a SCP module. These shunt elements operate and dissipate the currents of SCP modules sequentially according to the bus voltage error amp. signal. By using this method SHNT power dissipation is conducted much more efficiently than that of the analog linear shunt type. Two units have the same design and operate in parallel.

6.7 Command and Telemetry Items

6.7.1 Command Items

The PCD receives all commands for EPS through the PIM line.

On receiving each command, PCD controls EPS to operate as designated by the command.

The command types for EPS are Discrete Command (DC) and Block Command (BC).

A command list for EPS is shown in Table 6.7-1.

6.7.2 Telemetry Items

Most of all EPS telemetry items are sent out to DHU through the PCD PIM line. But the temperature telemetry items are managed by HCE.

A telemetry list for EPS is shown in Table 6.7-2.

Table 6. 7-1 EPS Command List (1/2)

NO	COMMAND ITEM	FUNCTION
1	BAT-A INT	BAT-A ON
2	BAT-A EXT	BAT-A EXTERNAL
3	BAT-A TEMP TRKL ENA	BAT-A TEMP TRICKLE ENABLE
4	BAT-A TEMP TRKL DIS	BAT-A TEMP TRICKLE DISABLE
5	BAT-A TAPR L1	BAT-A TAPR LEVEL1
6	BAT-A TAPR L2	BAT-A TAPR LEVEL2
7	BAT-B INT	BAT-B ON
8	BAT-B EXT	BAT-B EXTERNAL
9	BAT-B TEMP TRKL ENA	BAT-B TEMP TRICKLE ENABLE
10	BAT-B TEMP TRKL DIS	BAT-B TEMP TRICKLE DISABLE
11	BAT-B TAPR L1	BAT-B TAPR LEVEL1
12	BAT-B TAPR L2	BAT-B TAPR LEVEL2
13	BAT-A RCN ON	BAT-B RECONDITIONING ON
14	BAT-A RCN OFF	BAT-A RECONDITIONING OFF
15	BAT-B RCN ON	BAT-B RECONDITIONING ON
16	BAT-B RCN OFF	BAT-B RECONDITIONING OFF
17	UVC L1	UVC LEVEL1
18	UVC L2	UVC LEVEL2
19	BAT-A UVC ENA	BAT-A UVC ENABLE
20	BAT-A UVC DIS	BAT-A UVC DISABLE
21	BAT-B UVC ENA	BAT-A UVC ENABLE
22	BAT-B UVC DIS	BAT-B UVC DISABLE
23	BAT-A K1 SET ENA	BAT-A K1 SET ENABLE
24	BAT-A K2 SET ENA	BAT-A K2 SET ENABLE
25	BAT-A C/D SET ENA	BAT-A C/D SET ENABLE
26	BAT-B K1 SET ENA	BAT-B K1 SET ENABLE
27	BAT-B K2 SET ENA	BAT-B K2 SET ENABLE
28	BAT-B C/D SET ENA	BAT-B C/D SET ENABLE

Table 6. 7-1 EPS Command List (2/2)

NO	COMMAND ITEM	FUNCTION
2 9	PSU1 ON	PSU1 POWER ON
3 0	PSU1 OFF	PSU1 POWER OFF
3 1	PSU2 ON	PSU2 POWER ON
3 2	PSU2 OFF	PSU2 POWER OFF
3 3	PSU3 ON	PSU3 POWER ON
3 4	PSU3 OFF	PSU3 POWER OFF
3 5	PSU4 ON	PSU4 POWER ON
3 6	PSU4 OFF	PSU4 POWER OFF
3 7	PSU5 ON	PSU5 POWER ON
3 8	PSU5 OFF	PSU5 POWER OFF
3 9	PSU6 ON	PSU6 POWER ON
4 0	PSU6 OFF	PSU6 POWER OFF
4 1	PSU7 ON	PSU7 POWER ON
4 2	PSU7 OFF	PSU7 POWER OFF
4 3	PSU8 ON	PSU8 POWER ON
4 4	PSU8 OFF	PSU8 POWER OFF
4 5	PSU9 ON	PSU9 POWER ON
4 6	PSU9 OFF	PSU9 POWER OFF
4 7	PSU10 ON	PSU10 POWER ON
4 8	PSU10 OFF	PSU10 POWER OFF
4 9	PSU11 ON	PSU11 POWER ON
5 0	PSU11 OFF	PSU11 POWER OFF
5 1	PSU12 ON	PSU12 POWER ON
5 2	PSU12 OFF	PSU12 POWER OFF
5 3	PSU13 ON	PSU13 POWER ON
5 4	PSU13 OFF	PSU13 POWER OFF

Table 6. 7-2 EPS Telemetry List (1/2)

NO	TELEMETRY ITEM	FUNCTION
1	BAT-A INT/EXT	BAT-A INTERNAL/EXTERNAL
2	BAT-A F/T	BAT-A FULL/TRICKLE
3	BAT-A TRKL ENA/DIS	BAT-A TRICKLE ENABLE/DISABLE
4	BAT-A TAPR L1/L2	BAT-A TAPR LEVEL1/LEVEL2
5	BAT-A RCN ON/OFF	BAT-A RECONDITIONING ON/OFF
6	BAT-A UVC ENA/DIS	BAT-A UVC ENABLE/DISABLE
7	BAT-A UVC LEVEL	BAT-A UVC LEVEL
8	BAT-A K1 SET ENA/DIS	BAT-A K1 SET ENABLE/DISABLE
9	BAT-A K2 SET ENA/DIS	BAT-A K2 SET ENABLE/DISABLE
10	BAT-A C/D SET ENA/DIS	BAT-A C/D SET ENABLE/DISABLE
11	BAT-A K1 DATA	BAT-A K1 DATA
12	BAT-A K2 DATA	BAT-A K2 DATA
13	BAT-A C/D COUNT DATA	BAT-A C/D COUNTER DATA
14	BAT-B INT/EXT	BAT-B INTERNAL/EXTERNAL
15	BAT-B F/T	BAT-B FULL/TRICKLE
16	BAT-B TRKL ENA/DIS	BAT-B TRICKLE ENABLE/DISABLE
17	BAT-B TAPR L1/L2	BAT-B TAPR LEVEL1/LEVEL2
18	BAT-B RCN ON/OFF	BAT-B RECONDITIONING ON/OFF
19	BAT-B UVC ENA/DIS	BAT-B UVC ENABLE/DISABLE
20	BAT-B UVC LEVEL	BAT-B UVC LEVEL
21	BAT-B K1 SET ENA/DIS	BAT-B K1 SET ENABLE/DISABLE
22	BAT-B K2 SET ENA/DIS	BAT-B K2 SET ENABLE/DISABLE
23	BAT-B C/D SET ENA/DIS	BAT-B C/D SET ENABLE/DISABLE
24	BAT-B K1 DATA	BAT-B K1 DATA
25	BAT-B K2 DATA	BAT-B K2 DATA
26	BAT-B C/D COUNT DATA	BAT-B C/D COUNTER DATA
27	PSU1 ON/OFF	PSU1 POWER ON/OFF
28	PSU2 ON/OFF	PSU2 POWER ON/OFF

Table 6. 7-2 EPS Telemetry List (2/2)

NO	TELEMETRY ITEM	FUNCTION
29	PSU3 ON/OFF	PSU3 POWER ON/OFF
30	PSU4 ON/OFF	PSU4 POWER ON/OFF
31	PSU5 ON/OFF	PSU5 POWER ON/OFF
32	PSU6 ON/OFF	PSU6 POWER ON/OFF
33	PSU7 ON/OFF	PSU7 POWER ON/OFF
34	PSU8 ON/OFF	PSU8 POWER ON/OFF
35	PSU9 ON/OFF	PSU9 POWER ON/OFF
36	PSU10 ON/OFF	PSU10 POWER ON/OFF
37	PSU11 ON/OFF	PSU11 POWER ON/OFF
38	PSU12 ON/OFF	PSU12 POWER ON/OFF
39	PSU13 ON/OFF	PSU13 POWER ON/OFF

7. Structure

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7.1 Overview

The design of PLANET-B structure provides a light weight structure consistent with high reliability for the critical environments and loading conditions. The structure also provides an adequate mounting surface for all equipments and thermal control surfaces to regulate temperatures.

The PLANET-B structural configuration meets installation requirements of all components such as the High Gain Antenna (HGA), the RCS tanks, the extensible mast, the wire antennas, and other subsystems during all phase of the mission.

7.2 Spacecraft Configuration

The PLANET-B configuration is shown in Figure 7-1. The spacecraft structure consists of upper panel, 8 side panels, base panel and 16 struts. The HGA is mounted on the upper panel. The four RCS tanks are supported by base panel and 16 struts. Two solar array paddles are installed on outside of the side panels.

The length from the top of Low Gain Antenna (LGA-A) to spacecraft separation plane is 1945mm, and the length from spacecraft separation plane to nozzle end of 500N thruster is 463mm. Overall spacecraft height is 2408mm. Overall size and envelope are compatible with the M-V rocket interface.

The spacecraft component locations are shown in Figure 7-2.

7.3 Primary Structure

The PLANET-B primary structure is shown in Figure 7-3. The primary structure consists of upper panel, base panel, 8 side panels and truss construction assembled by 16 struts.

7.3.1 Upper Panel

The upper panel provides the mounting surface of HGA, Nutation Damper (ND), Two Dimensional Sun Aspect Sensor (TSAS) and solar array paddle hinges. The upper panel is installed to each top of side panels. This panel is a composite structure of a aluminum honeycomb core bonded to CFRP facesheet.

7.3.2 Side Panel

Eight side panels provide the primary attachment and radiation surfaces for the components. The side panels are composite structures of a aluminum honeycomb core bonded to aluminum or CFRP facesheets. The side panel #3 and #7 have aluminum facesheets, and the others have CFRP facesheets. The side panels support the upper panel and are installed to a base panel and other side panels. Threaded inserts are mounted into the side panels to install the components

7.3.3 Base Panel

The base panel provides the mounting surface of RCS such as four fuel tank modules, two thruster modules, three valve modules and pipes that these components are connected to each other by and several components. The base panel is a composite structure of a aluminum honeycomb core bonded to CFRP facesheets. Threaded inserts are mounted into the base panel to install the components. This panel is supported by the truss construction assembled by 16 struts.

7.3.4 Truss Construction

Truss construction consists of 16 struts which are CFRP cylindrical tube and the end fittings. These 16 struts are grouped into sets of four struts each. The struts in each set supports the base panel at four points around each fuel tank, and they join together at the M-V rocket interface. Then, the spacecraft is supported at four points on the interface. The truss construction provides the direct load path between the base panel and the M-V rocket interface points.

7.4 Mechanical Integration Parts

7.4.1 Overview

Mechanical integration parts include the mounting brackets of instruments, fasteners and the balance weights.

7.4.2 Components

(1) The mounting brackets and fasteners

The mounting brackets are used to install the instruments at the required position or direction. Fasteners are using for mounting all components on spacecraft structure. The instrument SSC, SSAS, LGA-B and ACM needs the mounting brackets.

(2) The balance weights

The balance weights which are made of brass or tungsten plate are installed on the spacecraft structure to adjust the spacecraft mass balance.

7.5 Structural Analysis

PLANET-B structural analyses are planned to perform the items shown below.

7.5.1 Dynamic Analysis

A dynamic analysis is performed to analyze elastic vibration modes, their frequencies and structural load, to confirm that the dynamic characteristics of spacecraft meet the M-V rocket interface requirement, and to establish mechanical environmental conditions of all components. A finite element model of the spacecraft is constructed by using the NASTRAN computer program.

7.5.2 Stress Analysis

A stress analysis is performed to analyze the force distribution in spacecraft structure and the load balance for each structural elements, and to confirm that the each elements have strength fully for the load. These analyses are performed by using the NASTRAN computer program with the same model as that for dynamic analysis.

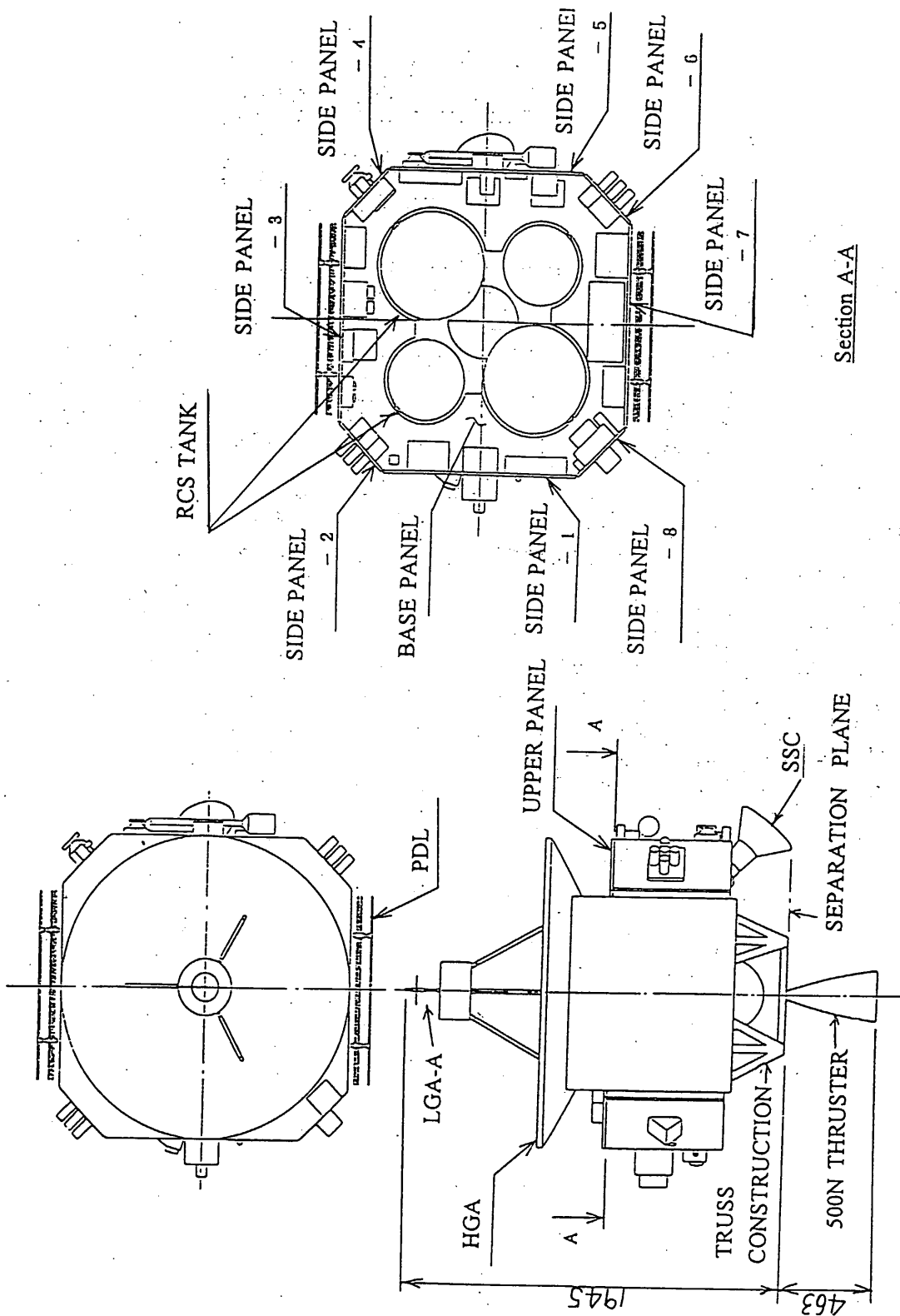


Figure 7-1 PLANET-B Configuration

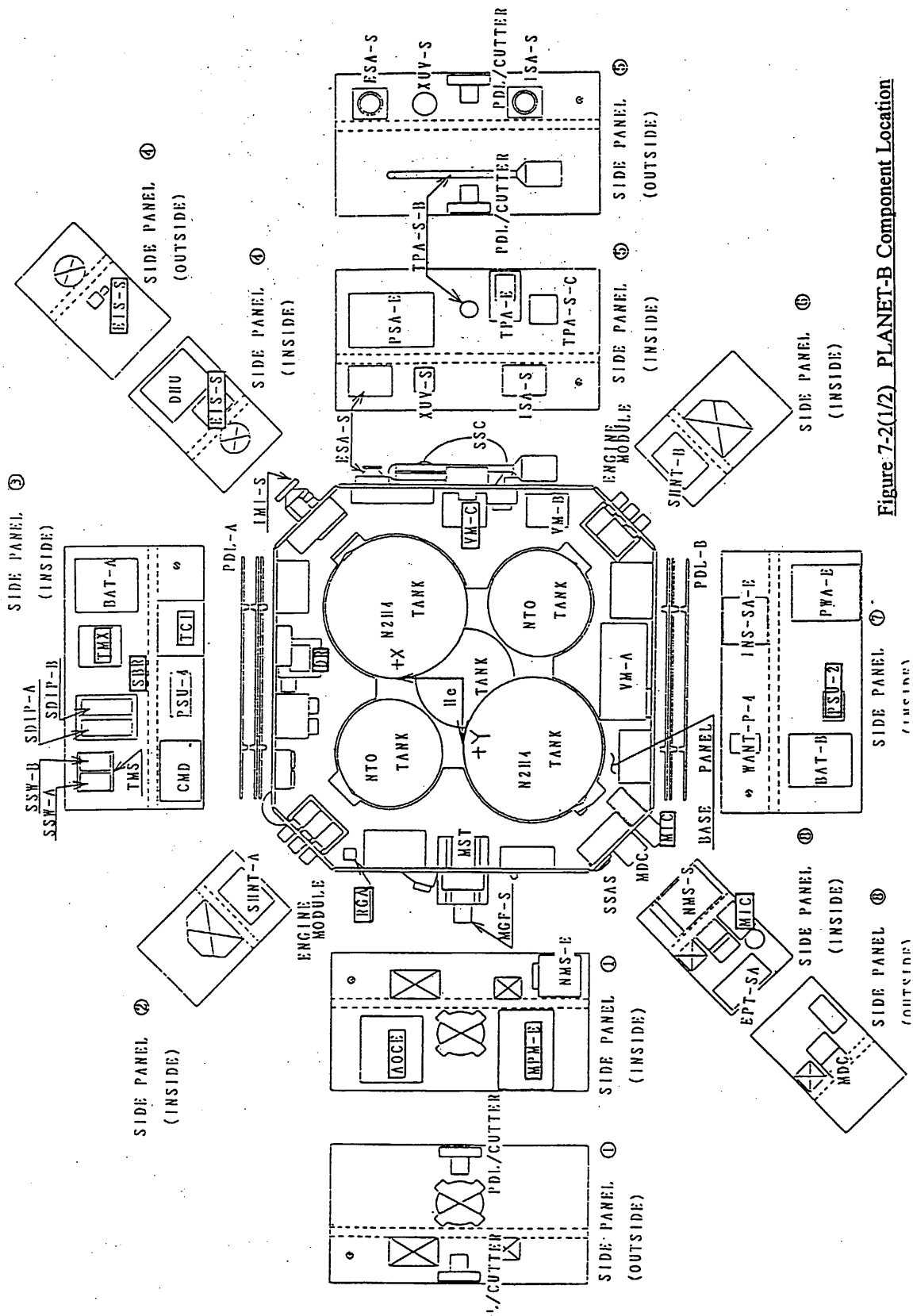


Figure 7-2(1/2) PLANET-B Component Location

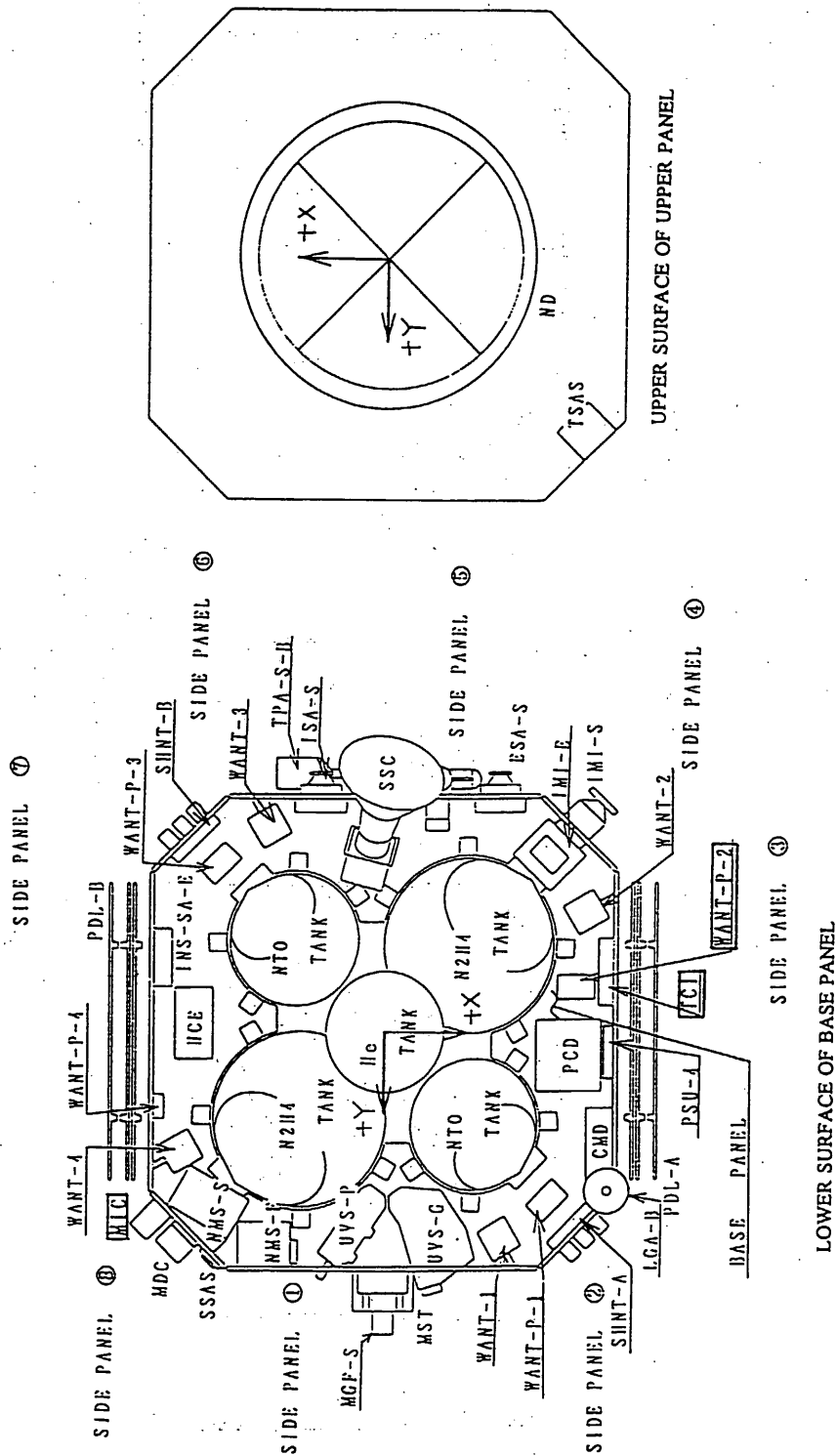


Figure 7-2(2/2) PLANET-B Component Location

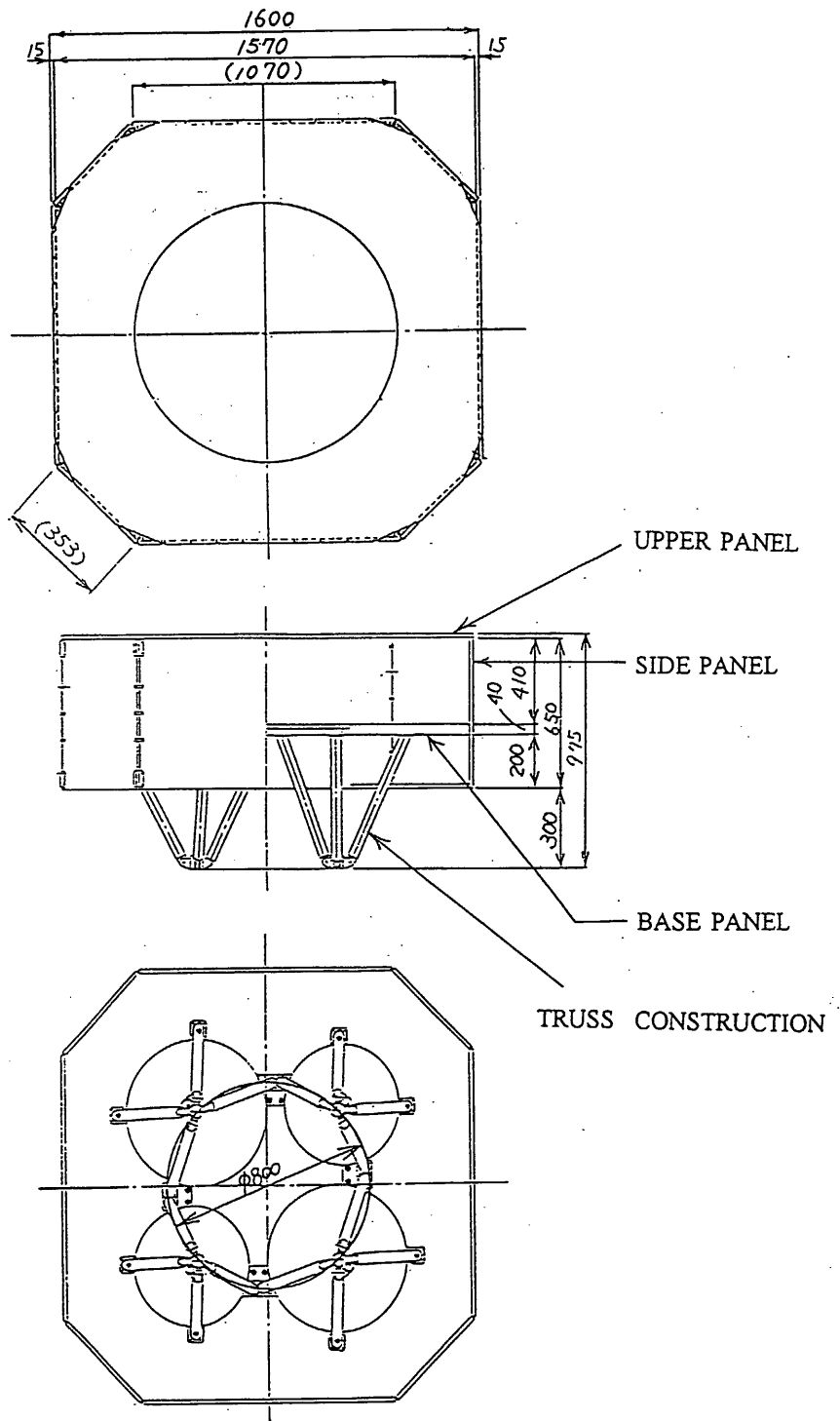


Figure 7-3 PLANET-B Primary Structure

8. Thermal Design and Control

Y.Kobayashi and A.Ohnishi (ISAS)

NEC Corporation

8.1 Overview

This section describes thermal design of the PLANET-B. The Thermal Control Subsystem (TCS) is required to maintain the onboard equipment and the main structure in proper temperature range during their entire mission life. Detailed thermal design of components is described individually in the each subsystem section.

8.2 Design Requirements

The thermal design requirements and thermal data are shown in Table 8-1.

8.3 Thermal Design

The PLANET-B thermal control is using combined method of passive and active thermal control. The thermal control design of the PLANET-B is shown in Figure 8-1.

The passive control methods are silver deposited Poly Ether Imide(PEI) film radiator, and multilayer insulation blanket(MLI). External surface of PEI and MLI have conductive coating.

The active control methods are automatically controlled heaters and manual control heaters.

Table 8-1 Thermal Design Requirements and System Design Parameters(1/2)

ITEMS	REQUIREMENTS AND PARAMETERS
Launch Condition	•Launch Window ; Summer in 1998 •Launch Vehicle ; M-V Rocket 3rd Flight
Mission Life	•Total 3.2 Years. ——— (1) Parking Phase ; 4 months (2) Crusing Phase ; 10 months (3) Planet Mars Phase ; 2 years
Orbit(*1)	(1)Parking Phase •After 1st Swing-by ; $7,000\text{km(Hp)} \times 400,000\text{km(Ha)}$ •Before 2nd Swing-by ; $7,000\text{km(Hp)} \times 1,500,000\text{km(Ha)}$ •Duration of Eclipse ; 19 min. (Max.) (2)Crusing Phase •Solar Pointing (about 40 days) ---> Earth Pointing •Without Eclipse (3)Planet Mars Phase •$150\text{km(Hp)} \times 15\text{Rm(Ha)}$ ($\text{Rm}=3547\text{km}$) •Max. Eclipse Period ; 65 min.
Attitude Control	•Spin Rate ; 7.5rpm •Sun angle (respect to Spin Axis) (1)Parking Phase ; 0 to 56deg. (2)Crusing Phase ; 0 to 10deg. (3)Planet Mars Phase ; 0 to 45deg.
Spacecraft shape and Dimension	•Main Structure ($W \times D \times H$) ; $1.6\text{m} \times 1.6\text{m} \times 0.6\text{m}$ •Paddle Tip to Tip Length ; 6.22m (2 wings style) •High Gain Antenna(HGA) Size ; $\phi 1.6\text{m}$
Spacecraft Weight	•WET ; 536kg •DRY ; 258kg
Internal heat dissipation (Preliminary)	•Min ; 74W(STAND-BY mode) (in Mars orbit) •Max ; 207W(REAL mode) (in Mars orbit)

note

(*1) Hp = Perigee , Ha = Apogee

Table 8-1 Thermal Design Requirements and System Design Parameters (2/2)

ITEMS	REQUIREMENTS AND PARAMETERS
Component Temperature Ranges Operating within specification	•ESA-S, EIS-S, XUV-S ; -30 to 30 °C •PWA-E, PET-S ; -20 to 50 °C •MGF-S ; -50 to 50 °C •UVS-G, -P ; -30 to 30 °C •MIC ; -25 to 40 °C •IMI-E ; -15 to 50 °C •IMI-S ; -15 to 20 °C •BAT ; 0 to 25 °C •SSC ; -30 to 20 °C •HCE ; -20 to 50 °C •CI and SI components except for the above components allow -30 to 50 °C.
Surface Conductivity	All external surface is required electrical conductivity to system ground. (Surface resistivity < 1GΩ/cm²)

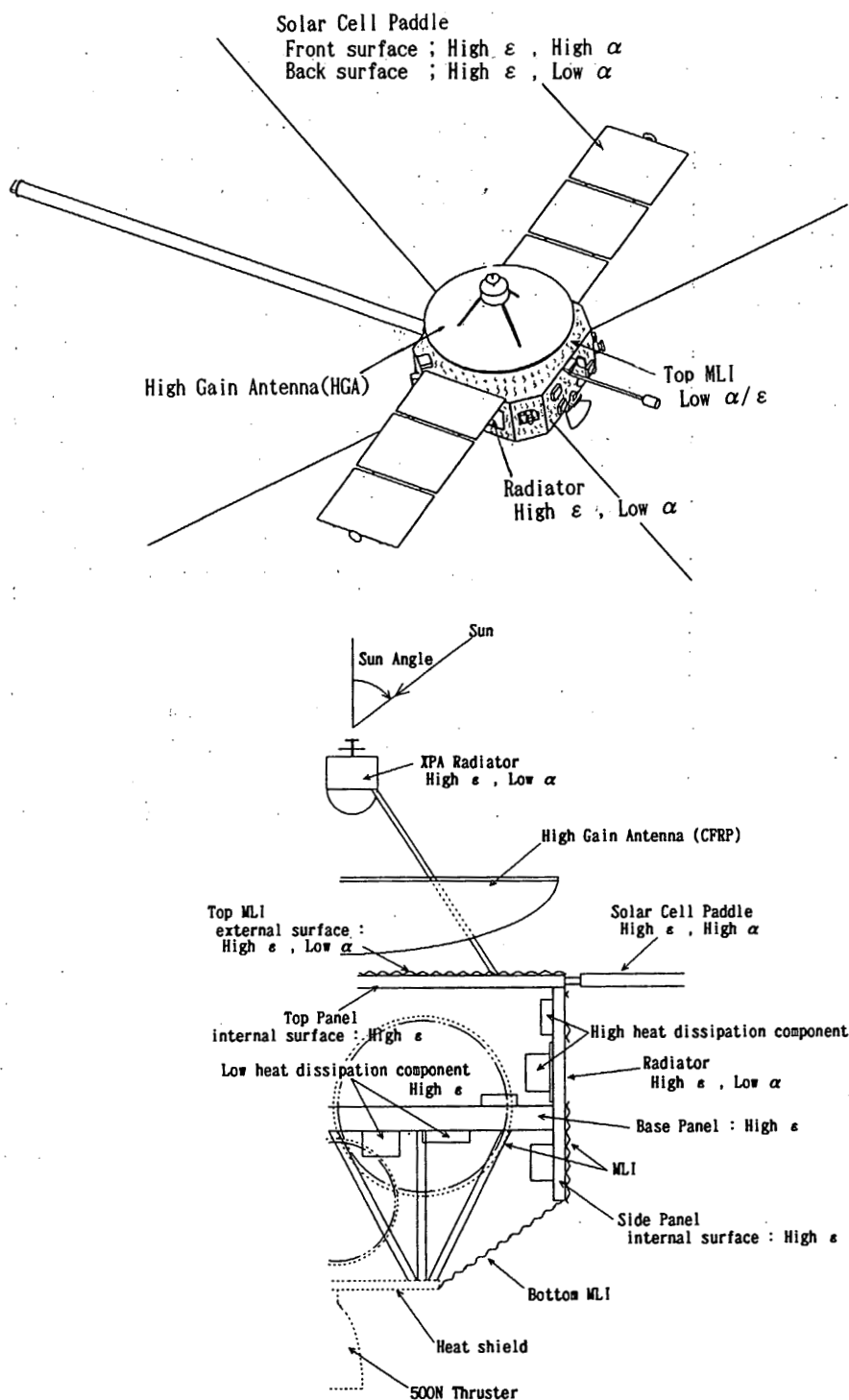


Figure 8-1 Thermal Design of the PLANET-B

8.3.1 Thermal Design of the Spacecraft Structure

Taking into consideration of the requirement in Table 8-1, the basic thermal design concept is as follows.

- Top, side and base panel internal surface have high emissivity to equalize internal temperature.
- The external surface of spacecraft is covered with MLI for isolation from external thermal environment.
- The external surface of top MLI have low α/ϵ to reduce external heat input to inside of spacecraft.
- The 500N thruster is located as far as possible from the main structure, it is isolated from main structure with a heat shield to avoid radiation from the 500N thruster.
- Basically, CI and SI components are located separately to reduce heater power of the spacecraft, because they have different thermal characteristics as shown below.
 - (1) CI components have stable heat dissipation. On the other hand, SI components have large variation of heat dissipation between ON and OFF.
 - (2) Operating temperature ranges of CI and SI components are different.

8.3.2 Thermal Design of Components

- The external surface of components have high emissivity finish to equalize spacecraft internal temperature.
- Basically, SI sensors have survival heaters controlled by themselves independent from TCS HCE.
- SI and CI sensors, which have opening to space, are isolated from the spacecraft with MLI and thermal stand off, in order to reduce their effect on other components when they are cold.
- BATs, SSC, MIC and RCS components have heaters controlled by TCS HCE, because they have to be kept in relatively narrower temperature range than other components.

- BATs are independently controlled with the aid of radiators, heaters and MLI as show in Figure 8-2. BAT mounting area is surrounded by low thermal conductor material for isolation.

- XPA are equipped with survival heater for off period since it is attached to the feed horn of HGA and exposed to space.

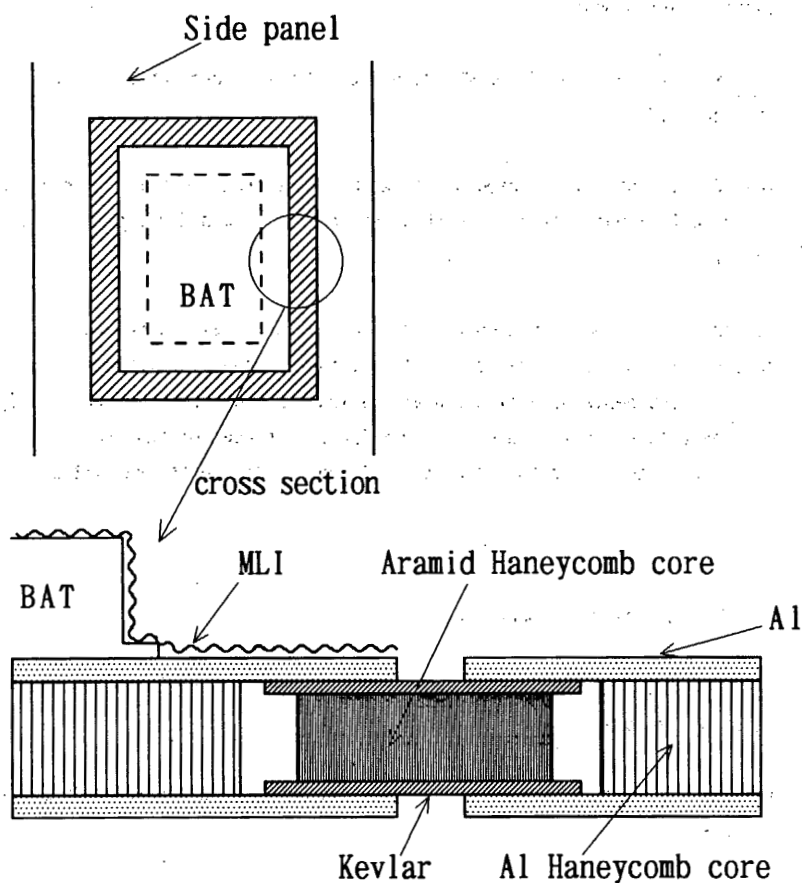


Figure 8-2 BAT thermal control method

8.3.3 Summary of Heaters

Summary of heaters is shown in Table 8-2. All of the thermal control heaters are automatically controlled by HCE except for some RCS/OMS heaters. They are also able to be turned ON/OFF by ground commands regardless of their temperature.

Table 8-2 Heater summary (Preliminary)

Component		Number of Heater CH	Activation Technique	Set Point (°C)	Heater Power (W)
BAT-A		2	Automatically controlled by HCE	TBD	TBD
BAT-B		2			
SSC		1			
XPA		1			
MIC		1			
SI Replacement Heater		4			
O M S / R C S	NTO Tank	2			
	N ₂ H ₄ Tank	2			
	GHe Tank	2	Manual control		
	Pipe	5	Automatically controlled by HCE		
	Valve Module	3			
	Engine Module	4			
	Thruster Bed	4	Manual control		
	OME injector	2			
Total		35			

8.4 Thermal analysis

The thermal mathematical model for preliminary thermal analysis has about 70 nodes. In this model, a side panel and components on it are reduced into one node. Conditions of HOT case and COLD case in this analysis is assumed as shown in Table 8-3. The preliminary computational result is shown in Table 8-4. The current analysis shows that the HOT case is not in the Earth orbit but in the Mars orbit.

Detailed thermal analysis is still underway. The thermal mathematical model for the detailed thermal analysis would have about 500 nodes including RCS.

Table 8-3 Conditions of HOT case and COLD case in the thermal preliminary analysis

Items	HOT case	COLD case
Orbit	Mars orbit	
Operational status	SIs are all ON	SIs are all STABD-BY
Solar constant(W/cm ²)	0.071	0.049
Sun incident angle(deg.)	45	0
Duration of eclipse (minutes)	0	65
Thermo-optical properties	max. absorptivity and min. emissivity.	min. absorptivity and max. emissivity.

Table 8-4 Preliminary temperature prediction of major structure

Structure	Temperature prediction result (°C) (*2)			
	HOT case		COLD case	
	Max. (*1)	Min. (*1)	Max. (*1)	Min. (*1)
HGA (Reflector)	29	26	17	-180.
Top panel	25	20	-15	-19
Side panel #1	26	22	-21	-22
Side panel #2	31	25	-13	-22
Side panel #3	32	20	-13	-15
Side panel #4	34	29	-5	-6
Side panel #5	20	15	-25	-26
Side panel #6	30	25	-14	-23
Side panel #7	28	24	-19	-20
Side panel #8	28	23	-13	-18
Base panel	29	24	-12	-14

note

(*1) Max. and Min. means time variation in a orbit.

(*2) All temperatures are averaged value over the panel.

8. 5 Heater Control Electronics (HCE)

8. 5. 1 Overview

The P L A N E T - B's Heater Control Electronics(HCE) controls heaters attached to RCS, BAT, SSC, OMS and XPA. HCE includes all functions of previous HK. HCE measures all temperature sensors and monitors temperature data all over the satellite.

HCE processes temperature sensor data attached to RCS, BAT, SSC, OMS and XPA by A/D converter. The measured temperature data for heater control is compared with target temperature data and HCE switches ON or OFF the power supply to heater.

Target temperature data can be changed by command in any time.

The measured temperature data, target temperature data and ON/OFF status of heaters etc. are supplied to DHU through PIM.

8. 5. 2 Functions

(1) BLOCK DIAGRAM

HCE functional block diagram is shown in Fig.8.5-1. HCE controls 38 points of temperatures for RCS, BAT, SSC, OMS and XPA, and deals with commands and heater status.

(1-1) MUX BLOCK

This block controls the sensor current in time division for 69 channel temperature sensors, obtains the differential voltage between the sensor and sends to A/D CONVERTER BLOCK.

(1-2) A/D CONVERTER BLOCK

This block processes by 12-bit resolution A/D converter and forms 8-bit digital data from analog data acquired in MUX BLOCK.

(1-3) MEMORY BLOCK

This block records all measured temperature data and target temperature data. The measured temperature data is recorded by a fixed cycle in static RAMs and periodically transmitted to the ground base as telemetry.

As target temperature data is recorded in non-volatile EEPROMs, it keeps target temperature data when the power supply of HCE is off. Target temperature data can be changed by block command in orbit.

(1-4) COMPARATOR BLOCK

This block compares the measured temperature data with target temperature data for 38 channel heaters recorded in MEMORY BLOCK.

(1-5) HEATER DRIVER BLOCK

This block switches ON and OFF the heaters as a result of COMPARATOR BLOCK. At the same time, it generates heater ON/OFF status for 38 channel heaters and HCE sends those data to DHU through PIM as telemetry.

(1-6) TIMING CONTROL BLOCK

This block decodes commands from DHU, formats telemetry data and generates every timing signal.

(2) MANUAL CONTROL

Every heater can be controlled by "ON/OFF" manual commands independent with automatic control commands. When HCE receives "ON/OFF" manual command, HCE forcibly cancels automatic control of the heater channel corresponded to the command and shifts to the manual control mode.

(3) AUTOMATIC CONTROL

Every heater can be controlled by "ON/OFF" auto commands. HCE measures every temperature sensor in a fixed cycle, especially the measured temperature data for heater control is compared with target temperature data and 38 channel heaters can be controlled in time division.

When the temperature exceeds the limit of measure range, the heater channel forcibly cancels automatic control by a function detecting sensor error and shifts to the manual control mode.

Target temperature data can be changed by block command and "in orbit temperature adjustment" is available.

The control characteristics of Sensor/Heater channel are shown in Table 8.5-1.

8. 5. 3 Shape and Size

WEIGHT : 3.3 Kg $\pm$ 0.5 Kg
SIZE : 240 mm(D) $\times$ 98 mm(W) $\times$ 210 mm(H)
SHAPE : see Fig. 8.5-2

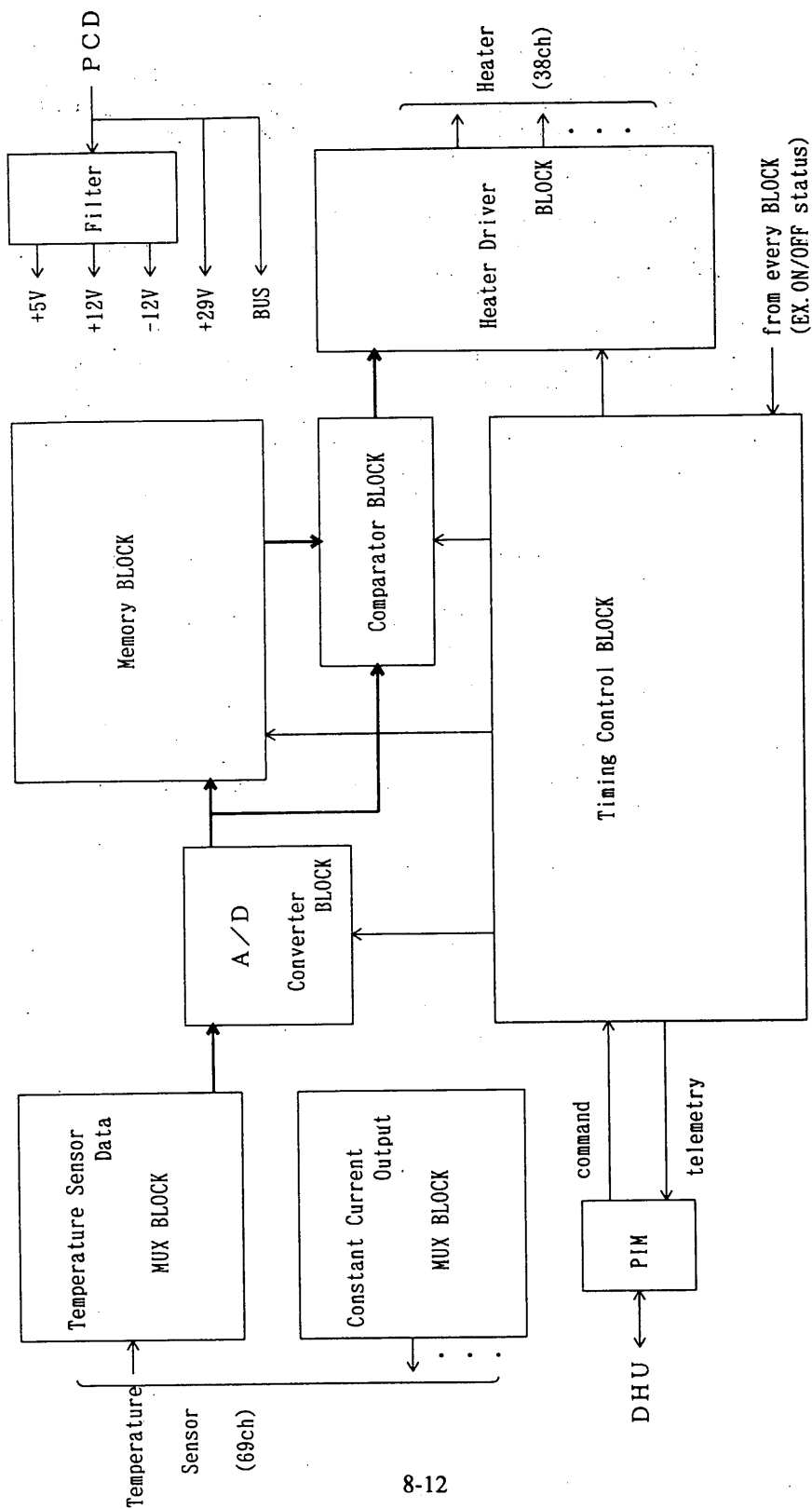


Fig. 8.5-1 HCE BLOCK DIAGRAM

Table 8.5-1 SENSOR/HEATER CONTROL CHARACTERISTICS(1/4)

No	SENSOR/ HEATER NAME	SETTING TEMPERATURE	AU TO	MA NU	POWER SOURCE	HEATER RESISTANCE	HEATER POWER	
							+29V	BUS
1	BPNL1-T	T. B. D.						
2	BPNL2-T	T. B. D.						
3	BPNL3-T	T. B. D.						
4	BPNL4-T	T. B. D.						
5	UPNL1-T	T. B. D.						
6	UPNL2-T	T. B. D.						
7	LSHLD1-T	T. B. D.						
8	LSHLD2-T	T. B. D.						
9	PDL1-T	T. B. D.						
10	PDL2-T	T. B. D.						
11	BATA1-T	T. B. D.	○	○	T. B. D.	T. B. D.	T. B. D.	T. B. D.
12	BATA2-T	T. B. D.	○	○	T. B. D.	T. B. D.	T. B. D.	T. B. D.
13	BATB1-T	T. B. D.	○	○	T. B. D.	T. B. D.	T. B. D.	T. B. D.
14	BATB2-T	T. B. D.	○	○	T. B. D.	T. B. D.	T. B. D.	T. B. D.
15	SHNT-T	T. B. D.						
16	SSCBLK-T	T. B. D.						
17	SSC-T	T. B. D.	○	○	T. B. D.	T. B. D.	T. B. D.	T. B. D.
18	SSAS-T	T. B. D.						
19	TSAS-T	T. B. D.						
20	HTNK1-T	T. B. D.	○	○	T. B. D.	T. B. D.	T. B. D.	T. B. D.

Table 8.5-1 SENSOR/HEATER CONTROL CHARACTERISTICS(2/4)

No	HEATER NAME	SETTING TEMPERATURE	AU TO	MA NU	POWER SOURCE	HEATER RESISTANCE	HEATER POWER	
							+29V	BUS
21	HTNK2-T	T. B. D.	○	○	T. B. D.	T. B. D.	T. B. D.	T. B. D.
22	NTNK1-T	T. B. D.	○	○	T. B. D.	T. B. D.	T. B. D.	T. B. D.
23	NTNK2-T	T. B. D.	○	○	T. B. D.	T. B. D.	T. B. D.	T. B. D.
24	GTNK1-T	T. B. D.	○	○	T. B. D.	T. B. D.	T. B. D.	T. B. D.
25	GTNK2-T	T. B. D.	○	○	T. B. D.	T. B. D.	T. B. D.	T. B. D.
26	RCSPP1-T	T. B. D.	○	○	T. B. D.	T. B. D.	T. B. D.	T. B. D.
27	RCSPP2-T	T. B. D.	○	○	T. B. D.	T. B. D.	T. B. D.	T. B. D.
28	RCSPP3-T	T. B. D.	○	○	T. B. D.	T. B. D.	T. B. D.	T. B. D.
29	RCSPP4-T	T. B. D.	○	○	T. B. D.	T. B. D.	T. B. D.	T. B. D.
30	RCSPP5-T	T. B. D.	○	○	T. B. D.	T. B. D.	T. B. D.	T. B. D.
31	OMSPP1-T	T. B. D.	○	○	T. B. D.	T. B. D.	T. B. D.	T. B. D.
32	OMSPP2-T	T. B. D.	○	○	T. B. D.	T. B. D.	T. B. D.	T. B. D.
33	VLVMA-T	T. B. D.	○	○	T. B. D.	T. B. D.	T. B. D.	T. B. D.
34	VLVMB-T	T. B. D.	○	○	T. B. D.	T. B. D.	T. B. D.	T. B. D.
35	VLVMC-T	T. B. D.	○	○	T. B. D.	T. B. D.	T. B. D.	T. B. D.
36	OME1-T	T. B. D.	○	○	T. B. D.	T. B. D.	T. B. D.	T. B. D.
37	OME2-T	T. B. D.	○	○	T. B. D.	T. B. D.	T. B. D.	T. B. D.
38	EMA1-T	T. B. D.	○	○	T. B. D.	T. B. D.	T. B. D.	T. B. D.
39	EMA2-T	T. B. D.	○	○	T. B. D.	T. B. D.	T. B. D.	T. B. D.
40	EMB1-T	T. B. D.	○	○	T. B. D.	T. B. D.	T. B. D.	T. B. D.

Table 8.5-1 SENSOR/HEATER CONTROL CHARACTERISTICS(3/4)

No	HEATER NAME	SETTING TEMPERATURE	AU TO	MA NU	POWER SOURCE	HEATER RESISTANCE	HEATER POWER	
							+29V	BUS
41	EMB2-T	T. B. D.	○	○	T. B. D.	T. B. D.	T. B. D.	T. B. D.
42	THRA1-T	—		○	T. B. D.	T. B. D.	T. B. D.	T. B. D.
43	THRA2-T	—		○	T. B. D.	T. B. D.	T. B. D.	T. B. D.
44	THRA3-T	—		○	T. B. D.	T. B. D.	T. B. D.	T. B. D.
45	THRA4-T	—		○	T. B. D.	T. B. D.	T. B. D.	T. B. D.
46	THRT1-T	—		○	T. B. D.	T. B. D.	T. B. D.	T. B. D.
47	THRT2-T	—		○	T. B. D.	T. B. D.	T. B. D.	T. B. D.
48	THRT3-T	—		○	T. B. D.	T. B. D.	T. B. D.	T. B. D.
49	THRT4-T	—		○	T. B. D.	T. B. D.	T. B. D.	T. B. D.
50	THRR1-T	—		○	T. B. D.	T. B. D.	T. B. D.	T. B. D.
51	THRR2-T	—		○	T. B. D.	T. B. D.	T. B. D.	T. B. D.
52	XPA-T	T. B. D.	○	○	T. B. D.	T. B. D.	T. B. D.	T. B. D.
53	HTNKSET	T. B. D.						
54	NTNKSET	T. B. D.						
55	GTNKSET	T. B. D.						
56	PPSET	T. B. D.						
57	VLVSET	T. B. D.						
58	OMESET	T. B. D.						
59	BATASET	T. B. D.						
60	BATBSET	T. B. D.						

Table 8.5-1 SENSOR/HEATER CONTROL CHARACTEISTICS(4/4)

No	HEATER NAME	SETTING TEMPERATURE	AU TO	MA NU	POWER SOURCE	HEATER RESISTANCE	HEATER POWER	
							+29V	BUS
61	SSCSET	T. B. D.						
62	XPASET	T. B. D.						
63	HTNK-P	T. B. D.						
64	NTNK-P	T. B. D.						
65	GTNK-P	T. B. D.						
66	RCSLN1-P	T. B. D.						
67	RCSLN2-P	T. B. D.						
68	OMSLN1-P	T. B. D.						
69	OMSLN2-P	T. B. D.						

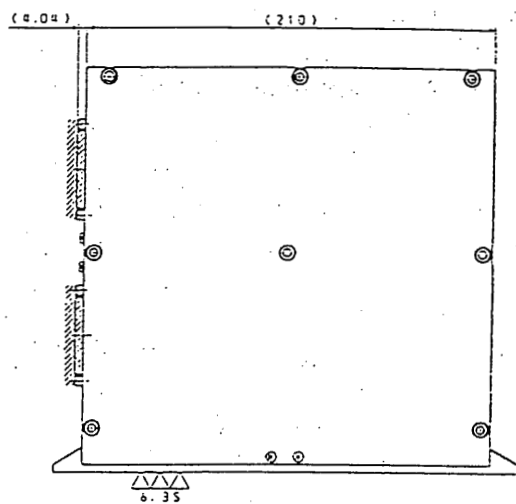
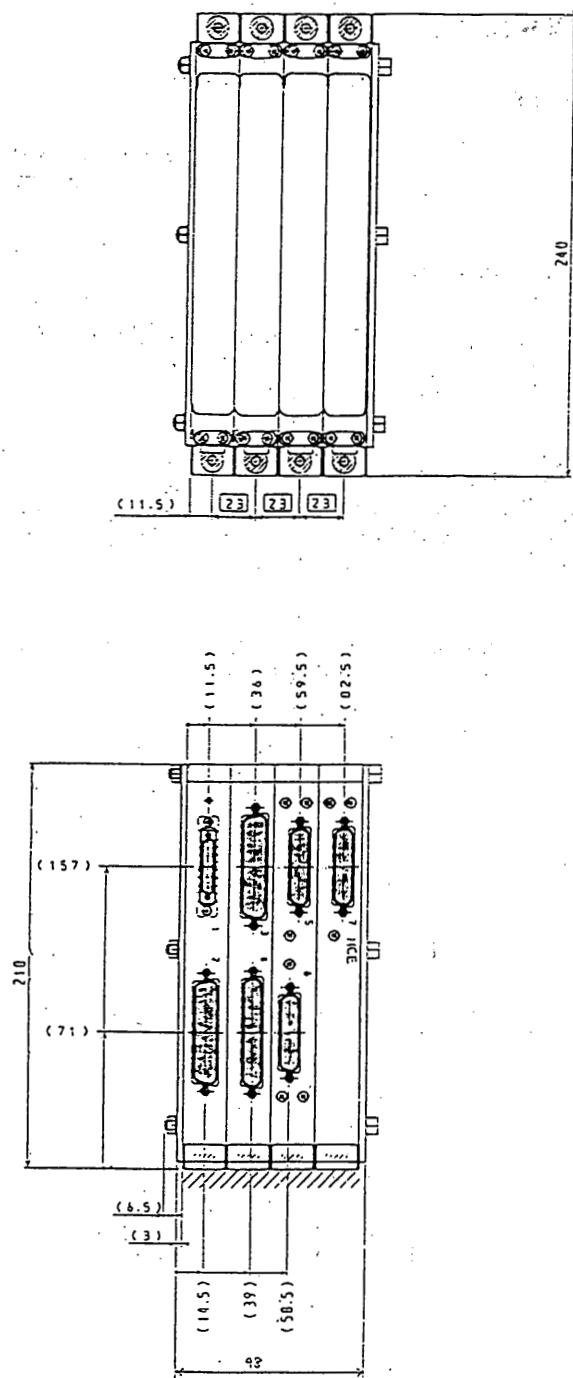


Fig. 8.5-2 HCE SHAPE

9. Other Onboard System

9.1 Launch Operation Subsystem

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Matsushita

9.1.1 Overview

The launch operation subsystem consists of:

- Electrical Programmable Timer - Satellite (EPT-SA)
- Instrument - Satellite (INS-SA)

EPT-SA controls to ignite pyro devices in accordance with the planned time sequence. INS-SA measures the environmental conditions during launch and send the telemetry to the ground through the launch vehicle and spacecraft.

9.1.2 Electrical Programmable Timer - Satellite (EPT-SA)

The EPT-SA carries out signal/command generation to igniter for 5 items; PLD-Deploy, KM-Deploy, KM-Dep-Mech-Separate, KM-Fire, and KM-Separate. See Figure 9.1-1 for details.

9.1.3 Instrument - Satellite (INS-SA)

The INS-SA measures launch environment of Kick-Motor and Spacecraft for 7 items; Axial-Acceleration, KM-Pressure, Lateral-Acceleration (Y and Z), and Vibration (V6, V7, and V8). See Figure 9.1-1 for details.

9.1.4 Command and Telemetry Items

T.B.S.

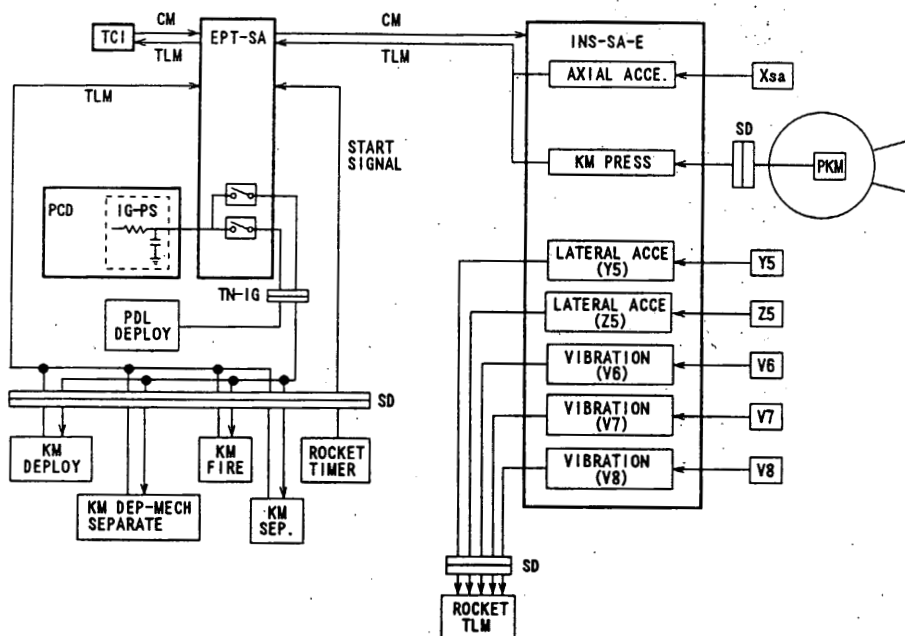


Figure 9.1-1 Launch Operation Subsystem Block Diagram

9.2 Wire Harness

I.Nakatani (ISAS)

NEC Corporation

9.2.1 Overview

PLANET-B wire harness is required to accomplish the high EMI protection and light weight. The data handling system uses a bus-line configuration as data lines between DHU and PIMs, and the power control system adopts the distributed power conversion method. One of purposes for these configuration is the harness weight reduction. And interface connectors between the harness and components are MDM type connectors, which are smaller and lighter than D-sub type.

9.2.2 Components

All wire harness are falled into the four categories as follows.

- 1) PIM line (twisted pair shield cables+MDM connectors)
- 2) Power lines (twisted pair shield cables+MDM or D-sub connectors)
- 3) RF lines (Semi rigid or flexible co-axial cable+co-axial connectors)
- 4) Subsystem lines

9.2.3 EMI Protection

PLANET-B digital data interface is basically a differential configuration and the twisted pair shield cables are used for the interface. All the primary power lines are pairs of hot and return lines and the twisted pair shield cables are used for each pair, respectively.

9.2.4 Mass Properties and Configuration

Total weight	7.0 kg
Mass Properties	TBD

9.3 Nitrogen Purge System

T. Yamamoto (ISAS)
NEC Corporation

The nitrogen purge is used to protect performance degradation of some components by dust, moisture, oxidation and so on. The nitrogen purge shall be carried out through;

- (a) integration and tests at ISAS,
- (b) Transportation from ISAS to KSC, and
- (c) Launch site operation at KSC.

Figure 9.3-1 shows the configuration of nitrogen purge using gas umbilical connectors. Table 9.3-1 shows the flow rate of nitrogen purge and Figure 9.3-2 shows piping layout of the nitrogen purge equipment.

9.3.1 Nitrogen Purge During the Integration and Test at ISAS

Table 9.3-2 shows the details of purge in PLANET-B FM integration and tests at ISAS. Nitrogen purge shall be carried out during all integration and tests except for the Thermal Vacuum Test. In several tests, gas umbilical connectors may be removed only when the tests are going on; *e.g.*, Spin Test, Mass Properties Measurements and some environmental tests. During the Shock and Vibration Tests, Dynamic Balance Adjustment and for storage of the spacecraft in the mechanical environmental test room at ISAS, a clean booth purged by dry air shall be used.

9.3.2 Nitrogen Purge During the Transportation

The spacecraft is transported from ISAS to KSC in the spacecraft container that is filled with nitrogen gas instead of the air at the start of the transportation.

9.3.3 Nitrogen Purge During the Launch Site Operation at KSC

T.B.D.

Figure 9.3-1 Nitrogen Purge Configuration in the System Test. T.B.S.

Figure 9.3-2 PLANET-B GN₂ Purge Piping Layout. T.B.S.

Table 9.3-1 Flow Rate of Nitrogen Purge in the System Test. T.B.S.

10. Orbit Design

Group of Orbit Design in ISAS and NEC

10.1 Overview

10.1.1 Special Acronyms

RCS	: Reaction Control System using Hydrazine Propellant (Isp of 180 sec)
OMS	: Bi-propellant Orbit Maneuver System using N_2H_4 and NTO (Isp of 310 sec)
LEO	: Low Earth Parking Orbit
M50-EC	: Ecliptic Coordinate fixed in 1950
Areo-EQ	: Equatorial Coordinate of Mars

10.1.2 Orbit Design Policy

Orbits from Earth launch to Mars arrival for the PLANET-B mission utilize lunar and earth gravity assists before the interplanetary transfer to Mars, so as to reduce the orbital energy required in the injection from LEO and to enlarge the net mass of the spacecraft. After the kick injection from a low earth parking orbit, the spacecraft remains in the earth-moon gravity field for several months. During this earth orbiting period, the spacecraft takes twice gravity advantage by the close encounter with the moon to increase the orbital energy. At the final perigee passage, velocity increment (ΔV) by the bi-propellant Orbit Maneuver System (OMS) inserts the spacecraft into a Mars transfer orbit.

Although to utilize lunar gravity assists increase the payload capability to the Mars transfer orbit, it strongly restricts the launch opportunity and complicates the sequence of the orbit operation. To expand the launch opportunity is a subject given the highest priority in the orbital design.

In the following sections, outline of the candidate PLANET-B orbits is described, and requirements from the launch vehicle, M-V-3, are also summarized later.

10.2 Summary of Orbital Events

The PLANET-B orbits consists of three orbital phases; 1) launch and earth orbiting phase, 2) Mars transfer phase, and 3) Mars orbiter and scientific observation phase. Typical time sequence of the orbital events is summarized here.

10.2.1 Launch and Earth Orbiting Phase

The launch and earth orbiting phase requires the most complicated orbital operations, which include 1) launch and injection into a low earth parking orbit, 2) velocity maneuvers in highly eccentric transfer orbits to the first lunar encounter, 3) precise target maneuvers in a large elliptic orbit with a distant apogee to the second lunar encounter, and 4) velocity kick maneuver at the final perigee to the Mars transfer orbit. Typical events and numerical results are exemplified in the following.

1) Insertion into a Low Earth Parking Orbit (Third Stage Burn-out Conditions)

Launch Site : Kagoshima Space Center (31.25° in latitude, 131.079° in longitude)
Parking Orbit : Circular Orbit of 200 km altitude
Epoch of Example : 16:57:44, on Aug. 6, 1998 (UTC)
Insertion Point : (200 km in altitude, 30.45° in latitude, 138.68° in longitude)
Insertion Velocity : (7,784 m/s, 0° in flight path angle, 97.38° in azimuth angle)
Coasting Angle and Time : 58.2° (14 minutes and 18 seconds)

2-a) Highly Eccentric Transfer Orbits to the First Lunar Encounter

Injection Date : 17:12:02, on Aug. 6, 1998 (UTC)
Injection Velocity : 3,137.6 m/s by the fourth stage kick motor
Apogee Distance : 410,000 to 430,000 km
Perigee Altitude : 600 to 1,200 km
Orbital Period : approximately 11 days
Transfer Duration : 49 days (4 rounds and a half revolution around Earth)
Eclipse : 15 and 19 minutes at the third and fourth perigee, respectively
Velocity Corrections : 13.6 m/s (ΔV_1 by OMS at the first apogee on Aug. 12)
 18.0 m/s (ΔV_2 by OMS at the second apogee on Aug. 23)
 3.448 m/s (ΔV_3 by RCS at the second perigee on Aug. 28)
Analytic C_3 : $-1.81 \text{ km}^2/\text{sec}^2$ (after ΔV_3)

2-b) First Lunar Encounter Conditions

Swingby Date : 16:41, on Sep. 24, 1998 (UTC)
Perilune Distance from Moon Center : 6,255 km
B-plane Angle : 346.782°
Relative Velocity at the Infinite Point : 938 m/s

3-a) Large Elliptic Orbit between the First and Second Lunar Encounter

Fifth Apogee Passage Date : on Nov. 4, 1998 (UTC)
Fifth Apogee Distance : 1,710,000 km
Velocity Correction by RCS : 5.33 m/s (ΔV_4 at the fifth apogee on Nov. 4)
Analytic C_3 : $-0.46 \text{ km}^2/\text{sec}^2$ (after ΔV_4)

3-b) Second Lunar Encounter Conditions

Swingby Date : 07:12, on Dec. 18, 1998 (UTC)
Perilune Distance from Moon Center : 4,457 km
B-plane Angle : 188.429°
Relative Velocity at the Infinite Point : 1,807 m/s

4) Final Kick Maneuver to Escape from Earth to Mars Transfer Orbit

Fifth Perigee Passage Date	: 07:34:44, on Dec. 20, 1998 (UTC)
Perigee Altitude	: 910 km
Velocity Correction by OMS	: 419.47 m/s (ΔV_5 at the fifth perigee on Dec. 20)
Analytic C_3	: 0.84 and 9.83 km ² /sec ² (before and after ΔV_5)

10.2.2 Mars Transfer Phase

Although no velocity correction is nominally scheduled in the Mars transfer phase, several maneuvers will actually be required to meet Mars insertion conditions. Predictable maneuvers are 1) a few weeks after the earth escape, 2) at an intermediate point of the Mars transfer orbit, and 3) a few weeks before the Mars insertion. Total amount of the above velocity corrections is estimated to be 50 m/s at maximum.

1) Heliocentric Elements of Mars Transfer Orbit (M50-EC)

Epoch	: 00:00:00 on Dec. 31, 1998 (UTC)
Semi-major Axis	: 179,506,726 km
Eccentricity	: 0.1869
Inclination	: 2.818°
Longitude of Ascending Node	: 87.153°
Argument of Perihelion	: 18.892°
Mean Anomaly	: 355.506°

10.2.3 Mars Orbiter and Scientific Observation Phase

Objectives of scientific instruments as well as limitations of the spacecraft system require several kinds of orbital characteristics in orbits around Mars. Major prescriptions are :

1) Requirements to Orbits around Mars

Peri-areon Altitude	: less than 300 km
Ap-areon Distance	: 15*R _m (Mean Mars Radius of 3,397 km)
Shadow Duration	: less than 90 minutes
Peri-areon at Sub-solar Point	: low latitude
Mars Surface Mapping	: wide range coverage
Observation Opportunities	: Phobos and Deimos
Operation Period	: more than two years

Considering the above requirements, orbital elements of a candidate orbit are listed as follows:

2) Mars Insertion Conditions (M50-EC)

Insertion Date	: 07:10 on Oct. 11, 1999 (UTC)
B-plane Angle of Incoming Asymptote	: 170°
Altitude at Insertion (Peri-areon)	: 300 km
Semi-major Axis of Hyperbolic Orbit	: 3,731.1 km
Eccentricity of Hyperbolic Orbit	: 1.99085
Inclination of Hyperbolic Orbit	: 163.92°
Deceleration Velocity	: 1,257 m/s (for 15 minutes by OMS)
ΔV Direction from Sun	: 128.17°
ΔV Direction from Earth	: 88.56°

3) Areocentric Elements of Orbits around Mars (Areo-EQ)

Epoch	: 07:10 on Oct. 11, 1999 (UTC)
Ap-areon Distance	: 15*R _m (Mean Mars Radius of 3,397 km)
Peri-areon Altitude	: 300 km --> 150 km
Semi-major Axis	: 27,326 km --> 27,251 km
Eccentricity	: 0.86471 --> 0.86984
Orbital Period	: 38.33 hours --> 38.17 hours
Inclination	: 137.641°
Longitude of Ascending Node	: 355.973° + 0.129*T(days)°
Argument of Peri-areon	: 174.974° + 0.151*T(days)°
Mean Anomaly	: 0.0275*T(days)°
Shadow Duration	: 66 minutes at maximum
Velocity for Peri-areon Change	: 5 m/s per 100 km change
Velocity Maneuver to keep Peri-areon	: approximately 10 m/s for 500 days
Altitude in 130 ± 30 km	

10.3 Launch Window and Launch Vehicle Capability

10.3.1 Launch Vehicle Capability

In the PLANET-B mission, M-V-3 is utilized as a launch vehicle. Since M-V is currently under development, the payload capability of the vehicle is still flexible. In the most progressive expectation, the payload mass into a low earth orbit (150 km x 300 km) amounts to 2,007 kg, while, in the most conservative estimation, the mass comes down to 1,865 kg. The LEO payload includes the fourth stage kick motor and the spacecraft, and the mass ratio of them is determined by the velocity increment required in the injection from LEO. Relating to the above LEO capabilities, the gross weights together with the net dry weights of the spacecraft are listed in the following.

LEO Capability	Gross Mass	Net Dry Mass
2,007 kg	536 kg	182 kg
1,865 kg	487 kg	157 kg

The gross mass includes the net mass of the spacecraft, the hardware weight of the propulsion system and the propellant weight. When the actual weight of the spacecraft exceeds the acceptable gross weight, the orbital scenario described thus far should be inevitably relinquished. For this undesirable contingency, another orbital scenario is simultaneously investigated.

10.3.2 Orbital Scenario in the Contingencies

In the nominal orbit design, the launch and the arrival are in August, 1998, and in October, 1999, respectively. On the other hand, the launch and the arrival of the other possibility are in August, 1998, and in March, 2001. Although the latter orbit takes longer flight time, it is able to enlarge the net dry mass of the spacecraft, because of the smaller deceleration velocity required at the Mars insertion. Table below shows comparison of the both orbital events.

	<Nominal Plan>	<Contingency Plan>
Launch	August, 1998	August, 1998
Departure from Earth	December, 1998	September, 1998
Arrival at Mars	October, 1999	March, 2001
Flight Time to Mars Arrival	14 months	31 months
C_3 in Earth Departure	$10.2 \text{ km}^2/\text{sec}^2$	$12.4 \text{ km}^2/\text{sec}^2$
C_3 in Mars Arrival	$11.6 \text{ km}^2/\text{sec}^2$	$6.25 \text{ km}^2/\text{sec}^2$
Revolution in Heliocentric Orbit	0.5	1.5
Stationary Orbit	Lunar Swingby Orbits	Elliptic Orbits
before Earth Departure		with 300,000 km Apogee
Lunar Swingby	Twice	Nothing

Referring to C_3 in the earth departure and the Mars arrival listed above, the departure velocity in the contingency plan is approximately 250 m/s larger than that in the nominal plan, while the arrival velocity in the contingency plan is approximately 400 m/s smaller than that in the nominal plan. Therefore, in adopting the 2001 arrival orbit, the net dry mass of the spacecraft is increased more than 30 kg as:

LEO Capability	Gross Mass	Net Dry Mass
2,007 kg	549 kg	217 kg
1,865 kg	498 kg	191 kg

Assuming that the gross weight of the spacecraft eventually integrated is 536 kg and the net dry weight is 182 kg, the 2001 arrival orbit could be accomplished without any hardware change. For the

most pessimistic LEO capability of 1,865 kg, to remove 38 kg of the propellant is only necessary before launch.

10.3.3 Launch Window

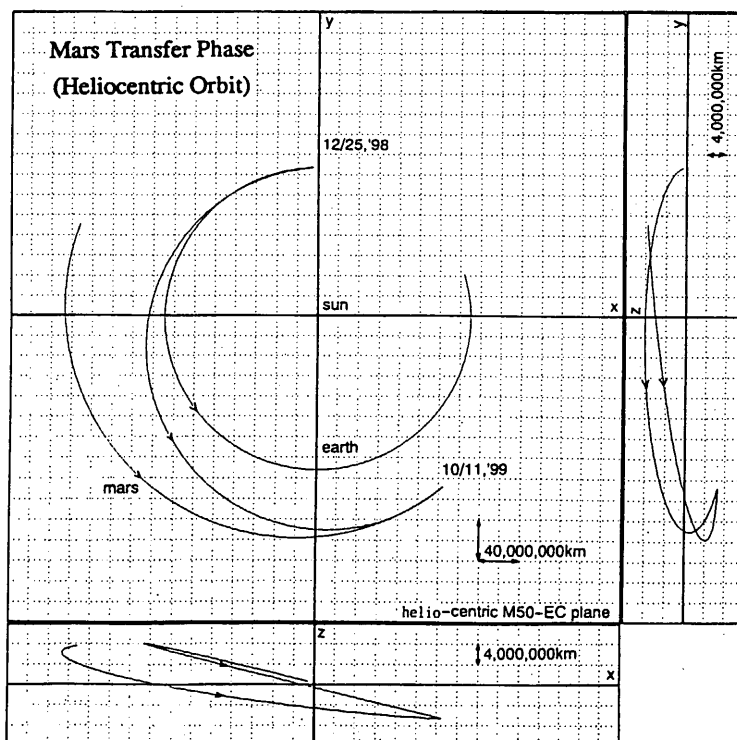
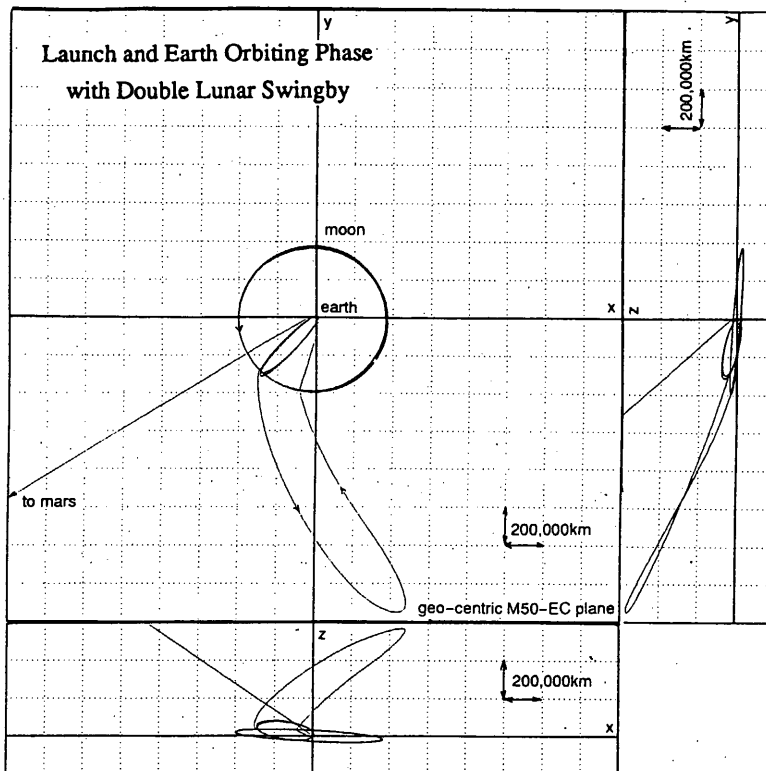
In the nominal orbit plan, lunar gravity assists are effectively utilized so as to enlarge the spacecraft weight. Lunar swingby makes the orbit design quite restricted and it reduces the launch opportunity. Primary target of the launch phase orbit design is to meet accurately the encounter conditions at the first lunar swingby. Since the relative position of the lunar swingby is almost fixed with respect to the sun and the earth, at most one week of the launch opportunity is assured, corresponding to one swingby conditions. Presently, the following launch window is planned:

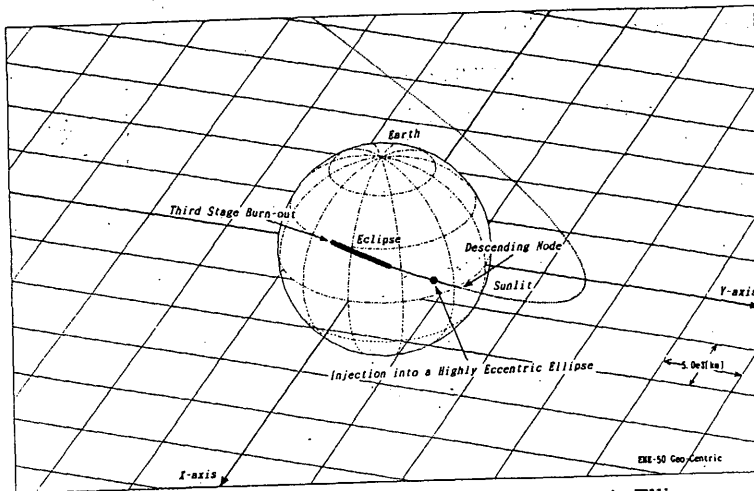
Launch Window in 1998	First Lunar Swingby Date	Earth Escape Date	Mars Arrival Date
5 days in the early August	September, 1998	December, 1998	October, 1999 (investigated)
5 days in the mid August	September, 1998	January, 1999	November, 1999 (abandoned)
5 days in the early September	October, 1998	December, 1998	October, 1999 (abandoned)
3 weeks from the mid August	Unused	September, 1999	March, 2001 (investigated)

Considering the actual launch operation, more than two weeks are necessary for the launch window. Only five days, however, in the early August, 1998, have currently been examined for the 1999 arrival orbits. Other launch windows with a different swingby date are continually inspected. For the 2001 arrival orbit, enough launch opportunity is able to be obtained, because the orbit uses only highly eccentric ellipses without a lunar swingby as the stationary orbit.

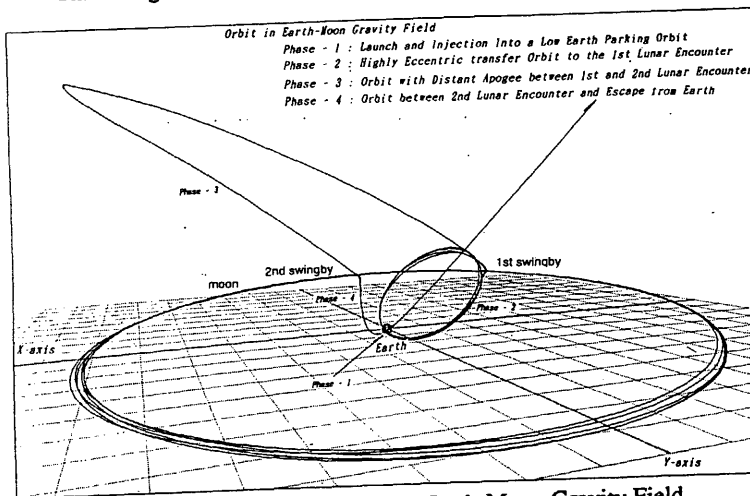
10.4 Orbital Properties

The following figures show the orbital configurations of the nominal PLANET-B orbit with double lunar swingby and the 1999 Mars arrival. Also depicted are properties of the orbit around Mars such as a distance from the earth, periapsis angles, shadow durations, altitude changes of ascending and descending nodes, and so forth. These figures indicate geometric relations among the spacecraft, Mars, the earth and the sun, for the purpose of understanding scientific observation possibilities.

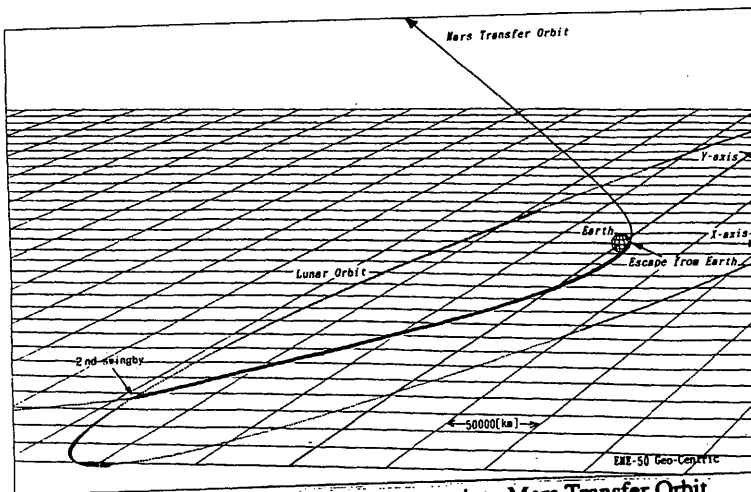




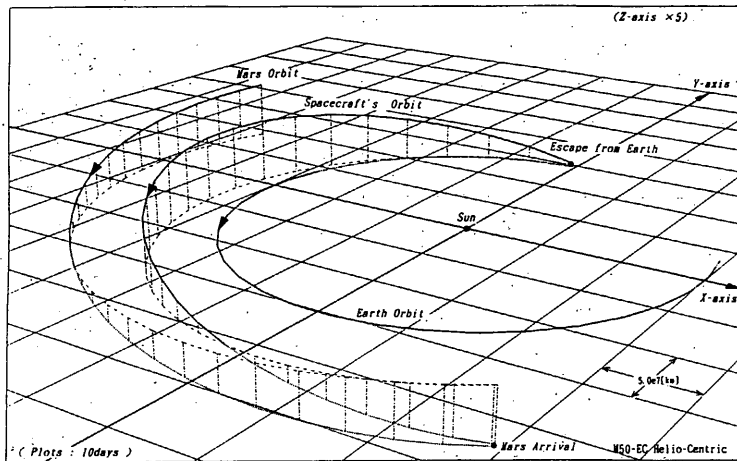
Third Stage Burn-out and Injection into a High Eccentric Ellipse



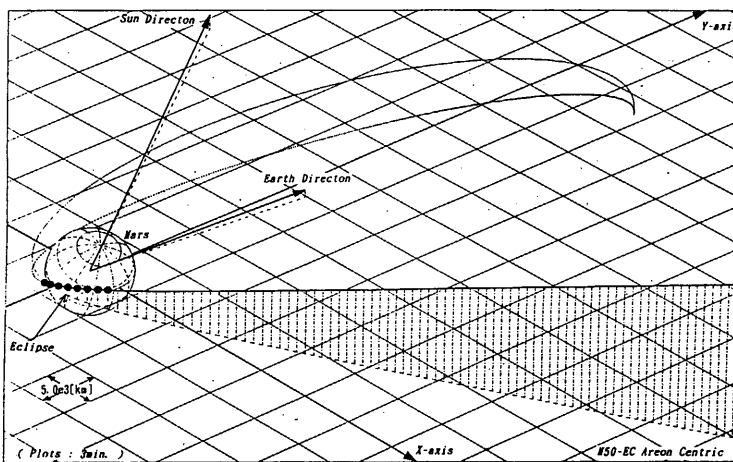
Double Lunar Swingby Orbit in Earth-Moon Gravity Field



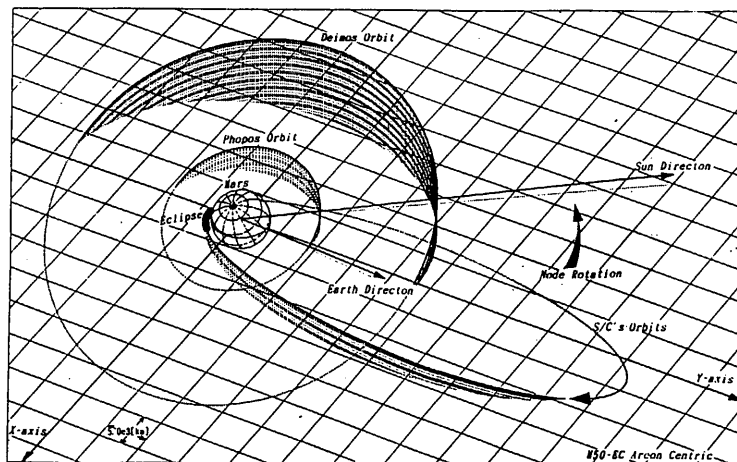
Second Lunar Encounter and Earth Escape into Mars Transfer Orbit



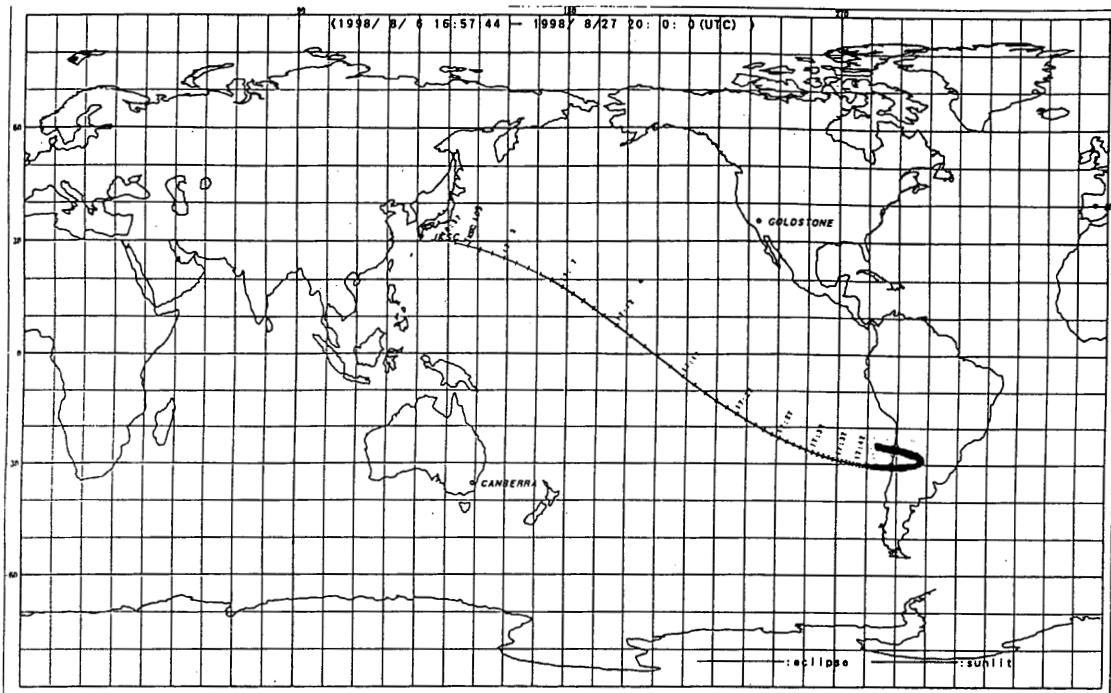
Heliocentric Mars Transfer Orbit from Earth Departure to Mars Arrival



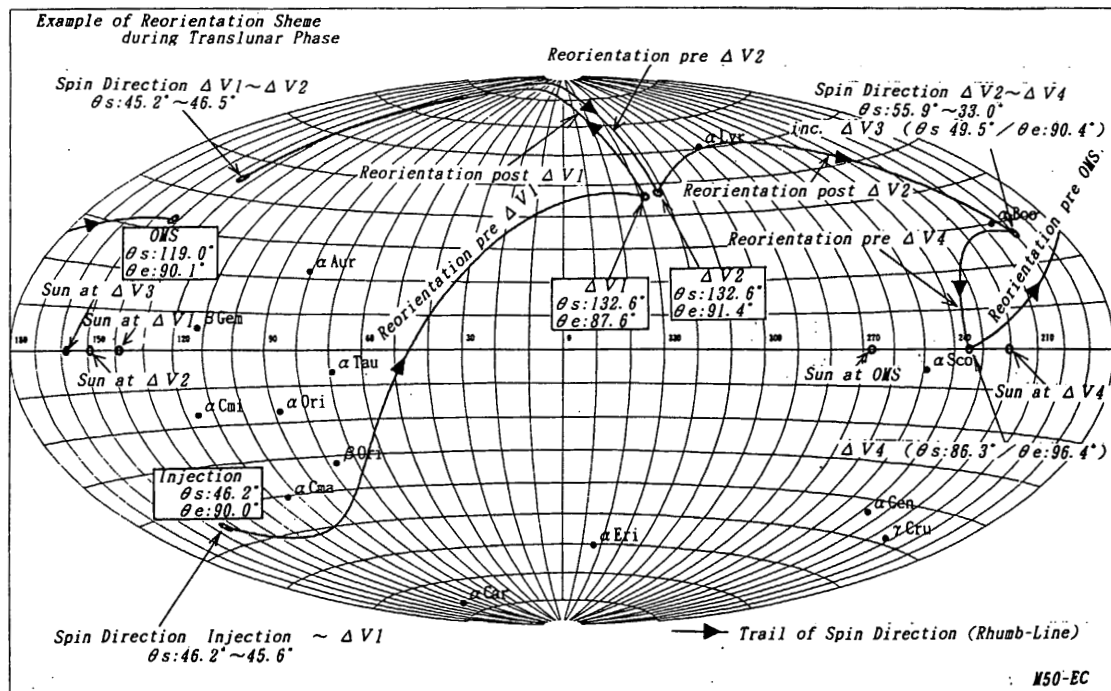
Mars Encounter and Insertion



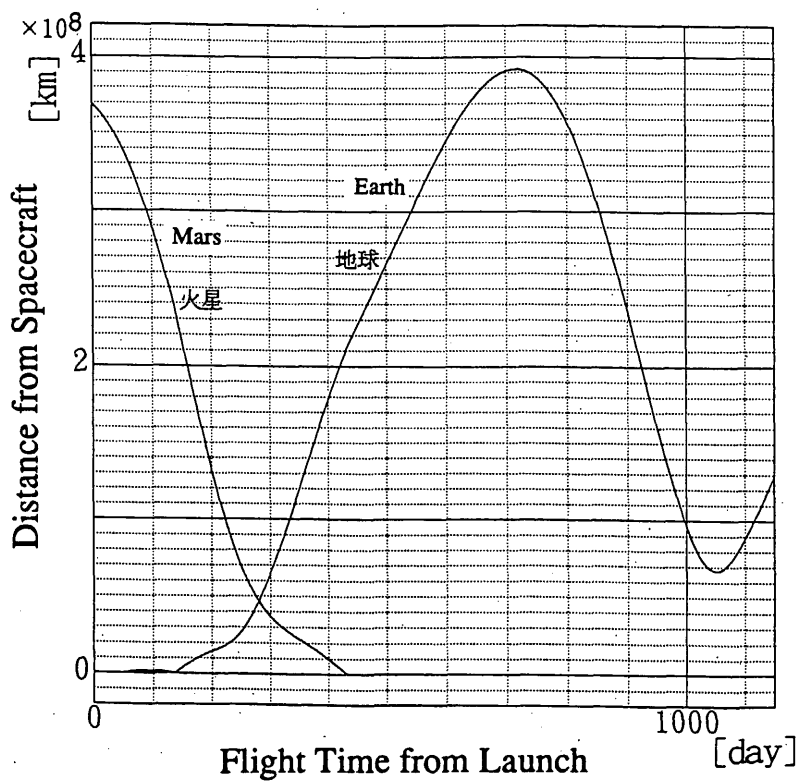
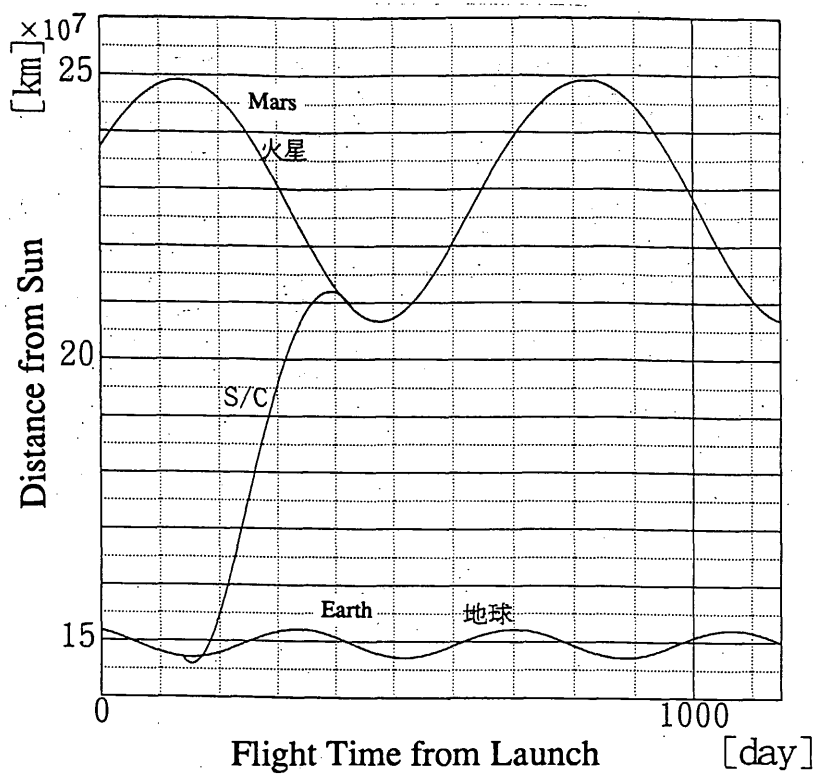
Elliptic Orbit around Mars

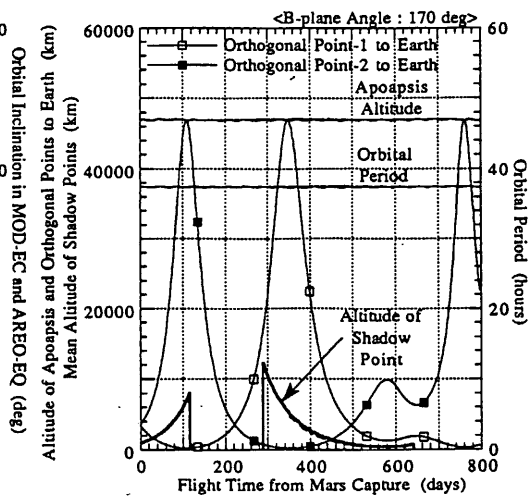
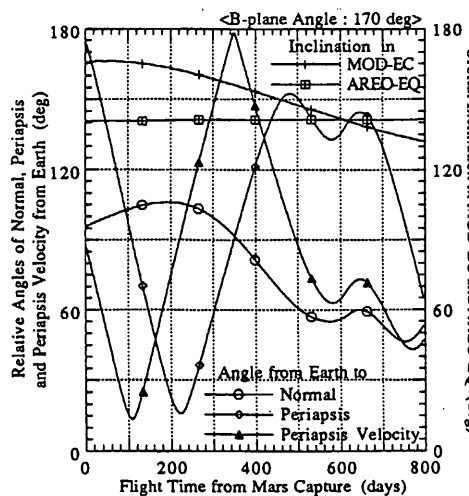
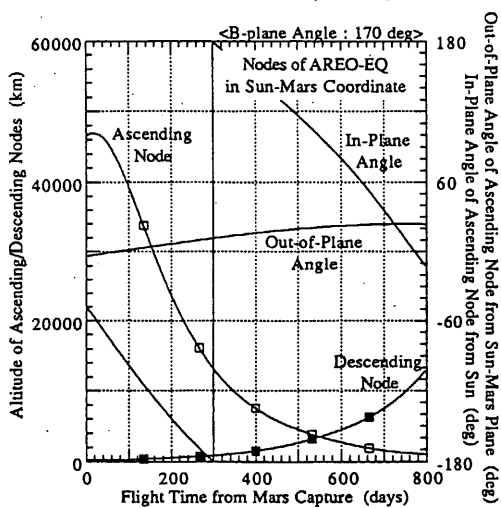
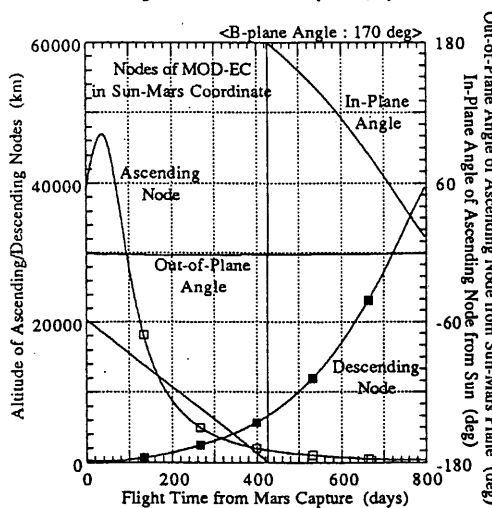
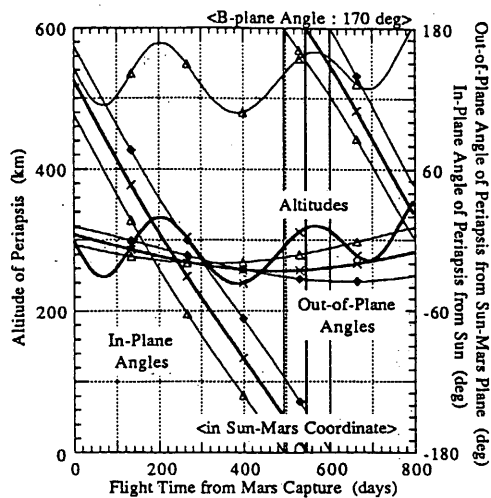
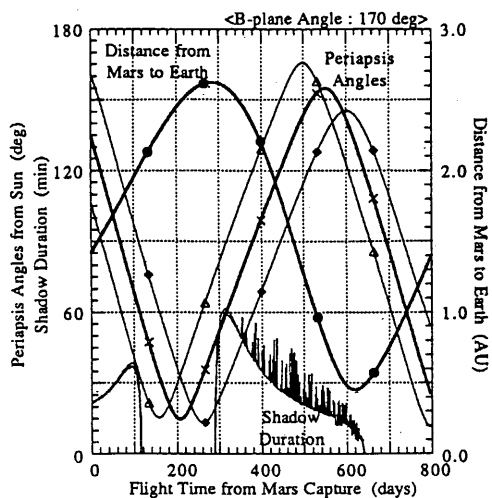


Foot Print from Third Stage Burn-out to Injection



Spin Axis Directions in Earth Orbiting Phase



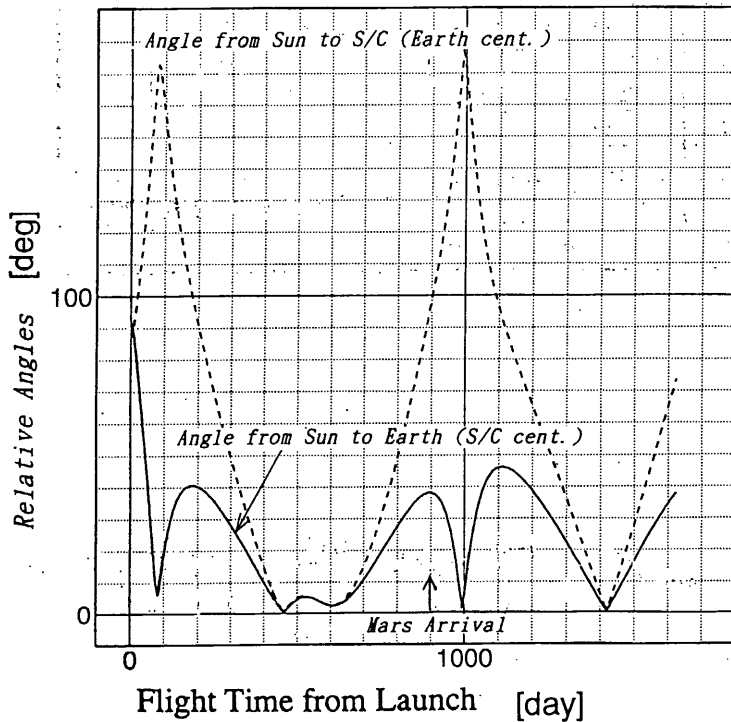
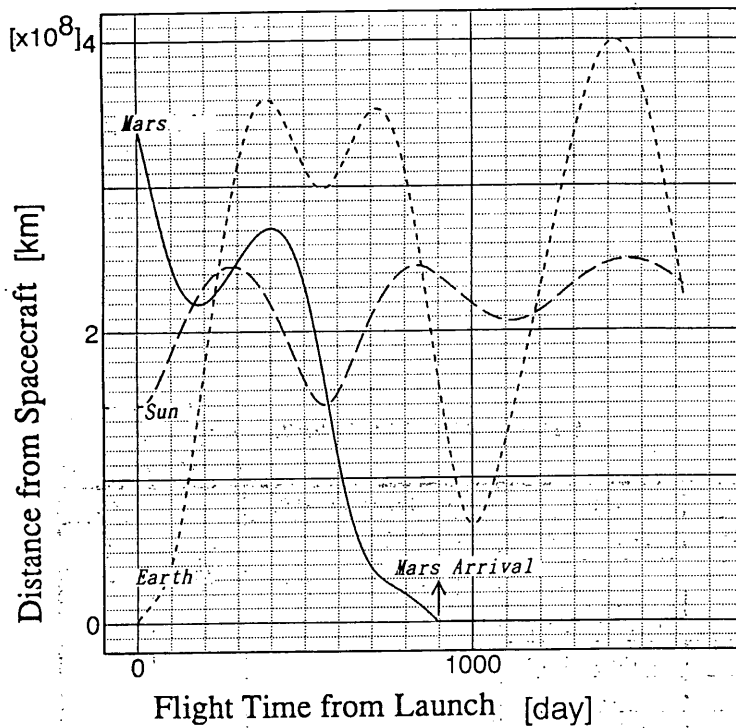


Properties of Orbits around Mars

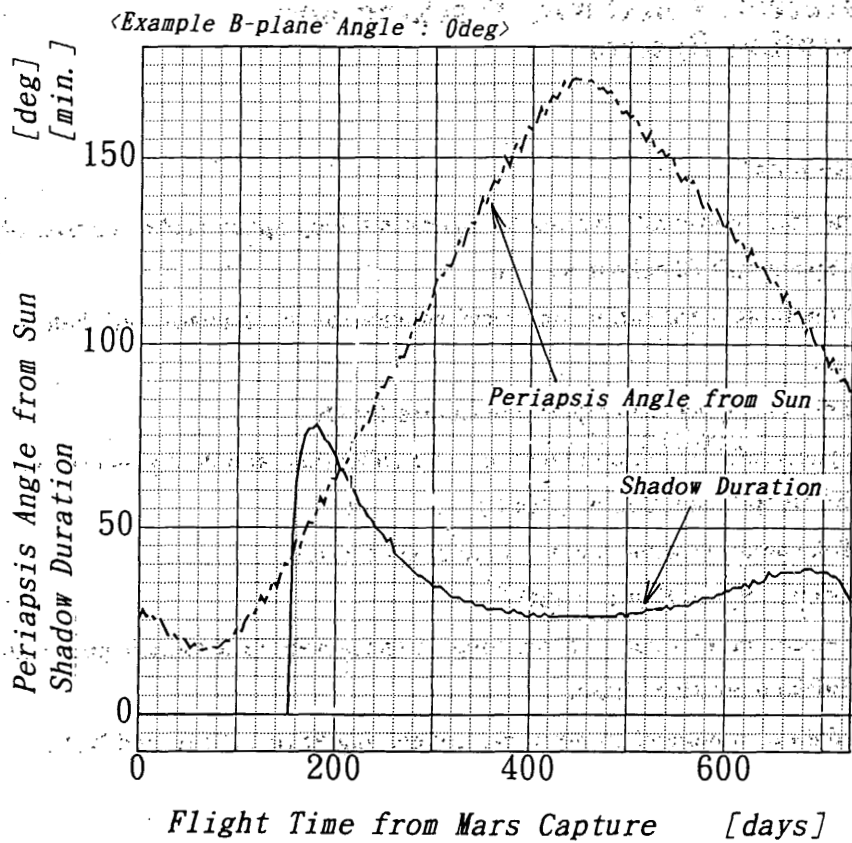
Mars Insertion Sequence

(arrival at 1999)

Time	Event	Spin direction (EC)	θ	θ
-45 (min.)	Reo. start	(85.2°, 1.8°)	41.7°	0°
	Reo. end	(356.2°, 15.9°)	128.2°	88.6°
	Nutation Dump			
-19	Eclipse start			
-10	LOS			
-8	OMS start			
0	ΔV center	(356.2° , 15.9°)	128.2°	88.6°
+5	Eclipse end			
+7	OMS end			
+14	AOS			
	Nutation Dump			
+45	Reo. start	(142.3°, 32.0°)	128.8°	88.6°
	Reo. end	(260.0°, 0.0°)	41.7°	0°



Properties of Orbit 2001 Arrival (1/2)



Properties of Orbit 2001 Arrival. (2/2)

11. Ground System and Mission Operations

11.1 Spacecraft Checkout, Tracking and Operation System

11.1.1 General

The ISAS's ground systems for operating deep space probes consist of :

(1) The Spacecraft Checkout System

Functions verification and performance tests of spacecraft before a flight.

(2) Sagami-hara Spacecraft Operation Center (SSOC)

Spacecraft control and monitor, data collection, and data processing.

(3) Usuda Deep Space Center (UDSC)

Telecommunication and tracking of spacecraft.

(4) Kagoshima Space Center (KSC)

Telecommunication and tracking of spacecraft in a launch phase and an initial operation phase.

(5) The data communication networks connecting SSOC, UDSC and KSC.

System configuration of the Spacecraft Checkout System are shown in Figure 1-1 and system configuration of Spacecraft Tracking and Operation System (KSC, UDSC and SSOC) are shown in Figure 1-2.

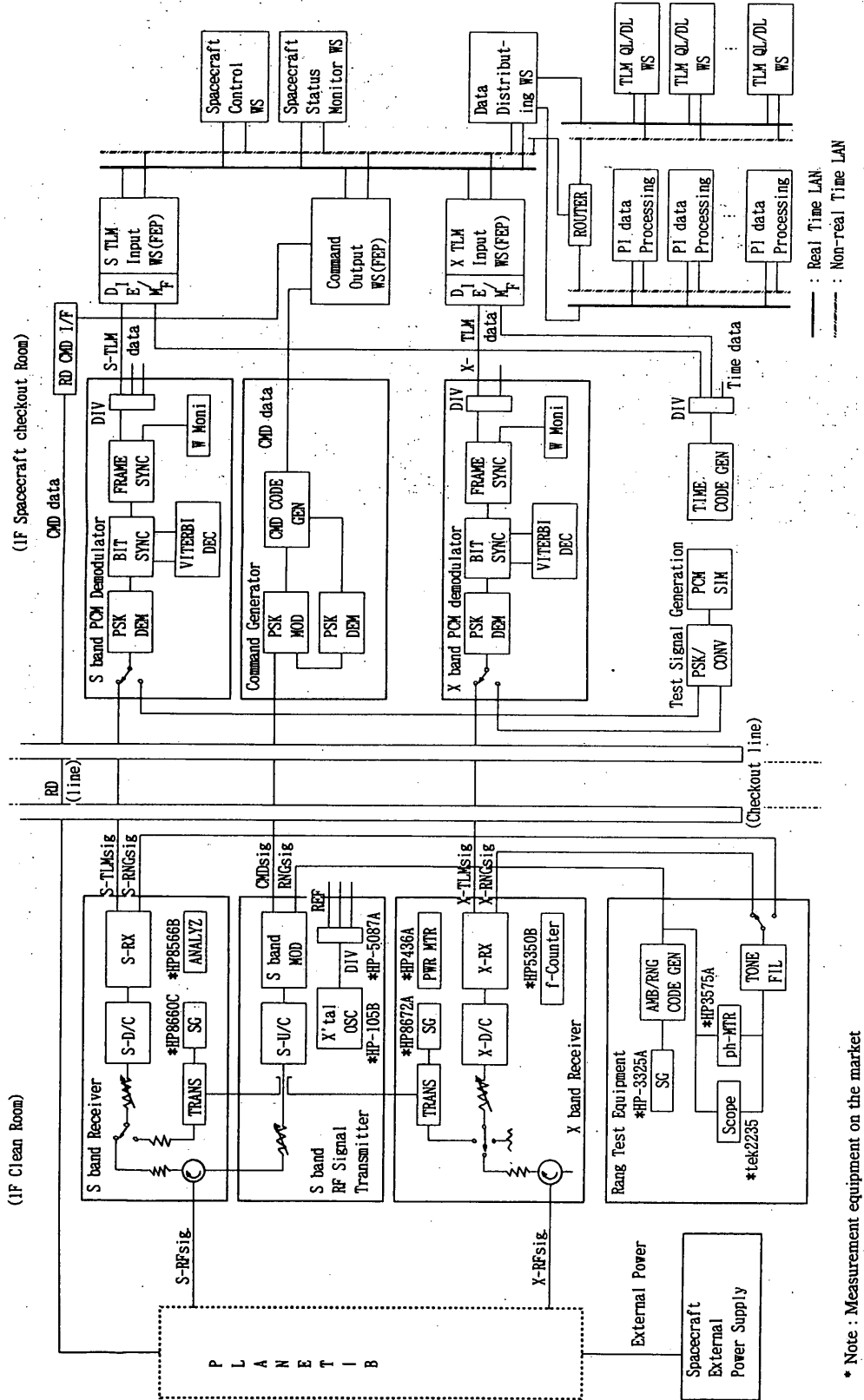


Figure 1-1 System configuration of the spacecraft checkout system (Plan)

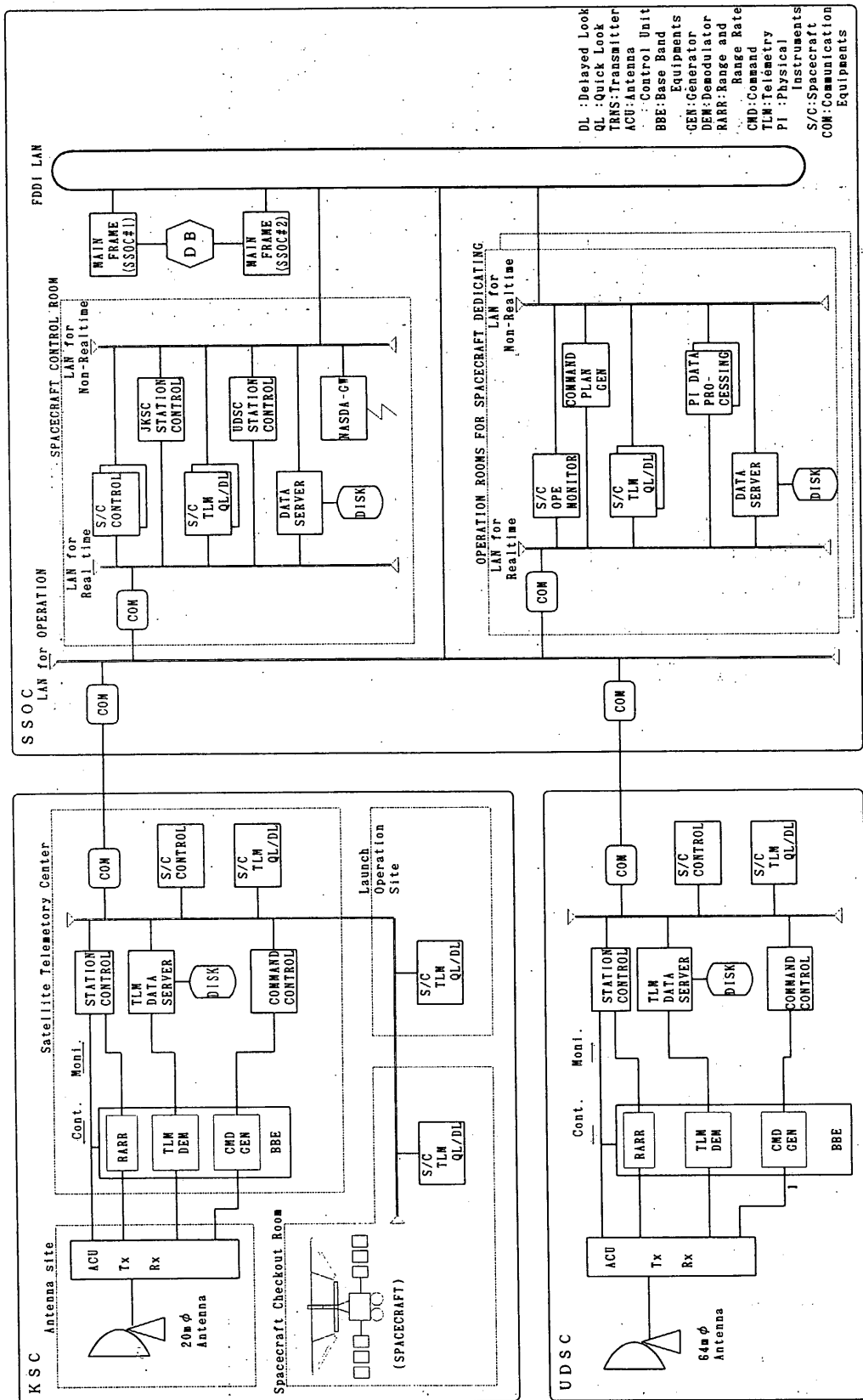


Figure 1-2 System configuration of spacecraft tracking and operation system (UDSC, KSC and SSOC) (Plan)

11.1.2 Function of Spacecraft Checkout System

Spacecraft checkout system have function of spacecraft verification and performance tests and PLANET-B is checked its all function by this checkout system before a flight in Sagamihara campus.

Following items show the major function and performance of Spacecraft Checkout System.

(1) S band transmitting function

Wire or wireless connection between spacecraft and checkout equipment.

(2) X band receiving function

Wire or wireless connection between spacecraft and checkout equipment.

(3) S band receiving function

Wire or wireless connection between spacecraft and checkout equipment.

(4) X band telemetry demodulation

PCM, PCM-PSK, PCM-CONV and PCM-CONV-PSK demodulation.

(5) S band telemetry demodulation

PCM, PCM-PSK, PCM-CONV and PCM-CONV-PSK demodulation.

(6) Command generation

Command code generation and transmission for spacecraft control

(7) Spacecraft control and monitor function

Making up command plan, controlling transmission of command code and spacecraft status monitor.

(8) Spacecraft data analysis

Spacecraft bus data and PI data analysis.

11.1.3 Function of Spacecraft Tracking and Operation System

11.1.3.1 Sagamihara Spacecraft Operation Center (SSOC)

The Sagamihara Spacecraft Operation Center(SSOC) operates ISAS's spacecraft. Telemetry, commanding and tracking operations are conducted at SSOC connected to UDSC and KSC tracking stations by data communication networks.

The major functions of SSOC are :

- (1) Spacecraft operation and control
- (2) Health and safety monitoring of instrument and spacecraft
- (3) Command/telemetry processing
- (4) Engineering trend analysis
- (5) Attitude and orbit determination
- (6) Management of operations(command planning)

11.1.3.2 Usuda Deep Space Center (UDSC) and Kagoshima Space Center (KSC)

The Usuda Deep Space Center(UDSC) is a ground station for Tracking,Telemetry and Command(TT&C) communication for deep space probes. The Kagoshima Space Center(KSC) supports TT&C communication during a launch phase and an initial orbit phase of interplanetary spacecraft. Range and Range Rate(RARR) measurements are carried out at UDSC and KSC.

The major functions of UDSC and KSC are :

- (1) Receiving and demodulation of telemetry signal by S– band down link.
- (2) Receiving and demodulation of telemetry signal by X– band down link.
- (3) Transmitting of command signal by S– band up link.
- (4) Range and Range Rate(RARR) measuring by:
 - S– band up link / S– band down link
 - S– band up link / X– band down link
 - S– band up link / S– band and X– band down link

The UDSC ground station consists of: the 64-meter diameter antenna, S-band transmitter, S/X-band receivers, telemetry demodulators, command generator, range and range rate measurement equipment, data communications terminal and consoles for station and spacecraft controls.

The KSC ground station consists of: the 20-meter diameter antenna, S-band transmitter, S/X-band receivers, telemetry demodulators, command generator, range and range rate measurement equipment, data communications terminal and consoles for station and spacecraft controls.

11.1.3.3 Data Communication Networks Connecting SSOC, UDSC and KSC

The commands generated at SSOC are transmitted to UDSC and KSC, and the telemetry and RARR data are transmitted from UDSC and KSC to SSOC. Monitor information on the ground stations are also carried on this network. The network consists of terminal computers, data multiplexers, two 384 kbps circuits, and the main computer at SSOC.

11.1.4 Characteristics of the Spacecraft Checkout, Tracking and Operation System and Their Equipment

Major performance of Checkout Equipment are shown on Table 4-1, major performance of Tracking and Operation System are shown on Table 4-2, and subsystem specifications of Tracking and Operation System are shown on Table 4-3.

Table 4-3(4/4) Subsystems specification of Tracking and Operation System

No	Items	Usuda Deep Space Center (UDSC)	Kagoshima Space Center (KSC)
Telemetry Demodulator			
1	Demodulation	PCM,PCM-PSK,PCM-CONV, PCM-CONV-PSK	PCM,PCM-PSK,PCM-CONV, PCM-CONV-PSK
2	PCM Input Codes	NRZ-L,M,S BiPH-L,M,S	NRZ-L,M,S BiPH-L,M,S
3	Convolutional Code	Constant Length : 7 Rate : 1/2	Constant Length : 7 Rate : 1/2
4	PSK Subcarrier Frequency	100Hz~999KHz	100Hz~999KHz
5	PCM Symbol Rate	5sps~600Ksps	5sps~600Ksps
6	PSK Subcarrier /PCM Symbol Rate	4 ~1000	4 ~1000
7	Required S/N₀	STs/N₀ : 5.5dB (with CONV) STs/N₀ : 11.0dB (without CONV)	STs/N₀ : 5.5dB (with CONV) STs/N₀ : 11.0dB (without CONV)
Command Generator			
1	Modulation	PCM(PN)-PSK	PCM(PN)-PSK
2	PSK Subcarrier Frequency	100Hz~16.384KHz	100Hz~16.384KHz
3	Bit Rate	100/256~16384/2 bps	100/256~16384/2 bps
4	PCM Code	NRZ-L/BiPH-L	NRZ-L/BiPH-L

Table 4-3(3/4) Subsystems specification of Tracking and Operation System

No	Items	Usuda Deep Space Center (UDSC)	Kagoshima Space Center (KSC)
RARR Measurement			
1	Range Measuring Method	Sequential Code	PN-Code
2	Ranging Frequency	$f_{up}/2^{11} \sim f_{up}/2^{14}$ (1000/500/250/125KHz)	500/100/20KHz
3	Range Modulation Index	0.2~1.0rad	0.2~1.5rad
4	Range Measuring	about 3AU	about 500,000Km
5	Range Measuring Accuracy	less than 2m rss (at 500KHz)	less than 1m rss (at 500KHz)
6	Range Measuring Resolution	0.15m	0.15m
7	Required S/No	9 dBHz	27 dBHz
8	Data Sampling Rate	1~60 data/time	1,1/2,1/4 data/sec
9	Range Rate Measuring Method	Integrated Doppler	Integrated Doppler
10	Doppler Measuring	$\pm 30\text{Km/sec}$	$\pm 12\text{Km/sec}$
11	Range Rate Measuring Accuracy		
	(1)1WAY	less than 0.5mm/sec rss (at 1/60data/sec)	less than 5 cm/sec rss (at 1data/sec)
	(2)2WAY	less than 0.1mm/sec rss (at 1/60data/sec)	less than 1 cm/sec rss (at 1data/sec)
12	Range Rate Measuring Resolution		
	(1)1WAY	0.01 cycle	1 cm/sec
	(2)2WAY	0.01 cycle	0.05 cm/sec
13	Data Sampling Rate	1,1/2,1/10,1/30,1/60 data/sec	1,1/2,1/4 data/sec

Table 4-3(2/4) Subsystems specification of Tracking and Operation System

No	Items	Usuda Deep Space Center (UDSC)	Kagoshima Space Center (KSC)
S-band Transmitter			
1	Frequency	2080~2120MHz	2025~2120MHz
2	Power	20/2/0.2KW	10/1/0.1KW
3	Feed Loss	less than 0.5dB	less than 0.5dB
4	Carrier Sweep		
	(1)Sweep Rate	±30KHz/sec max	±30KHz/sec max
	(2)Sweep Band Width	±300KHz max	±300KHz max
5	Modulation	PM	PM
6	Modulation Index	2.0rad max	2.0rad max
7	Modulation Signals	CMD : 50Hz~200KHz RNG : 1KHz~1.5MHz	CMD : 50Hz~200KHz RNG : 1KHz~1.5MHz
S/X-band Receiver			
1	Frequency	S-band : 2200~2300MHz X-band : 8400~8500MHz	S-band : 2200~2300MHz X-band : 8400~8500MHz
2	Receiving Noise Temperature	S-band : 45K X-band : 55K	S-band : 45K X-band : 55K
3	Input Level	-85~-162dBm(S/X-band)	-55~-155dBm(S/X-band)
4	Auto Tracking Input Level	-85~-140dBm (S-band Only)	-55~-140dBm(S/X-band)
5	Receiving Method	Single (S/X-band)	Polarization Diversity Receiving (S/X-band)
6	Carrier Tracking	PLL	PLL
	(1)Tracking Range	S-band : ±500KHz X-band : ±2MHz (additional doppler aid)	S-band : ±500KHz X-band : ±2MHz (additional doppler aid)
	(2)Loop Band Width (2BL)	1KHz/300Hz/100Hz/ 30Hz/10Hz/3Hz	3KHz/1KHz/300Hz/ 100Hz/30Hz/10Hz
7	Demodulation	PM 1.5rad max	PM 1.5rad max
8	Demodulation Signals	TLM : 1.5MHz RNG : 1.5MHz	TLM : 1.5MHz RNG : 1.5MHz

Table 4-3(1/4) Subsystems specification of Tracking and Operation System

No	Items	Usuda Deep Space Center (UDSC)	Kagoshima Space Center (KSC)
Antenna			
1	Transmit Frequency	S-band : 2080~2120MHz	S-band : 2025~2120MHz
2	Receiving Frequency	S-band : 2200~2300MHz X-band : 8400~8500MHz	S-band : 2200~2300MHz X-band : 8400~8500MHz
3	Method	64m ϕ Cassegrain	20m ϕ Cassegrain
4	Polarization(TX)	S-band : RHCP/(LHCP)	S-band : RHCP/LHCP
5	Polarization(RX)	S-band : RHCP/(LHCP) X-band : RHCP/(LHCP)	S-band : RHCP/LHCP X-band : RHCP/LHCP
6	Antenna Gain	S-band TX : 59.9dB (at 2.12GHz) S-band RX : 61.5dB (at 2.3GHz) X-band RX : 70.6dB (at 8.5GHz)	S-band TX : 51.5dB (at 2.12GHz) S-band RX : 52.2dB (at 2.3GHz) X-band RX : 62.8dB (at 8.5GHz)
7	Antenna Noise Temp(EL 90°)	S-band RX : 44K X-band RX : 31K	S-band RX : 41K X-band RX : 39K
8	Driving Angle	Az : $\pm 270^\circ$ (South Center) EL : $5^\circ \sim 92^\circ$	Az : $\pm 270^\circ$ (South Center) EL : $-1^\circ \sim 91^\circ$
9	Driving Speed	Az : $0.5^\circ/\text{sec}$, $0.5^\circ/\text{sec}^2$ EL : $0.5^\circ/\text{sec}$, $0.5^\circ/\text{sec}^2$	Az : $5^\circ/\text{sec}$, $5^\circ/\text{sec}^2$ EL : $2.5^\circ/\text{sec}$, $2.5^\circ/\text{sec}^2$
10	Driving Mode	Auto Tracking(S-band), Program,Program Scan, Manual	Auto Tracking(S/X-band), Coasting,Program,Slave, Manual

Table 4-2 Major performance of Tracking and Operation System

No	Items	Usuda Deep Space Center (UDSC)	Kagoshima Space Center (KSC)
1	Transmit Frequency	S-band : 2025~2120MHz	S-band : 2025~2120MHz
2	Receiving Frequency	S-band : 2200~2300MHz X-band : 8400~8500MHz	S-band : 2200~2300MHz X-band : 8400~8500MHz
3	Antenna Mount	64m ϕ Az-EL Mount	20m ϕ Az-EL Mount
4	EIRP	S-band : 132.4dBm (at 2.12GHz)	S-band : 121.2dBm (at 2.12GHz)
5	G/T (EL 90°)	S-band : 42.0dB/K (at 2.3GHz) X-band : 51.2dB/K (at 8.5GHz)	S-band : 32.8dB/K (at 2.3GHz) X-band : 43.0dB/K (at 8.5GHz)
6	Polarization(TX)	S-band : RHCP/(LHCP)	S-band : RHCP/LHCP
7	Polarization(RX)	S-band : RHCP/(LHCP) X-band : RHCP/(LHCP)	S-band : Polarization Diversity Receiving X-band : Polarization Diversity Receiving
8	RARR (1)Range Measuring (2)Ranging Method (3)Ranging Frequency (4)Doppler Measuring (5)Doppler Measuring Mode	about 3 AU Sequential code fup/2 ¹¹ ~2 ¹⁴ (1000/500/250/125KHz) $\pm$ 30Km/sec 1WAY/2WAY	about 500,000Km PN-code 500/100/20KHz $\pm$ 12Km/sec 1WAY/2WAY
9	Telemetry Demodulator (1)Demodulation	PCM,PCM-PSK,PCM-CONV ,PCM-CONV-PSK	PCM,PCM-PSK,PCM-CONV ,PCM-CONV-PSK
10	Command Generator (1)Modulation	PCM(PN)-PSK	PCM(PN)-PSK

Table 4-1(2/2) Major performance of Spacecraft Checkout equipments

No	Items	Specification
Telemetry Demodulator (S/X BAND)		
1	Demodulation	PCM,PCM-PSK,
2	PCM Input Codes	PCM-CONV,PCM-CONV-PSK
		NRZ-L,M,S
		BiPH-L,M,S
3	Convolutional Code	Constant Length : 7
		Rate : 1/2
4	PSK Subcarrier	200Hz~1MHz
	Frequency	
5	PCM Symbol Rate	50sps~600Ksps
6	PSK Subcarrier	4 ~1000
	/PCM Symbol Rate	
7	Required S/N₀	STs/N₀ : 5.5dB
		(with CONV)
		STs/N₀ : 11.0dB
		(without CONV)
Command Generator		
1	Modulation	PCM(PN)-PSK
2	PSK Subcarrier	100Hz~16.384KHz
	Frequency	
3	Bit Rate	100/256~16384/2 bps
4	PCM Code	NRZ-L/BiPH-L

Table 4-1(1/2) Major performance of Spacecraft Checkout equipments

No	Items	Specification
S-band Transmitter		
1	Frequency	(2025~2120MHz)
2	Power	-35~-85dBm
3	Carrier Sweep	
	(1)Sweep Rate	$\pm 30\text{KHz/sec max}$
	(2)Sweep Band Width	$\pm 120\text{KHz max}$
4	Modulation	PM
5	Modulation Index	2.0rad max
6	Modulation Signals	CMD : 50Hz~50KHz RNG : 1KHz~2MHz
S/X-band Receiver		
1	Frequency	S-band : 2200~2300MHz X-band : 8400~8500MHz
2	Input Level	+30~-40 dBm(S/X-band)
3	Carrier Tracking	PLL
	(1)Tracking Range	S-band : $\pm 120\text{KHz}$ X-band : $\pm 120\text{kHz}$ (additional doppler aid)
	(2)Loop Band Width (2BL)	3KHz/1KHz/300Hz/ 100Hz/30Hz
4	Demodulation	PM 1.5rad max
5	Demodulation Signals	TLM : 1.5MHz RNG : 1.5MHz

11.2 Orbit Determination System

ISAS OD group

11.2.1 Introduction

Tracking and control (telemetry, command, and ranging) of Planet-B mission is carried out by using frequency of S band and X band at the ground station. The major object of orbit determination system for the navigation is precise estimation of orbital elements and the other dynamics parameters of spacecraft. On the basis of this determination result, the guidance and control is carried out to the spacecraft. And another important part is to generate the antenna prediction data of the ground station. As these operations for the spacecraft, the orbit determination system consists of the following programs which function with the workstation.

- (1) The orbit determination program
- (2) The orbit prediction program
- (3) The real time Doppler monitoring program

11.2.2 Orbit Determination Program

This program is to preprocess the tracking data and to estimate the state vector of the spacecraft.

Function

- (i) Preprocessing of tracking data

The tracking data are edited, rejected bad data and compressed.

- (ii) Estimation of the spacecraft orbit and dynamics

The state vector of the spacecraft and the parameters are estimated

- 1) Tracking data : S band RARR (Range and Range rate),
X band RARR
- 2) Estimator : batch sequential filter,
least square filter
- 3) Estimated parameter : Several dynamics parameters

11.2.3 Orbit Prediction Program

This program is to generate the antenna prediction data for ground station. The antenna prediction data consists of antenna angle information and data to correct RARR.

Function

- (i) To generate the spacecraft trajectory by the orbit estimation result
- (ii) To predict antenna pointing data and RARR data in time series.
And send these data from Sagami-hara Operation Center to the ground station with the network.
- (iii) To calculate the ephemeris for the orbit.

11.2.4 Real Time Monitor Program

The objective of this program is to display the difference between observable and calculated values of tracking data (O-C) in real time.

And to support the guidance and control for the spacecraft at the orbit and attitude maneuvering.

Function

This program has two functions as follows :

- (i) The difference to the tracking data, which are stored in the real time file, and the computed values from the orbit model are described on graphic display.
- (2) During orbit and attitude maneuver, the magnitude along the line of sight are calculated from observation doppler data between the start time and end time.

11.3 Operation Planning System

M. Hoshino and T. Yamamoto (ISAS)

11.3.1 Introduction

Operations of satellites have become increasingly complicated in recent years with the following background:

- (1) reception of TLM data by ground stations abroad,
- (2) cooperative operations by many scientists of scientific instruments on-board a satellite,
- (3) increase of dangerous commands related to high voltages and attitude control system,
- (4) conflicts of operation tracking facilities among a number of satellites, and
- (5) especially for a deep space mission, retarded time effect of data transmission arising from a long distance from the earth.

Intelligent Satellite Control Software (ISACS) will be developed to help the operators to make the operation/command planning at ease. The ultimate goal of the ISACS, which system is now in operation in both AKEBONO and GEOTAIL missions at ISAS, is to make the satellite operation automatic. The ISACS can generate the operation Program (OP), and real-time command plans which consist of the following command groups:

- (1) Data Recorder (DR) mode,
- (2) onboard antenna mode,
- (3) Scientific Instrument (SI) mode, and
- (4) orbit/attitude control mode.

Another purpose of the ISACS is to realize a highly reliable satellite operation by introducing the Artificial Intelligence (AI) technologies. Main features of the ISACS system as follows:

- (1) ISACS system supports the satellite operation planning and trouble shooting,
- (2) the operators who do not have much expertise in satellite operations can plan the operation at ease,
- (3) ISACS prevents the operators from sending mis-commands,
- (4) ISACS provides a software to conduct simulations on the thermal and electrical state of the satellite, and check the consistency of a command plans, and
- (5) the knowledge database in the ISACS system is accumulated and to be improved in the process of real operations.

11.3.2 Operation/Command Planning

The operation/command planning can be automatically produced in this system based on the knowledge database which was prepared by the experts of satellite operations. The following functions are supported:

Schedule Making

The function of the Schedule Making is to generate;

- Observation plan and observation mode,
- TLM data reception plan,
- Ranging plan,
- Command plan, using the following input items,
 - Requests from orbit control system,
 - Requests from attitude control system (station view predict, ephemeris etc.),
 - Requests from Common Instruments (CI) and Scientific Instruments (SI),
 - Operation information on the tracking stations, and
 - Operation time of some other satellites.

Simulation

The simulation software can check the following items;

- Power consumption,
- Thermal balance,
- Communication line margin, and
- Retarded time effect of data transmission.

Command Check

To confirm the safety of the command, the ISACS system carries out the following checks;

- basic logics,
- Prohibited command, and
- Consistency of requested items and restricted items.

Command Conversion

After the above confirmations of its safety operation, those commands are automatically converted to the command plan and operational program (OP).

Operation/Command Plan Updating

Both the operation plan and the command plan can be easily modified on the screen when it is necessary to change the original plan. It is required to conduct the simulation check again on a new command plan whenever the operation or command plan is modified.

Control Parameter Management

The control parameters to manage the operation/command plan can be easily updated.

Display and List Output

The following information can be displayed on the computer screen and be output;

- Orbit information,
- Operation plan,
- Command plan and operation program (OP),
- Simulation and Check results, and
- Visible time of ground stations.

11.3.3 Configuration of ISACS

T.B.D.

11.4 Operation Supporting System

TBS

11.5 Data Archive

TBS

11.6 Ground Data Handling System for Scientific Instruments

TBS

12. System Tests

12.1 Electric Interface Test

I.Nakatani (ISAS)

NEC Corporation

Electric Interface test is included in the FM integration test (October 1997 - July 1998). The purpose of this test is to confirm the electrical interface / functions before / after integration / environmental tests.

12.2 Electromagnetic Compatibility Tests

T. Yamamoto (ISAS)
NEC Corporation

In the PLANET-B mission, the EMC (Electromagnetic Compatibility) design standard is defined, aiming at minimizing Electromagnetic interference between onboard components. All the components should be designed to meet the specifications defined in the PLANET-B EMC design standard. The EMC tests shall be carried out during the ground tests at ISAS in the magnetic-shield chamber.

12.2.1 EMC Specification for Onboard Components

The Component Electromagnetic Compatibility should be evaluated for the following items.

CE : Conducted Emission

Measured value on the current probe (30 Hz – 1 MHz) with the power lines (HOT/RETURN) should be less than CE limitation shown in Figure 12.2-1a. Test configuration is shown in Figure 12.2-1b.

Related MIL-Standard	Remarks
CE01	30 Hz – 20 kHz
CE02	20 kHz – 1 MHz

RE : Radiated Emission

Narrow band electrical field intensity measured by an antenna (20 Hz – 1 MHz) should be less than RE limitation shown in Figure 12.2-2a. Test configuration is shown in Figure 12.2-2b.

Related MIL-Standard	Remarks
RE02	20 Hz – 1 MHz

Magnetic Field Intensity

Magnetic flux density at any point 1 m apart from the component should meet the following specifications.

- (1) DC magnetic field should be less than 5 nT.
- (2) AC magnetic field below 29 Hz should be less than 0.3 nT.

Switching Frequency

The switching frequency of switching regulator for DC/DC converter etc., should be one of the harmonic frequencies of 100 kHz or 160 kHz, and more than 33 kHz.

CS : Conducted Susceptibility

All the component should not operate at fault or result in inferior performance, even if the other noise besides converter ripple and noise, should be added in the power line. The CS specification is shown in Table 12.2-1

Frequency	Specification
0.1 Hz – 400 MHz	1.0 V _{p-p}

Table 12.2-1 PLANET-B CS Specification

Rush Current

The rush current value caused by "primary power line turned-on" and "relay turned-on in power line" etc., should be less than limitation specified in Figure 12.2-3a. For the component with PSU, the rush current specification is given in Figure 12.2-3b and c. The measurement configuration is shown in Figure 12.2-3d.

12.2.2 EMC Design Standard for Onboard Components

All the onboard components should be designed in accordance with following design standard to meet with the PLANET-B EMC specification.

Shielding for Enclosure

Discontinuities on the component enclosure shall be as little as possible. Material for enclosure and screw should be basically aluminum or titanium. Stainless steel and steel screw are not preferable for the components.

Magneto Substance

The use of magnetizer such as permanent magnet and electromagnet should be minimized. If it is unavoidable, stray magnetic field should be made as little as possible, for instance, by putting a cancel magnet.

Filtering for Power Line

Suitable filters should be installed in the component to prevent noise leakage through the power line.

Suppression of Rush Current

The component with a large in-rush current should take a stepwise turn-on sequence to suppress its in-rush current.

Wire Harness Routing

The wire harness should be routed to minimize its current loop area. The twisted pair shielding line should be used for large current lines, even if its current loop area is small.

12.2.3 System EMC Test

The system EMC test shall be carried out as one of the system function tests during the ground testing at ISAS. The whole spacecraft system shall be set in the magnetic shield chamber and measurements shall be carried out for all the spacecraft operation mode, to see any interference between onboard components, and to get total noise level for each scientific instrument.

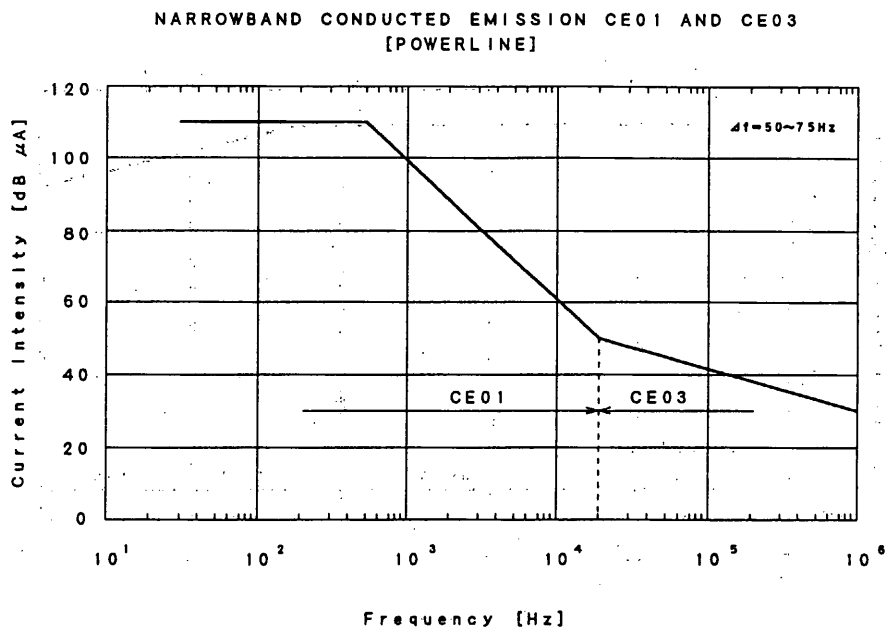


Figure 12.1-1a: PLANET-B CE Specification.

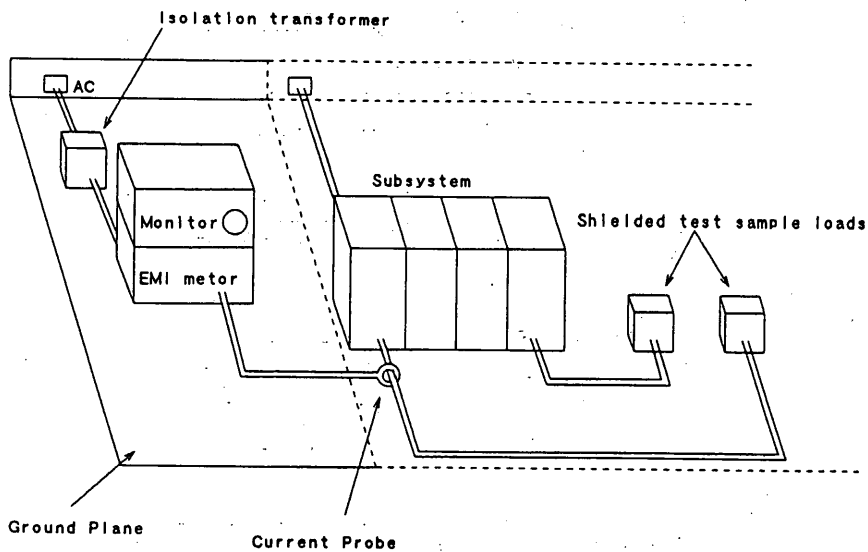


Figure 12.1-1b: Test Configuration for CE measurement.

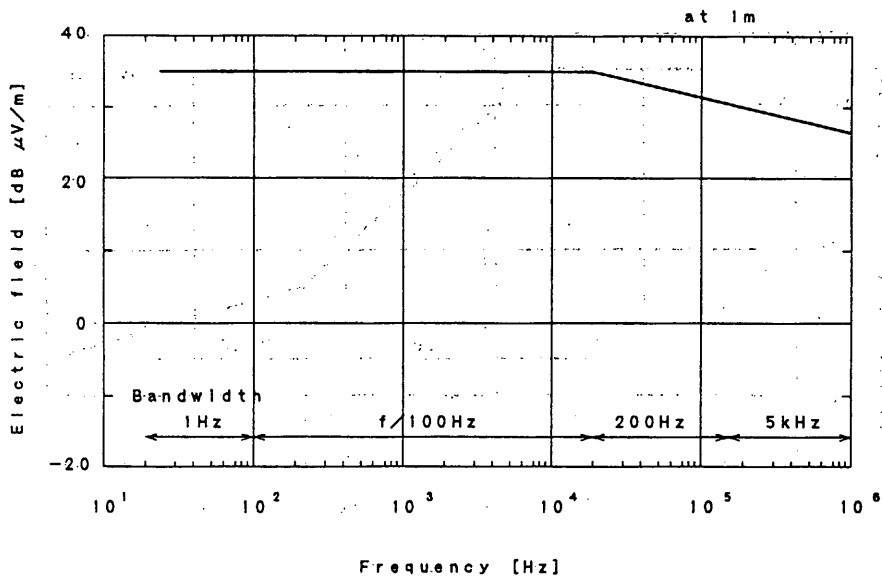
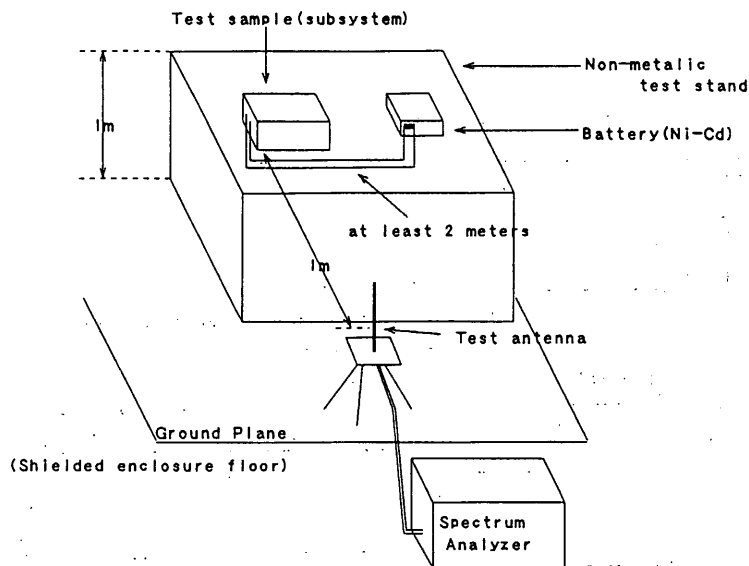


Figure 12.1-2a. PLANET-B RE Specification.



NOTES:

- ① Height of test antenna shall be adjusted for maximum pickup levels.
- ② Power line between Battery and subsystem shall be twisted.

Figure 12.1-2b. Test Configuration for RE measurement.

Items	Specification
ΔI_{mp}	N/A
I_{mp}	$< 5 \times I_n$
T_1	$< 500 \mu \text{ sec}$
ΔI_p	$< 50,000 \text{ A/sec}$
I_p	$< 2 \times I_n$
T_2	$< 50 \text{ m sec}$

I_n : Steady current in max current mode
 I_{mp} : Momentary current
 ΔI_{mp} : Momentary current fluctuation rate
 T_1 : show in figure below
 I_p : Peak current value
 ΔI_p : Current fluctuation rate
 T_2 : show in figure below

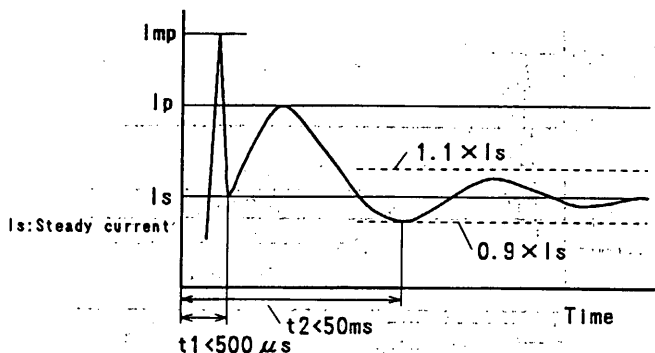


Figure 12.1-3a. Specification for Rush Current at Primary Power Line Turned-on.

Items	Specification
ΔI_{mp}	N/A
I_{mp}	$< 3 \times I_n$
T_1	$< 50 \mu \text{ sec}$
ΔI_p	$< 50,000 \text{ A/sec}$
I_p	$< 2 \times I_n$
T_2	$< 50 \text{ m sec}$

I_n : Steady current in max current mode
 I_{mp} : Momentary current
 ΔI_{mp} : Momentary current fluctuation rate
 T_1 : show in figure below
 I_p : Peak current value
 ΔI_p : Current fluctuation rate
 T_2 : show in figure below

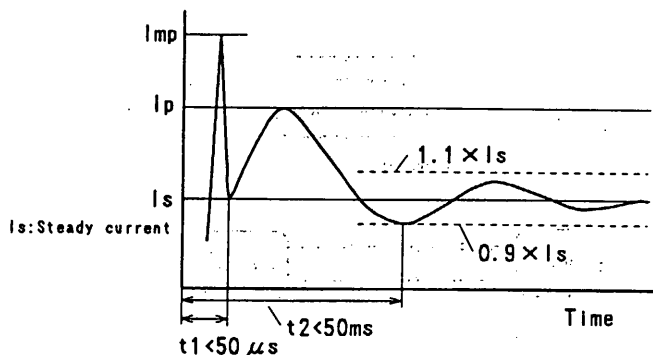


Figure 12.1-3b. Specification for Rush Current at Secondary Power Line Turned-on.

Items	Specification
ΔI_{mp}	N/A
I_{mp}	$< 3 \times I_n$
T_1	$< 50 \mu \text{ sec}$
ΔI_p	$< 50,000 \text{ A/sec}$
I_p	$< 2 \times I_n$
T_2	$< 50 \text{ m sec}$

I_n : Steady current in max current mode
 I_{mp} : Momentary current
 ΔI_{mp} : Momentary current fluctuation rate
 T_1 : show in figure below
 I_p : Peak current value
 ΔI_p : Current fluctuation rate
 T_2 : show in figure below

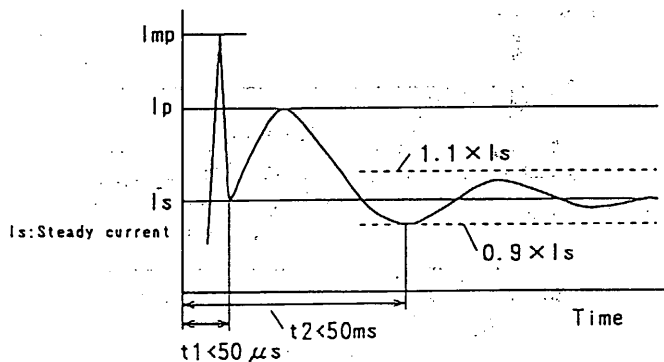


Figure 12.1-3c. Specification for Rush Current at PSU Turned-on.

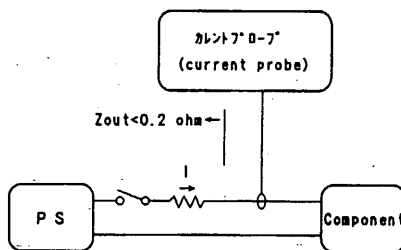


Figure 12.1-3d. Measurement Configuration for Power-on Rush Current.

12.3 Mechanical Test

J. Onoda and K Minesugi (ISAS)
NEC Corporation

12.3.1 Random Vibration Tests

Random Vibration Tests levels at the spacecraft separation plane are shown in Table 12.3-1 and Figure 12.3-1.

12.3.2 Shock Tests

Shock Test level is shown in Table 12.3-2.

Table 12.3-1 Vibration Test Level

Thrust Axis (5.4Grms)	
frequency(Hz)	PSD
20~ 40	0.08 G^2/Hz
40~ 80	-12.0 dB/oct
80~ 364	0.005 G^2/Hz
364~ 400	11.6 dB/oct
400	0.0072 G^2/Hz
400~ 1130	4.4 dB/oct
1130	0.033 G^2/Hz
1130~ 1700	-11.4 dB/oct
1700~ 2000	0.007 G^2/Hz

Lateral Axis (6.8Grms)	
frequency (Hz)	PSD
20	0.02 G^2/Hz
20~ 40	-6.0 dB/oct
40~ 195	0.005 G^2/Hz
195~ 450	6.1 dB/oct
450	0.027 G^2/Hz
450~ 850	2.6 dB/oct
850~ 1200	0.047 G^2/Hz
1200~ 1650	-21.2 dB/oct
1650~ 2000	0.005 G^2/Hz

Table 12.3-2 Shock Test Level

Shock Test Level	thrust axis : +15G 10msec half sine wave , twice lateral axis: not tested

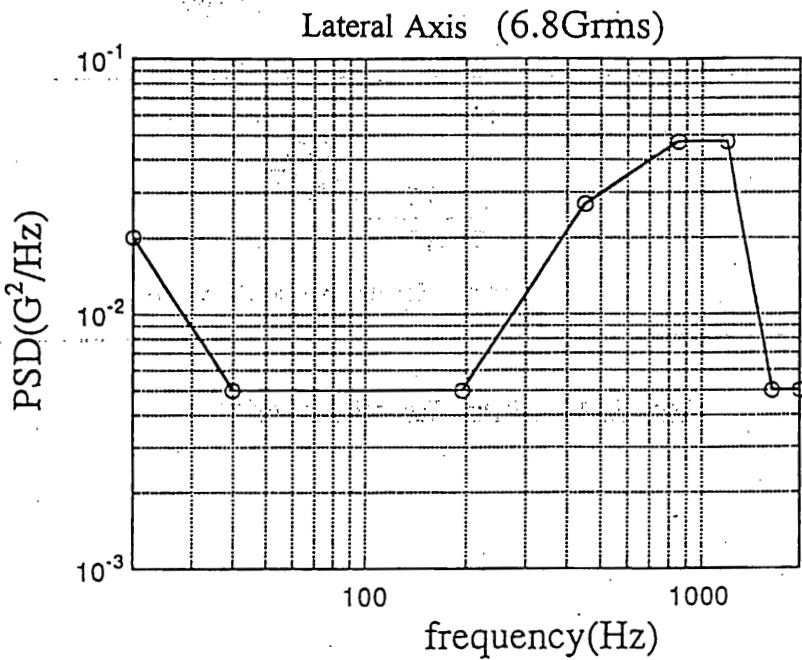
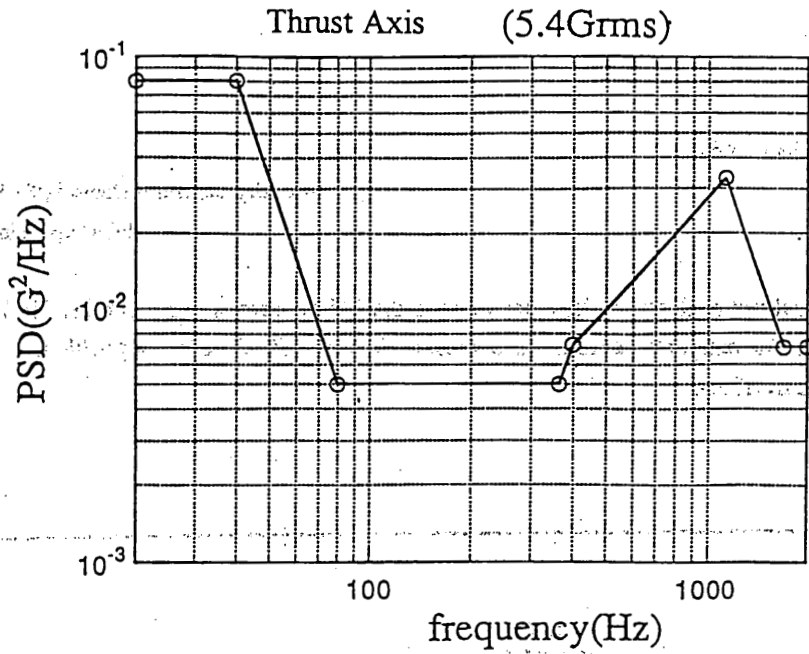


Figure 12.3-1 Vibration Test Level

12.4 Thermal Tests

M.Hashimoto and A.Ohnishi (ISAS)

NEC Corporation

The thermal test of flight model is included in the FM integration test (October 1997 - July 1998). The temperature range of this test is $-30^{\circ}\text{C} \sim +60^{\circ}\text{C}$. And test profile is shown in figure 12.4-1.

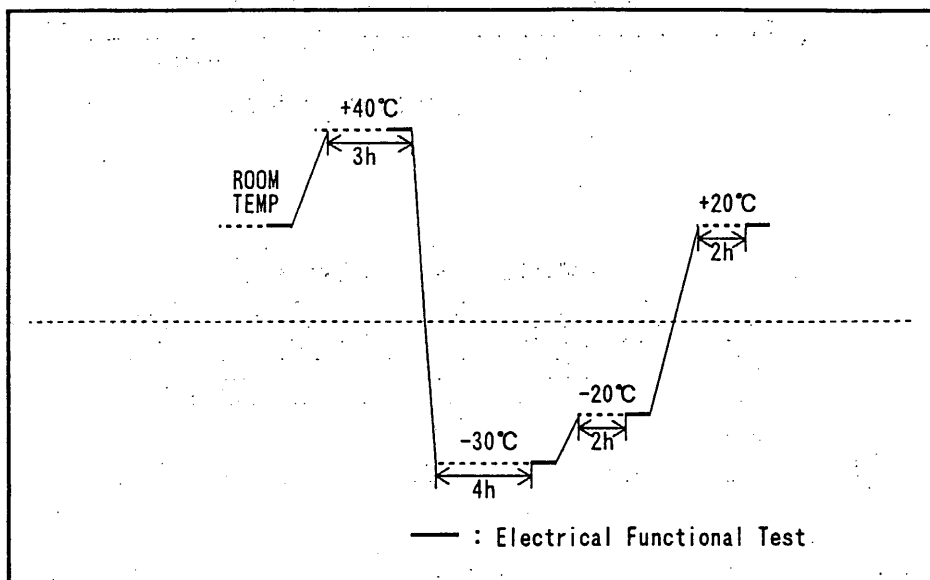


Figure 12.4-1 System Thermal Test Profile

12.5 Thermal Vacuum Test (TVT)

We are thinking of TVT at ISAS. Detailed TVT items are investigated.

12.6 Surface Conductivity Test

TBD

Appendix-A : Telemetry Format

Table A-1 Edition Formats

FORMAT No (HEX)	OPERATIONAL MODE	Number of packets in a packet repetition pattern															REMARK			
		Common Instruments							Scientific Instruments											
		Total	HK	AOCE	DHU	PCD	TCI	DR	HCE	FSA	PWA	MPM	MIC	TPA	IMI	NMS		MDC		
00	N/A																			
01	Launch	64	2	26	0	0	36	0	0	0	0	0	0	0	0	0	0	0	0	S-BAND ONLY
02	AOCS (Maneuver)	64	8	56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
03	Extension [MST]	64	8	32	0	0	0	0	0	0	0	24	0	0	0	0	0	0	0	MST Extension
04	Extension [WANT]	64	8	32	0	0	0	0	0	0	0	24	0	0	0	0	0	0	0	WANT Extension
05	Deployment [TPA]	64	8	32	0	0	0	0	0	0	0	0	0	0	24	0	0	0	0	TPA Boom Deployment
06	Program Check Error	64	8	0	56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Check Error data and address
07	Program Dump	64	8	0	56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Memory dump (BPM&S/S RAM)
08	AOCE Program Dump	64	8	56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	AOCE Memory dump
09	Command Answer Back	64	8	0	56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	CAB
0A	Analysis (Common)	64	16	16	32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Common Instruments
0B	Emergency_1	64	32	32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	UVC or X-TLM Contingency
0C	Emergency_2	64	64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	S/C SURVIVAL MODE
0D	spare																			
0E	spare																			
0F	spare																			
10	Observation_P	64	4	0	0	0	0	0	0	12	16	8	0	8	12	4	0	0	0	Portapsis Mode
11	Observation_S	64	8	0	0	0	0	0	0	12	16	8	0	8	12	0	0	0	0	Standard Mode
12	spare																			
13	UVS/UV	64	8	0	0	0	0	0	0	6	8	32	0	4	6	0	0	0	0	UVS Mode
14	MIC	64	8	0	0	0	0	0	0	6	8	4	28	4	6	0	0	0	0	MIC-data dump Mode
15	WFC-M	64	8	0	0	0	0	0	0	6	36	4	0	4	6	0	0	0	0	WFC-data dump Mode
16	MDC	64	8	0	0	0	0	0	0	6	8	4	0	4	6	0	28	0	0	MDC-data dump Mode
17	spare																			
18	spare																			
19	spare																			
1A	spare																			
1B	spare																			
1C	spare																			
1D	spare																			
1E	spare																			
1F	spare																			

Table A-2 Packet Allocation (1/5)

*1 (FORMAT-01 :Launch)

PS No	0	1	2	3	4	5	6	7
0	HK	EPT/INS	AOCS	EPT/INS	AOCS	EPT/INS	AOCS	EPT/INS
8	EPT/INS	EPT/INS	AOCS	EPT/INS	AOCS	EPT/INS	AOCS	EPT/INS
16	EPT/INS	EPT/INS	AOCS	EPT/INS	AOCS	EPT/INS	AOCS	EPT/INS
24	AOCS	EPT/INS	AOCS	EPT/INS	AOCS	EPT/INS	AOCS	EPT/INS
32	HK	EPT/INS	AOCS	EPT/INS	AOCS	EPT/INS	AOCS	EPT/INS
40	EPT/INS	EPT/INS	AOCS	EPT/INS	AOCS	EPT/INS	AOCS	EPT/INS
48	EPT/INS	EPT/INS	AOCS	EPT/INS	AOCS	EPT/INS	AOCS	EPT/INS
56	AOCS	EPT/INS	AOCS	EPT/INS	AOCS	EPT/INS	AOCS	EPT/INS

(FORMAT-02 :AOCS [Maneuver])

PS No	0	1	2	3	4	5	6	7
0	HK	AOCS	AOCS	AOCS	AOCS	AOCS	AOCS	AOCS
8	HK	AOCS	AOCS	AOCS	AOCS	AOCS	AOCS	AOCS
16	HK	AOCS	AOCS	AOCS	AOCS	AOCS	AOCS	AOCS
24	HK	AOCS	AOCS	AOCS	AOCS	AOCS	AOCS	AOCS
32	HK	AOCS	AOCS	AOCS	AOCS	AOCS	AOCS	AOCS
40	HK	AOCS	AOCS	AOCS	AOCS	AOCS	AOCS	AOCS
48	HK	AOCS	AOCS	AOCS	AOCS	AOCS	AOCS	AOCS
56	HK	AOCS	AOCS	AOCS	AOCS	AOCS	AOCS	AOCS

(FORMAT-03 :Extension [MST])

PS No	0	1	2	3	4	5	6	7
0	HK	AOCS	MPM	AOCS	MPM	AOCS	MPM	AOCS
8	HK	AOCS	MPM	AOCS	MPM	AOCS	MPM	AOCS
16	HK	AOCS	MPM	AOCS	MPM	AOCS	MPM	AOCS
24	HK	AOCS	MPM	AOCS	MPM	AOCS	MPM	AOCS
32	HK	AOCS	MPM	AOCS	MPM	AOCS	MPM	AOCS
40	HK	AOCS	MPM	AOCS	MPM	AOCS	MPM	AOCS
48	HK	AOCS	MPM	AOCS	MPM	AOCS	MPM	AOCS
56	HK	AOCS	MPM	AOCS	MPM	AOCS	MPM	AOCS

(FORMAT-04 :Extension [WANT])

PS No	0	1	2	3	4	5	6	7
0	HK	AOCS	PWA	AOCS	PWA	AOCS	PWA	AOCS
8	HK	AOCS	PWA	AOCS	PWA	AOCS	PWA	AOCS
16	HK	AOCS	PWA	AOCS	PWA	AOCS	PWA	AOCS
24	HK	AOCS	PWA	AOCS	PWA	AOCS	PWA	AOCS
32	HK	AOCS	PWA	AOCS	PWA	AOCS	PWA	AOCS
40	HK	AOCS	PWA	AOCS	PWA	AOCS	PWA	AOCS
48	HK	AOCS	PWA	AOCS	PWA	AOCS	PWA	AOCS
56	HK	AOCS	PWA	AOCS	PWA	AOCS	PWA	AOCS

NOTE *1)"PS No" means Packet Sequence Number.

Table A-2 Packet Allocation (2/5)

*1 (FORMAT-05 :Deployment [TPA])

PS No	0	1	2	3	4	5	6	7
0	HK	AOCS	TPA	AOCS	TPA	AOCS	TPA	AOCS
8	HK	AOCS	TPA	AOCS	TPA	AOCS	TPA	AOCS
16	HK	AOCS	TPA	AOCS	TPA	AOCS	TPA	AOCS
24	HK	AOCS	TPA	AOCS	TPA	AOCS	TPA	AOCS
32	HK	AOCS	TPA	AOCS	TPA	AOCS	TPA	AOCS
40	HK	AOCS	TPA	AOCS	TPA	AOCS	TPA	AOCS
48	HK	AOCS	TPA	AOCS	TPA	AOCS	TPA	AOCS
56	HK	AOCS	TPA	AOCS	TPA	AOCS	TPA	AOCS

(FORMAT-06 :Program Check ERROR)

PS No	0	1	2	3	4	5	6	7
0	HK	CHKERR	CHKERR	CHKERR	CHKERR	CHKERR	CHKERR	CHKERR
8	HK	CHKERR	CHKERR	CHKERR	CHKERR	CHKERR	CHKERR	CHKERR
16	HK	CHKERR	CHKERR	CHKERR	CHKERR	CHKERR	CHKERR	CHKERR
24	HK	CHKERR	CHKERR	CHKERR	CHKERR	CHKERR	CHKERR	CHKERR
32	HK	CHKERR	CHKERR	CHKERR	CHKERR	CHKERR	CHKERR	CHKERR
40	HK	CHKERR	CHKERR	CHKERR	CHKERR	CHKERR	CHKERR	CHKERR
48	HK	CHKERR	CHKERR	CHKERR	CHKERR	CHKERR	CHKERR	CHKERR
56	HK	CHKERR	CHKERR	CHKERR	CHKERR	CHKERR	CHKERR	CHKERR

(FORMAT-07 :Program Dump)

PS No	0	1	2	3	4	5	6	7
0	HK	RAMDMP	RAMDMP	RAMDMP	RAMDMP	RAMDMP	RAMDMP	RAMDMP
8	HK	RAMDMP	RAMDMP	RAMDMP	RAMDMP	RAMDMP	RAMDMP	RAMDMP
16	HK	RAMDMP	RAMDMP	RAMDMP	RAMDMP	RAMDMP	RAMDMP	RAMDMP
24	HK	RAMDMP	RAMDMP	RAMDMP	RAMDMP	RAMDMP	RAMDMP	RAMDMP
32	HK	RAMDMP	RAMDMP	RAMDMP	RAMDMP	RAMDMP	RAMDMP	RAMDMP
40	HK	RAMDMP	RAMDMP	RAMDMP	RAMDMP	RAMDMP	RAMDMP	RAMDMP
48	HK	RAMDMP	RAMDMP	RAMDMP	RAMDMP	RAMDMP	RAMDMP	RAMDMP
56	HK	RAMDMP	RAMDMP	RAMDMP	RAMDMP	RAMDMP	RAMDMP	RAMDMP

(FORMAT-08 :AOCE Program Dump)

PS No	0	1	2	3	4	5	6	7
0	HK	AOCS DMP	AOCS DMP	AOCS DMP	AOCS DMP	AOCS DMP	AOCS DMP	AOCS DMP
8	HK	AOCS DMP	AOCS DMP	AOCS DMP	AOCS DMP	AOCS DMP	AOCS DMP	AOCS DMP
16	HK	AOCS DMP	AOCS DMP	AOCS DMP	AOCS DMP	AOCS DMP	AOCS DMP	AOCS DMP
24	HK	AOCS DMP	AOCS DMP	AOCS DMP	AOCS DMP	AOCS DMP	AOCS DMP	AOCS DMP
32	HK	AOCS DMP	AOCS DMP	AOCS DMP	AOCS DMP	AOCS DMP	AOCS DMP	AOCS DMP
40	HK	AOCS DMP	AOCS DMP	AOCS DMP	AOCS DMP	AOCS DMP	AOCS DMP	AOCS DMP
48	HK	AOCS DMP	AOCS DMP	AOCS DMP	AOCS DMP	AOCS DMP	AOCS DMP	AOCS DMP
56	HK	AOCS DMP	AOCS DMP	AOCS DMP	AOCS DMP	AOCS DMP	AOCS DMP	AOCS DMP

NOTE *1)"PS No" means Packet Sequence Number.

Table A-2 Packet Allocation (3/5)

*1 (FORMAT-09 :Command Answer Back)

PS No	0	1	2	3	4	5	6	7
0	HK	CAB	CAB	CAB	CAB	CAB	CAB	CAB
8	HK	CAB	CAB	CAB	CAB	CAB	CAB	CAB
16	HK	CAB	CAB	CAB	CAB	CAB	CAB	CAB
24	HK	CAB	CAB	CAB	CAB	CAB	CAB	CAB
32	HK	CAB	CAB	CAB	CAB	CAB	CAB	CAB
40	HK	CAB	CAB	CAB	CAB	CAB	CAB	CAB
48	HK	CAB	CAB	CAB	CAB	CAB	CAB	CAB
56	HK	CAB	CAB	CAB	CAB	CAB	CAB	CAB

(FORMAT-0A :Analysis [Common].)

PS No	0	1	2	3	4	5	6	7
0	HK	DHU	AOCS	DHU	HK	DHU	AOCS	DHU
8	HK	DHU	AOCS	DHU	HK	DHU	AOCS	DHU
16	HK	DHU	AOCS	DHU	HK	DHU	AOCS	DHU
24	HK	DHU	AOCS	DHU	HK	DHU	AOCS	DHU
32	HK	DHU	AOCS	DHU	HK	DHU	AOCS	DHU
40	HK	DHU	AOCS	DHU	HK	DHU	AOCS	DHU
48	HK	DHU	AOCS	DHU	HK	DHU	AOCS	DHU
56	HK	DHU	AOCS	DHU	HK	DHU	AOCS	DHU

(FORMAT-0B :Emergency_1)

PS No	0	1	2	3	4	5	6	7
0	HK	AOCS	HK	AOCS	HK	AOCS	HK	AOCS
8	HK	AOCS	HK	AOCS	HK	AOCS	HK	AOCS
16	HK	AOCS	HK	AOCS	HK	AOCS	HK	AOCS
24	HK	AOCS	HK	AOCS	HK	AOCS	HK	AOCS
32	HK	AOCS	HK	AOCS	HK	AOCS	HK	AOCS
40	HK	AOCS	HK	AOCS	HK	AOCS	HK	AOCS
48	HK	AOCS	HK	AOCS	HK	AOCS	HK	AOCS
56	HK	AOCS	HK	AOCS	HK	AOCS	HK	AOCS

(FORMAT-0C :Emergency_2)

PS No	0	1	2	3	4	5	6	7
0	HK	HK	HK	HK	HK	HK	HK	HK
8	HK	HK	HK	HK	HK	HK	HK	HK
16	HK	HK	HK	HK	HK	HK	HK	HK
24	HK	HK	HK	HK	HK	HK	HK	HK
32	HK	HK	HK	HK	HK	HK	HK	HK
40	HK	HK	HK	HK	HK	HK	HK	HK
48	HK	HK	HK	HK	HK	HK	HK	HK
56	HK	HK	HK	HK	HK	HK	HK	HK

NOTE *1)"PS No" means Packet Sequence Number.

Table A-2 Packet Allocation (4/5)

*1 (FORMAT-10 : Observation_P (64K-16K); Periapsis Mode)

PS No	0	1	2	3	4	5	6	7
0	HK	MPM	PWA	PSA	IMI	TPA	PWA	IMI
8	NMS	MPM	PWA	PSA	IMI	TPA	PWA	PSA
16	HK	MPM	PWA	PSA	IMI	TPA	PWA	IMI
24	NMS	MPM	PWA	PSA	IMI	TPA	PWA	PSA
32	HK	MPM	PWA	PSA	IMI	TPA	PWA	IMI
40	NMS	MPM	PWA	PSA	IMI	TPA	PWA	PSA
48	HK	MPM	PWA	PSA	IMI	TPA	PWA	IMI
56	NMS	MPM	PWA	PSA	IMI	TPA	PWA	PSA

(FORMAT-11 : Observation_S (64K-2K,[1K],512,[256,64]; Standard Mode)

PS No	0	1	2	3	4	5	6	7
0	HK	MPM	PWA	PSA	IMI	TPA	PWA	IMI
8	HK	MPM	PWA	PSA	IMI	TPA	PWA	PSA
16	HK	MPM	PWA	PSA	IMI	TPA	PWA	IMI
24	HK	MPM	PWA	PSA	IMI	TPA	PWA	PSA
32	HK	MPM	PWA	PSA	IMI	TPA	PWA	IMI
40	HK	MPM	PWA	PSA	IMI	TPA	PWA	PSA
48	HK	MPM	PWA	PSA	IMI	TPA	PWA	IMI
56	HK	MPM	PWA	PSA	IMI	TPA	PWA	PSA

(FORMAT-13:UVS/XUV (64K-2K); UVS Mode)

PS No	0	1	2	3	4	5	6	7
0	HK	MPM*	MPM	MPM*	PWA	MPM*	PSA	MPM*
8	HK	IMI	MPM*	TPA	MPM*	PWA	MPM*	IMI
16	HK	MPM*	MPM	MPM*	PWA	MPM*	PSA	MPM*
24	HK	IMI	MPM*	TPA	MPM*	PWA	MPM*	PSA
32	HK	MPM*	MPM	MPM*	PWA	MPM*	PSA	MPM*
40	HK	IMI	MPM*	TPA	MPM*	PWA	MPM*	IMI
48	HK	MPM*	MPM	MPM*	PWA	MPM*	PSA	MPM*
56	HK	IMI	MPM*	TPA	MPM*	PWA	MPM*	PSA

(FORMAT-14 : MIC (64K-2K,[256,64]; MIC Mode,MIC Dump)

PS No	0	1	2	3	4	5	6	7
0	HK	MIC*	MPM	MIC*	PWA	MIC*	PSA	MIC*
8	HK	IMI	MIC*	TPA	MIC*	PWA	MIC*	IMI
16	HK	MIC*	MPM	MIC*	PWA	MIC*	PSA	MIC*
24	HK	IMI	MIC*	TPA	MIC*	PWA	MIC*	PSA
32	HK	MIC*	MPM	MIC*	PWA	MIC*	PSA	MIC*
40	HK	IMI	MIC*	TPA	MIC*	PWA	MIC*	IMI
48	HK	MIC*	MPM	MIC*	PWA	MIC*	PSA	MIC*
56	HK	IMI	MIC*	TPA	MIC*	PWA	MIC*	PSA

NOTE *1)"PS No" means Packet Sequence Number.

Table A-2 Packet Allocation (5/5)

*1

(FORMAT-15 :WFC-M (64K-2K,[256,64];WFC-M Dump)

PS No	0	1	2	3	4	5	6	7
0	HK	PWA*	MPM	PWA*	PWA	PWA*	PSA	PWA*
8	HK	IMI	PWA*	TPA	PWA*	PWA	PWA*	IMI
16	HK	PWA*	MPM	PWA*	PWA	PWA*	PSA	PWA*
24	HK	IMI	PWA*	TPA	PWA*	PWA	PWA*	PSA
32	HK	PWA*	MPM	PWA*	PWA	PWA*	PSA	PWA*
40	HK	IMI	PWA*	TPA	PWA*	PWA	PWA*	IMI
48	HK	PWA*	MPM	PWA*	PWA	PWA*	PSA	PWA*
56	HK	IMI	PWA*	TPA	PWA*	PWA	PWA*	PSA

(FORMAT-16 :MDC(64K-2K,[256,64];MDC Dump)

PS No	0	1	2	3	4	5	6	7
0	HK	MDC*	MPM	MDC*	PWA	MDC*	PSA	MDC*
8	HK	IMI	MDC*	TPA	MDC*	PWA	MDC*	IMI
16	HK	MDC*	MPM	MDC*	PWA	MDC*	PSA	MDC*
24	HK	IMI	MDC*	TPA	MDC*	PWA	MDC*	PSA
32	HK	MDC*	MPM	MDC*	PWA	MDC*	PSA	MDC*
40	HK	IMI	MDC*	TPA	MDC*	PWA	MDC*	IMI
48	HK	MDC*	MPM	MDC*	PWA	MDC*	PSA	MDC*
56	HK	IMI	MDC*	TPA	MDC*	PWA	MDC*	PSA

The others ; SPARE

Table A-3 Operation Matrix

FORMAT No (HEX)	OPERATION MODE		BIT RATE													REMARKS
			RECORD													
			X-REAL(Kbps)						S-REAL(bps)							
			64	32	16	8	4	2	1k	512	256	128	64			
00	N/A		-	-	-	-	-	-	-	-	-	-	-			
01	Launch	REC	-	-	-	N	-	-	-	-	-	-	-			
		REAL	-	-	-	-	-	-	N	-	-	-	-			
02	AOCS (Maneuver)	REC	-	-	-	N	-	-	-	-	-	-	-			
		REAL	-	-	-	N	N	N	N	N	N	N	N			
03	Extension [MST]	REC	-	-	-	-	B	-	-	-	-	-	-			
		REAL	-	-	-	-	N	-	-	-	-	B	-			
04	Extension [WANT]	REC	-	-	-	-	B	-	-	-	-	-	-			
		REAL	-	-	-	-	N	-	-	-	-	B	-			
05	Deployment [TPA]	REC	-	-	-	-	B	-	-	-	-	-	-			
		REAL	-	-	-	-	N	-	-	-	-	B	-			
06	Program Check ERROR	REC	-	-	-	-	-	-	-	-	-	-	-			
		REAL	-	N	N	N	N	N	N	-	-	-	B	↑		
07	Program Dump	REC	-	-	-	-	-	-	-	-	-	-	-			
		REAL	-	N	N	N	N	N	N	-	-	-	B	S-REAL 1Kbps will be use		
08	AOCE Program Dump	REC	-	-	-	-	-	-	-	-	-	-	-			
		REAL	-	N	N	N	N	N	N	-	-	-	B	In Parking and Trans-MARS orbit		
09	Command Answer Back	REC	-	-	-	-	-	-	-	-	-	-	-			
		REAL	-	N	N	N	N	N	N	-	-	-	B			
0A	Analysis	REC	-	-	-	-	-	-	-	-	-	-	-			
		REAL	-	N	N	N	N	N	N	-	-	-	B	↓		
0B	Emergency_1	REC	-	-	-	-	-	-	-	-	-	-	-			
		REAL	-	-	-	-	-	-	-	-	-	-	N			
0C	Emergency_2	REC	-	-	-	-	-	-	-	-	-	-	-			
		REAL	-	-	-	-	-	-	-	-	-	-	N			
0D	SPARE		-	-	-	-	-	-	-	-	-	-	-			
0E	SPARE		-	-	-	-	-	-	-	-	-	-	-			
0F	SPARE		-	-	-	-	-	-	-	-	-	-	-			
10	Observation P	REC	N	N	TBD	-	-	-	-	-	-	-	-	↑ Perilapsis mode		
		REAL	-	N	TBD	-	-	-	-	-	-	-	-	↓		
11	Observation S	REC	N	N	-	-	-	-	-	N	-	-	-	↑ Standard observation		
		REAL	-	N	N	N	N	N	B	-	B	-	B	↓ mode		
12	SPARE	REC	-	-	-	-	-	-	-	-	-	-	-			
		REAL	-	-	-	-	-	-	-	-	-	-	-			
13	UVS/XUV	REC	N	N	N	N	N	N	-	-	-	-	-	↑ UVS mode		
		REAL	-	N	N	N	N	N	-	-	-	-	-	↓		
14	MIC	REC	N	N	-	-	-	-	-	-	-	-	-	MIC mode		
		REAL	-	N	N	N	N	N	-	-	B	-	B	MIC-dump		
15	WFC-M	REC	-	-	-	-	-	-	-	-	-	-	-			
		REAL	-	N	N	N	N	N	-	-	B	-	B	WFC-M-dump		
16	MDC	REC	-	-	-	-	-	-	-	-	-	-	-			
		REAL	-	N	N	N	N	N	-	-	B	-	B	MDC-dump		
17	SPARE		-	-	-	-	-	-	-	-	-	-	-			
18	SPARE		-	-	-	-	-	-	-	-	-	-	-			
19	SPARE		-	-	-	-	-	-	-	-	-	-	-			
1A	SPARE		-	-	-	-	-	-	-	-	-	-	-			
1B	SPARE		-	-	-	-	-	-	-	-	-	-	-			
1C	SPARE		-	-	-	-	-	-	-	-	-	-	-			
1D	SPARE		-	-	-	-	-	-	-	-	-	-	-			
1E	SPARE		-	-	-	-	-	-	-	-	-	-	-			
1F	SPARE		-	-	-	-	-	-	-	-	-	-	-			

NOTE: N: Normal mode
B: Back up for TMX and/or DR failure

Table A-4 Cyclic Period per Bit Rate and Repetition Packet Size

BIT RATE (BPS)	Cyclic Period (sec or minute)								Rec/Real	
	64 packets	*1 32 packets	16 packets	8 packets	4 packets	2 packets	1 packet		Rec	Real
65536	4 s	2 s	1 s	0.5 s	0.25 s	0.125 s	0.063 s		use	N/A
32768	8 s	4 s	2 s	1 s	0.5 s	0.25 s	0.125 s		use	use
16384	16 s	8 s	4 s	2 s	1 s	0.5 s	0.25 s		use	use
8192	32 s	16 s	8 s	4 s	2 s	1 s	0.5 s		use	use
4096	64 s	32 s	16 s	8 s	4 s	2 s	1 s		use	use
2048	2.1 m	64 s	32 s	16 s	8 s	4 s	2 s		use	use
1024	4.3 m	2.1 m	64 s	32 s	16 s	8 s	4 s		use	use
512	8.5 m	4.3 m	2.1 m	64 s	32 s	16 s	8 s		use	use
256	17.1 m	8.5 m	4.3 m	2.1 m	64 s	32 s	16 s		use	use
128	34.1 m	17.1 m	8.5 m	4.3 m	2.1 m	64 s	32 s		use	use
64	68.3 m	34.1 m	17.1 m	8.5 m	4.3 m	2.1 m	64 s		use	use

NOTE : 1) Repetition packet size for each Format

Table A-5 Types of Packets

Packet ID CODE NAME (HEX)	Using S/S Name	MAIN DATA	PURPOSE
00	N/A		
01	HK	ALL S/S	Standard Observation
02	DHU	DHU	DHU error check
03	CHKERR	DHU(Using RAM S/S)	On-board comparison with BFM
04	RAMDMP	DHU(Using RAM S/S)	Memory Dump to Ground
05	AOCSDMP	AOCE	Memory Dump to Ground
06	CAB	DHU(checking S/S)	S/C check
07	AOCS	AOCE	Launch/Maneuver
08	EPT/INS	TCI(EPT-SA/INS-SA)	Launch
09	spare		
0A	spare		
0B	spare		
0C	spare		
0D	spare		
0E	spare		
0F	spare		
10	MPM	MGF/UVS/MST	
11	PSA	ESA/ISA/EIS/XUV	Observation
12	PWA	PWS/LFA	
13	MIC	MIC	
14	TPA	TPA	
15	IMI	IMI	
16	MDC	MDC	
17	NMS	NMS	
18	spare		
19	spare		
1A	spare		
1B	spare		
1C	spare		
1D	spare		
1E	spare		
1F	spare		

Table A-6a Transfer Frame Structure

SYNC. MARKER		CHANNEL ACCESS SLOT										SYNC. MARKER				
.Sync Marker "1ACFFC1D"h (32)*1		Channel Access Slot (4064)														
Transfer Frame Header (48)							Packet Data (3488)		CLCW(16)							Reed Solomon Check Symbol
Ver. No.	VCDU ID (14)		Virtual ch. Unit Count	Signaling Field (8)	Replay Spare Flag	Packet Header	User Data Field	Spare	RF Lock	CMD Dec. Lock	CMD Dec. Error	CMD Dec. Bit rate	Receiver Select	CMD Retransmit Request	Frame No.	
	Space-craft ID (8)	Virtual ch. ID (6)														
(2)			(24)	(1)	(7)	(32)	(3456)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(8)	(512)
01	TBD	000001:REAL DATA 000010:REP. DATA 111111:FILL DATA	000000h ~ FFFFFFh	00h				0		1: on 0:off	1:err 0:no err.	1:Hi 0:Lo	1:B 0:A	1:Request 0:No req.	00h ~ FFh	

NOTE *1 : (X) A number of bit in the section.

*2 : SBR-A SQ 1=ON,0=OFF

*3 : SBR-B SQ 1=ON,0=OFF

Table A-6b Packet Data Structure

Packet Header (32)*1		User Data Field (3456)				
Spare	Packet	Time	Secondary header (24) *3			Application
	ID	Code*2	Data Type ID*4	Packet Sequence Control		Data
(2)	(6)	(24)	(8)	Sequence Flags	Packet Sequence Control	
			(2)	(14)		
Generated by User						
↑						
↓						
User Data Field (432bytes=3456bits)						
Data 1						
Bit0	Bit1	Bit2	Bit3	Bit4	Bit5	Bit6
Bit7						
MSB						LSB
RD7	RD6	RD5	RD4	RD3	RD2	RD1
						RD0
←PIM Signal ID						
.....					Data 432	

NOTE *1: (X) A number of bit in the section.

*2: MSB=524288sec, LSB=31.25msec

*3: Each User can use the secondary header, if necessary. Use or No use is decided as each packet ID.

Table A-7 Data type ID Structure in Secondary Header

	PACKET ID	B0 MSB	B1	B2	B3	B4	B5	B6	B7 LSB
GENERAL	N/A	1:To need compare with program on the system ground support equipment. 0:Except above data	spare			Definition by each subsystems			

PACKET NAME	PACKET ID	B0 MSB	B1	B2	B3	B4	B5	B6	B7 LSB
RAMDMP	07	1	0			PIM ID			
AOCSDMP	08	0	0			AOCS Identification ID			

Table A-8 PIM ID Code

PIM ID (Hex)	S/S NAME
01	DHU
02	AOCE
03	TCI
04	HCE
05	PCD
06	DR
07	PSA
08	PWA
09	MPM
0A	MIC
0B	IMI
0C	MDC
0D	TPA
0E	NMS

Appendix-B : HK Items

Table B-1 HK Packet Structure (2/2)

- Bilevel DATA -

Word #1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Packet ID	Time Code															
0	0th															
16	DHU 13 (01,8008)	DHU 14 (01,8010)	DHU 15 (01,8011)	DHU 16 (01,8000)	DHU 17 (01,FFFF)	DHU 18 (01,FFFF)	DHU 19 (01,FFFF)	DHU 20 (01,FFFF)	DHU 21 (01,FFFF)	DHU 22 (01,FFFF)	DHU 23 (01,FFFF)	DHU 24 (01,FFFF)	DHU 25 (01,FFFF)	DHU 26 (01,FFFF)	DHU 27 (01,FFFF)	DHU 28 (01,FFFF)
32	DHU 29 (01,FFFF)	DHU 30 (01,FFFF)	DHU 31 (01,FFFF)	DHU 32 (01,FFFF)	DHU 33 (01,FFFF)	DHU 34 (01,FFFF)	DHU 35 (01,FFFF)	DHU 36 (01,FFFF)	DHU 37 (01,FFFF)	DHU 38 (01,FFFF)	DHU 39 (01,FFFF)	DHU 40 (01,FFFF)	DHU 41 (01,FFFF)	DHU 42 (01,FFFF)	DHU 43 (01,FFFF)	DHU 44 (01,FFFF)
48	AOCE 2 (02,8000)	AOCE 3 (02,8001)	AOCE 4 (02,8002)	AOCE 5 (02,8003)	AOCE 6 (02,8004)	AOCE 7 (02,8005)	AOCE 8 (02,8006)	AOCE 9 (02,8007)	AOCE 10 (02,8015)	AOCE 11 (02,8009)	AOCE 12 (02,800A)	AOCE 13 (02,800B)	AOCE 14 (02,800C)	AOCE 15 (02,800D)	AOCE 16 (02,800E)	AOCE 17 (02,800F)
64	AOCE 18 (02,8010)	AOCE 19 (02,8011)	AOCE 20 (02,8012)	AOCE 21 (02,8013)	AOCE 22 (02,8014)	TCI 1 (03,8000)	TCI 2 (03,8001)	TCI 3 (03,8002)	TCI 4 (03,8003)	TCI 5 (03,8004)	TCI 6 (03,8005)	HCE 1 (04,8000)	HCE 2 (04,8001)	HCE 3 (04,8002)	HCE 4 (04,8003)	HCE 5 (04,8004)
80	HCE 6 (04,8005)	HCE 7 (04,8006)	HCE 8 (04,8007)	HCE 9 (04,8008)	HCE 10 (04,8009)	PCD 1 (05,8000)	PCD 2 (05,8001)	PCD 3 (05,8002)	PCD 4 (05,8003)	PCD 5 (05,8004)	PCD 6 (05,8005)	PCD 7 (05,8006)	DR 1 (06,8000)	DR 2 (06,8001)	DR 3 (06,8002)	DR 4 (06,8003)
96	DR 5 (06,8004)	DR 6 (06,8005)	DR 7 (06,8006)	DR 8 (06,8007)	PSA 1 (07,8000)	PSA 2 (07,8001)	PSA 3 (07,8002)	PSA 4 (07,8003)	PSA 5 (07,8004)	SPARE (08,0000)	MIC 1 (0A,8000)	MIC 2 (0A,8001)	MIC 3 (0A,8002)	MIC 4 (0A,8003)	MIC 5 (0A,8004)	MIC 6 (0A,8005)
112	IM11 (0B,8000)	IM12 (0B,8001)	IM13 (0B,8002)	SPARE (0C,0000)	MPM1 (09,8000)	MPM2 (09,8001)	MPM3 (09,8002)	MPM4 (09,8003)	MPM5 (09,8004)	SPARE (0C,0000)	MDC 1 (0C,8000)	MDC 2 (0C,8001)	SPARE (0E,0000)	NMS1 (0E,8000)	NMS2 (0E,8001)	NMS3 (0E,8002)
128	PWA 1 (08,8000)	PWA 2 (08,8001)	PWA 3 (08,8002)	PWA 4 (08,8003)	PWA 5 (08,8004)	PWA 6 (08,8005)	PWA 7 (08,8006)	PWA 8 (08,8007)	PWA 9 (08,8008)	PWA 10 (08,8009)	PWA 11 (08,800A)	PWA 12 (08,800B)	PWA 13 (08,800C)	PWA 14 (08,800D)	PWA 15 (08,800E)	PWA 16 (08,800F)
144	TPA1 (0D,8000)	TPA2 (0D,8001)	TPA3 (0D,8002)	TPA4 (0D,8003)	AOC S1 (02,8000)	AOC S2 (02,8001)	AOC S3 (02,8002)	AOC S4 (02,8003)	AOC S5 (02,8004)	AOC S6 (02,8005)	AOC S7 (02,8006)	AOC S8 (02,8007)	AOC S9 (02,8008)	AOC S10 (02,8009)	AOC S11 (02,800A)	AOC S12 (02,800B)
160	AOC S13 (02,800C)	AOC S14 (02,800D)	AOC S15 (02,800E)	AOC S16 (02,800F)	AOC S17 (02,8010)	AOC S18 (02,8011)	AOC S19 (02,8012)	AOC S20 (02,8013)	AOC S21 (02,8014)	AOC S22 (02,8015)	AOC S23 (02,8016)	AOC S24 (02,8017)	AOC S25 (02,8018)	AOC S26 (02,8019)	AOC S27 (02,801A)	AOC S28 (02,801B)
176	AOC S29 (02,801C)	AOC S30 (02,801D)	AOC S31 (02,801E)	AOC S32 (02,801F)	AOC S33 (02,8020)	AOC S34 (02,8021)	AOC S35 (02,8022)	AOC S36 (02,8023)	AOC S37 (02,8024)	AOC S38 (02,8025)	AOC S39 (02,8026)	AOC S40 (02,8027)	AOC S41 (02,8028)	AOC S42 (02,8029)	AOC S43 (02,802A)	AOC S44 (02,802B)
192	AOC S45 (02,802C)	AOC S46 (02,802D)	AOC S47 (02,802E)	AOC S48 (02,802F)	AOC S49 (02,8030)	AOC S50 (02,8031)	AOC S51 (02,8032)	AOC S52 (02,8033)	AOC S53 (02,8034)	AOC S54 (02,8035)	AOC S55 (02,8036)	AOC S56 (02,8037)	AOC S57 (02,8038)	AOC S58 (02,8039)	AOC S59 (02,803A)	AOC S60 (02,803B)
208	AOC S61 (02,803C)	AOC S62 (02,803D)	AOC S63 (02,803E)	AOC S64 (02,803F)												

NOTE #1: "W0" is located a head of Packet data.

PIM ID CODE PIM IP ADDRESS

Table B-1 HK Packet Structure (1/2)
- 8Bits DATA (Analog)-

Word #1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
208	MIC-I (05.8013)	TPA-I (05.8014)	IMI-I (05.8015)	MDC-I (05.8016)	SCP-I (05.8007)	LOAD-I (05.8008)	BATA-I (05.8009)	BATB-I (05.800A)	DHU-I (05.800B)	AOCE-I (05.800C)	RF-I (05.800D)	FSU_C1-I (05.800E)	HTR-I (05.800F)	MPM-I (05.8010)	PSA-I (05.8011)	PWA-I (05.8012)
224	B_PNL2-I (04.8013)	U_PNL1-I (04.8014)	IMI-I (05.8015)	MDC-I (05.8016)	NMS-I (05.8017)	PCD-SPARE (05.8018)	BUS-V (05.8019)	BATA-V (05.801A)	BATB-V (05.801B)	PCD+5V (05.801C)	PCD+12V (05.801D)	PCD-12V (05.801E)	PCD-SPARE (05.801F)	B_PNL1-I (04.8010)	B_PNL2-I (04.8011)	B_PNL3-I (04.8012)
240	B_PNL2-I (04.8013)	U_PNL1-I (04.8014)	IMI-I (05.8015)	MDC-I (05.8016)	NMS-I (05.8017)	PCD-SPARE (05.8018)	BUS-V (05.8019)	BATA-V (05.801A)	BATB-V (05.801B)	PCD+5V (05.801C)	PCD+12V (05.801D)	PCD-12V (05.801E)	PCD-SPARE (05.801F)	B_PNL1-I (04.8010)	B_PNL2-I (04.8011)	B_PNL3-I (04.8012)
256	HTNK1-I (04.8023)	HTNK2-I (04.8024)	NTNK1-I (04.8025)	NTNK2-I (04.8026)	GTNK1-I (04.8027)	GTNK2-I (04.8028)	RCSPIP1-I (04.8029)	RCSPIP2-I (04.802A)	RCSPIP3-I (04.802B)	RCSPIP4-I (04.802C)	RCSPIP5-I (04.802D)	OMSPIP1-I (04.802E)	OMSPIP2-I (04.802F)	VLVMA-I (04.8030)	VLVMB-I (04.8031)	VLVMC-I (04.8032)
272	OMEL-I (04.8033)	OME2-I (04.8034)	EMAI-I (04.8035)	EMA2-I (04.8036)	EMBI-I (04.8037)	EMB2-I (04.8038)	THRA1-I (04.8039)	THRA2-I (04.803A)	THRA3-I (04.803B)	THRA4-I (04.803C)	THRT1-I (04.803D)	THRT2-I (04.803E)	THRT3-I (04.803F)	THRT4-I (04.8040)	THRR1-I (04.8041)	THRR2-I (04.8042)
288	XPA-I (04.8043)	HTNK SET-I (04.8044)	NTNK SET-I (04.8045)	GTNK SET-I (04.8046)	PIP SET-I (04.8047)	VLV SET-I (04.8048)	OME SET-I (04.8049)	BATA SET-I (04.804A)	BATB SET-I (04.804B)	SSC SET-I (04.804C)	XPA SET-I (04.804D)	HCE SPARE (04.804E)	HTNK P (04.804F)	NTNK P (04.8050)	GTNK P (04.8051)	RCSLNI-P (04.8052)
304	RCSLNI2-P (04.8053)	OMSLNI-P (04.8054)	OMSLNI2-P (04.8055)	HCE SPARE (04.8056)	RF+5V (03.8010)	RF+12V (03.8011)	RF-12V (03.8012)	DHU+5V (03.8013)	DHU+12V (03.8014)	ACMB-I (03.8015)	SBR-A (03.8016)	CMD-I (03.8017)	TMS-I (03.8018)	TMX-I (03.8019)	XPA-I (03.801A)	SBR-A-GC (03.801B)
320	SBR-A-LPS (03.801C)	SBRB-AGC (03.801D)	SBRB-LPS (03.801E)	PSA-E-T (03.801F)	ISA-S-T (03.8020)	PSU_C1-5V (03.8021)	PSU_C1-12V (03.8022)	ACMA-I (03.8023)	ACMB-I (03.8024)	ACMC-I (03.8025)	ACMD-I (03.8026)	AOCE+5V (03.8027)	AOCE+12V (03.8028)	AOCE+15V (03.8029)	AOCE+18V (03.802A)	AOCE+20V (03.802B)
336	AOCE-SPARE (02.8029)	AOCE-SPARE (02.802A)	PSA-E-T (03.801F)	ISA-S-T (03.8020)	ISA-S-T (03.8020)	XUV-S-T (07.8013)	XUV-MCP-T (07.8014)	ESA-HVIN (07.8015)	ESA-MESH (07.8016)	ESA-HVOUT (07.8017)	ISA-HV (07.8018)	XUV-HV (07.8019)	EIS-S-T (07.801A)	EIS+5V (07.801B)	EIS+12V (07.801C)	EIS+15V (07.801D)
352	EIS-MCP (07.801E)	EIS-SSD (07.801F)	LFA-E-T (07.8010)	PWS-RX-T (07.8011)	SFW-AMP-T (07.8012)	PWA-SPARE (08.8013)	W-PRE1-T (08.8014)	W-PRE2-T (08.8015)	W-PRE3-T (08.8016)	W-PRE4-T (08.8017)	WANT1-T (08.8018)	WANT2-T (08.8019)	WANT3-T (08.801A)	WANT4-T (08.801B)	PWA+5V (08.801C)	PWA+12V (08.801D)
368	PWA+12V (08.801E)	PWA+29V (08.801F)	MGF-E-T (09.8010)	MGF-S-T (09.8011)	PET-I (09.8012)	MIC-T (09.8013)	CLUMP-V (09.8014)	REF-V (09.8015)	THR-V (09.8016)	MIC+5V (09.8017)	MIC+12V (09.8018)	MIC-12V (09.8019)	MIC-SPARE (0A.801A)	MIC-SPARE (0A.801B)	MPM+5V (09.801C)	MPM+12V (09.801D)
384	MPM+12V (09.801E)	MPM+29V (09.801F)	MGF-E-T (09.8010)	MGF-S-T (09.8011)	PET-I (09.8012)	MIC-T (09.8013)	CLUMP-V (09.8014)	REF-V (09.8015)	THR-V (09.8016)	MIC+5V (09.8017)	MIC+12V (09.8018)	MIC-12V (09.8019)	MIC-SPARE (0A.801A)	MIC-SPARE (0A.801B)	MPM+5V (09.801C)	MPM+12V (09.801D)
400	CREADLE-T (0D.F806)	BOOK C_RES (09.801F)	IMI-I (0B.F807)	IMI-HV1 (0B.F808)	IMI-HV2 (0B.F809)	IMI-HV3 (0B.F80A)	IMI-HV4 (0B.F80B)	IMI-T1-T (0B.F80C)	IMI-T2-T (0B.F80D)	IMI-T3-T (0B.F80E)	IMI-T4-T (0B.F80F)	IMI-T5-T (0B.F800)	IMI-T6-T (0B.F801)	IMI-T7-T (0B.F802)	IMI-T8-T (0B.F803)	IMI-T9-T (0B.F804)
416	MDC-T (0C.F804)	MDC-TCC (0C.F805)	MDC-IMPC (0C.F806)	MDC-NC1 (0C.F807)	MDC-NC2 (0C.F808)	MDC-NC3 (0C.F809)	MDC-EC (0C.F80A)	NMS-A-1 (0E.F80B)	NMS-A-2 (0E.F80C)	NMS-A-3 (0E.F80D)	NMS-A-4 (0E.F80E)	NMS-A-5 (0E.F80F)	NMS-A-6 (0E.F800)	NMS-A-7 (0E.F801)	NMS-A-8 (0E.F802)	NMS-A-9 (0E.F803)
432	NMS-A-10 (0E.F80C)	SPARE (00.0000)	SPARE (00.0000)	SPARE (00.0000)	SPARE (00.0000)	SPARE (00.0000)	SPARE (00.0000)	SPARE (00.0000)	SPARE (00.0000)	SPARE (00.0000)	SPARE (00.0000)	SPARE (00.0000)	SPARE (00.0000)	SPARE (00.0000)	SPARE (00.0000)	SPARE (00.0000)

NOTE *1: "W0" is located a head of Packet data.

PIM ID CODE PIM I/F ADDRESS

Table B-2 Bilevel Data List (1/11)

ADRS (Hex)	WORD	Bit	ITEM	STATUS	
				1	0
8024	DHU 1 (w 4)	B0	42°26sec = 776.7 day	MSB	
		B1	2°25		
		B2	2°24		
		B3	2°23		
		B4	2°22		
		B5	2°21		
		B6	2°20		
		B7	2°19		
8025	DHU 2 (w 5)	B0	2°18		
		B1	2°17		
		B2	2°16		
		B3	2°15		
		B4	2°14		
		B5	2°13		
		B6	2°12		
		B7	2°11sec = 2048sec	LSB	
8021	DHU 3 (w 6)	B0	SPARE		
		B1	SPARE		
		B2	SPARE		
		B3	SPARE		
		B4	TLM	MSB	
		B5	EDITION	3-Dh=64 - 65536bps	
		B6	RATE		
		B7		LSB	
8022	DHU 4 (w 7)	B0		MSB	
		B1	X BIT	8-Ch=2048 - 32768bps	
		B2	RATE		
		B3		LSB	
		B4		MSB	
		B5	S BIT	3-7h= 64 - 1024bps	
		B6	RATE		
		B7		LSB	

ADRS (Hex)	WORD	Bit	ITEM	STATUS	
				1	0
8020	DHU 5 (w 8)	B0	TLM FMT ROM SEL	B	A
		B1	TLM FMT ROM 1BIT ECC	DIS	ENA
		B2	SPARE		
		B3	FMT ID4		
		B4	FMT ID3		
		B5	FMT ID2		
		B6	FMT ID1		
		B7	FMT ID0		
8023	DHU 6 (w 9)	B0	SPARE		
		B1	SPARE		
		B2	SPARE		
		B3	REC DATA OUTPUT	ON	OFF
		B4	X TLM SEL	REP	REAL
		B5	X TLM OUTPUT	ON	OFF
		B6	S TLM SEL	REP	REAL
		B7	S TLM OUTPUT	ON	OFF
FFFF	DHU 7 (w 10)	B0		MSB	
		B1			
		B2			
		B3			
		B4			
		B5			
		B6	OP TIME		
		B7	INTERVAL		
FFFF	DHU 8 (w 11)	B0			
		B1			
		B2			
		B3			
		B4			
		B5			
		B6			
		B7		LSB	

ADRS (Hex)	WORD	Bit	ITEM	STATUS	
				1	0
FFFF	DHU 9 (w 12)	B0		MSB	
		B1			
		B2			
		B3	OP ADDRESS		
		B4			
		B5			
		B6			
		B7		LSB	
FFFF	DHU 10 (w 13)	B0	SPARE		
		B1		MSB	
		B2			
		B3			
		B4	OG ADDRESS		
		B5			
		B6			
		B7		LSB	
FFFF	DHU 11 (w 14)	B0	SPARE		
		B1	SPARE		
		B2	SPARE		
		B3		MSB	
		B4			
		B5	OGE ADDRESS		
		B6			
		B7		LSB	
FFFF	DHU 12 (w 15)	B0	SPARE		
		B1	SPARE		
		B2	SPARE		
		B3	SPARE		
		B4	SPARE		
		B5	SPARE		
		B6	SPARE		
		B7	SPARE		

ADRS (Hex)	WORD	Bit	ITEM	STATUS	
				1	0
8008	DHU 13 (w 16)	B0		MSB	
		B1	CMD REJECT		
		B2	COUNTER		
		B3		LSB	
		B4	RD ENA/DIS	ENA	DIS
		B5	CPU RST	RST	
		B6	SPARE		
		B7	DMA ACCESS ENA/DIS	ENA	DIS
8010	DHU 14 (w 17)	B0	SPARE		
		B1	SPARE		
		B2	SPARE	ACT	NON
		B3	POC CPU RST	RST	
		B4	WDT CPU RST	RST	
		B5	2BIT ERR CPU RST	RST	
		B6	SOFT CPU RST	RST	
		B7	REQUIRED RST	RST	
8011	DHU 15 (w 18)	B0	SPARE		
		B1	SPARE		
		B2	SPARE		
		B3			
		B4	APPLIROM ECC DETECT	ENA	DIS
		B5	W RAM 1BIT ECC	ENA	DIS
		B6	W RAM ECC DETECT	ENA	DIS
		B7	WDT ENA/DIS	ENA	DIS
8000	DHU 16 (w 19)	B0	SPARE		
		B1	SPARE		
		B2	CONTROL BUS A OUT	ON	OFF
		B3	CONTROL BUS B OUT	ON	OFF
		B4	BUS MAST CLK A OUT	ON	OFF
		B5	BUS MAST CLK B OUT	ON	OFF
		B6	RES BUS A INPUT	ENA	DIS
		B7	RES BUS B INPUT	ENA	DIS

Table B-2 Bilevel Data List (2/11)

ADRS (Hex)	WORD	Bit	ITEM	STATUS	
				1	0
FFFF	DHU 17 (W 20)	B0	▲	MSB	
		B1			
		B2			
		B3			
		B4			
		B5			
		B6	PROGRAM ADDRESS		
		B7			
FFFF	DHU 18 (W 21)	B0			
		B1			
		B2			
		B3			
		B4			
		B5			
		B6			
		B7	▼	LSB	
F812	DHU 19 (W 22)	B0	DRV HANDL ERR	ERR	
		B1	MEM BLK GET ERR	ERR	
		B2	ABNML INTERRUPT ERR	ERR	
		B3	SPARE		
		B4	SPARE		
		B5	SPARE		
		B6	USER PROG COMP ERR	ERR	
		B7	DHU PROG COMP ERR	ERR	
F813	DHU 20 (W 23)	B0	UPLINK CMD R-BUF FUL	FUL	
		B1	BC CMD ERR	ERR	
		B2	ABNML DC CMD ERR	ERR	
		B3	UPLINK CMD SEQ ERR	ERR	
		B4	SPARE		
		B5	SPARE		
		B6	SPARE		
		B7	SPARE		

ADRS (Hex)	WORD	Bit	ITEM	STATUS	
				1	0
F814	DHU 21 (W 24)	B0	▲		
		B1			
		B2			
		B3	PROGRAM		
		B4	MODE		
		B5			
		B6			
		B7	▼		
F815	DHU 22 (W 25)	B0	▲		
		B1			
		B2			
		B3	TURN-ON		
		B4	MODE		
		B5			
		B6			
		B7	▼		
F816	DHU 23 (W 26)	B0	▲		
		B1			
		B2			
		B3	TLM FORMAT		
		B4	MEM SYNC		
		B5	STATUS		
		B6			
		B7	▼		
F817	DHU 24 (W 27)	B0	▲		
		B1			
		B2			
		B3	BROADCAST CMD		
		B4	COUNTER		
		B5			
		B6			
		B7	▼		

ADRS (Hex)	WORD	Bit	ITEM	STATUS	
				1	0
F818	DHU 25 (W 28)	B0	▲		
		B1			
		B2			
		B3	MESSAGE AREA		
		B4	RESENDING		
		B5	COUNTER		
		B6			
		B7	▼		
FFFF	DHU 26 (W 29)	B0	▲		
		B1			
		B2			
		B3	ECC ERROR		
		B4	STATUS		
		B5			
		B6			
		B7	▼		
FFFF	DHU 27 (W 30)	B0	▲		
		B1			
		B2			
		B3	MEMORY CHECK		
		B4	RESULT		
		B5			
		B6			
		B7	▼		
F81B	DHU 28 (W 31)	B0	▲		
		B1			
		B2			
		B3	TLM FORMAT		
		B4	MEM SELECT		
		B5			
		B6			
		B7	▼		

ADRS (Hex)	WORD	Bit	ITEM	STATUS	
				1	0
FFFF	DHU 29 (W 32)	B0	▲		
		B1			
		B2			
		B3			
		B4			
		B5			
		B6			
		B7			
FFFF	DHU 30 (W 33)	B0			
		B1			
		B2			
		B3	USER REQUEST		
		B4	DETECT STATUS		
		B5			
		B6			
		B7			
FFFF	DHU 31 (W 34)	B0			
		B1			
		B2			
		B3			
		B4			
		B5			
		B6			
		B7			
FFFF	DHU 32 (W 35)	B0			
		B1			
		B2			
		B3			
		B4			
		B5			
		B6			
		B7	▼		

Table B-2 Bilevel Data List (3/11)

ADRS (Hex)	WORD	Bit	ITEM	STATUS	
				1	0
F820	DHU 33 (W 36)	B0	▲	MSB	
		B1			
		B2			
		B3			
		B4	CMD INPUT		
		B5	INTERRUPT COUNTER		
		B6			
		B7			
F821	DHU 34 (W 37)	B0			
		B1			
		B2			
		B3			
		B4			
		B5			
		B6			
		B7			
F822	DHU 35 (W 38)	B0	▲	LSB	
		B1			
		B2			
		B3			
		B4	CTL BUS TIMING		
		B5	INTERRUPT COUNTER		
		B6			
		B7			
F823	DHU 36 (W 39)	B0			
		B1			
		B2			
		B3			
		B4			
		B5			
		B6			
		B7	▼	LSB	

ADRS (Hex)	WORD	Bit	ITEM	STATUS	
				1	0
F824	DHU 37 (W 40)	B0	▲		
		B1			
		B2			
		B3			
		B4	TI TIMING		
		B5	INTERRUPT COUNTER		
		B6			
		B7			
F825	DHU 38 (W 41)	B0			
		B1			
		B2			
		B3			
		B4			
		B5			
		B6			
		B7	▼		
FFFF	DHU 39 (W 42)	B0	SPARE		
		B1	SPARE		
		B2	SPARE		
		B3	SPARE		
		B4	SPARE		
		B5	SPARE		
		B6	SPARE		
		B7	SPARE		
8028	DHU 40 (W 43)	B0	SPARE		
		B1	▲		A22
		B2			A21
		B3	DMP HEAD ADRS		A20
		B4			A19
		B5			A18
		B6			A17
		B7	▼		A16

ADRS (Hex)	WORD	Bit	ITEM	STATUS	
				1	0
8029	DHU 41 (W 44)	B0	▲		A15
		B1			A14
		B2			A13
		B3	DMP HEAD ADRS		A12
		B4			A11
		B5			A10
		B6			A9
		B7	▼		A8
802A	DHU 42 (W 45)	B0	▲		L7
		B1			L6
		B2			L5
		B3	DMP DATA BLK NUMBER		L4
		B4			L3
		B5			L2
		B6			L1
		B7	▼		L0
802B	DHU 43 (W 46)	B0	▲	MSB	
		B1	DMP LOOP NUMBER		
		B2	▼	LSB	
		B3	▲	MSB	
		B4			
		B5	PIM ID		
		B6			
		B7	▼	LSB	
8000	AOCE 1 (W 47)	B0	AOCE ON/OFF	ON	OFF
		B1	AOCE WDT OVF	ERR	NML
		B2	SSC ON/OFF	ON	OFF
		B3	SSC CAL	CAL	NML
		B4	RFU3		
		B5	RFU2		
		B6	RFU1		
		B7	RFU0		

ADRS (Hex)	WORD	Bit	ITEM	STATUS	
				1	0
8001	AOCE 2 (W 48)	B0	AOCE OFF ENA/DIS	ENA	DIS
		B1	MRM OFF ENA/DIS	ENA	DIS
		B2	AOCE RST ENA/DIS	ENA	DIS
		B3	SSAS OFF ENA/DIS	ENA	DIS
		B4	TSAS OFF ENA/DIS	ENA	DIS
		B5	SSC OFF ENA/DIS	ENA	DIS
		B6	RGA OFF ENA/DIS	ENA	DIS
		B7	ACM OFF ENA/DIS	ENA	DIS
8002	AOCE 3 (W 49)	B0	RCS OFF ENA/DIS	ENA	DIS
		B1	OMS OFF ENA/DIS	ENA	DIS
		B2	CONFIG BC ENA/DIS	ENA	DIS
		B3	SPARE		
		B4	SPARE		
		B5	DE	ENA	DIS
		B6	EE	ENA	DIS
		B7	SPARE		
8003	AOCE 4 (W 50)	B0	RCS DRV PWR	ON	OFF
		B1	RCS PARITY ENA/DIS	ENA	DIS
		B2	RCS WDT ENA/DIS	ENA	DIS
		B3	RCS ENA/DIS	ENA	DIS
		B4	RCS CNTIN ENA/DIS	ENA	DIS
		B5	RCS PARITY	ERR	NML
		B6	RCS WDT OVF	ERR	NML
		B7	SPARE		
8004	AOCE 5 (W 51)	B0	OMS DRV PWR	ON	OFF
		B1	OMS BCMASK	MASK	NML
		B2	OMS ENA/DIS	ENA	DIS
		B3	OMS MBT ENA/DIS	ENA	DIS
		B4	OMS ERROR	ERR	NML
		B5	SPARE		
		B6	SPARE		
		B7	SPARE		

Table B-2 Bilevel Data List (4/11)

ADRS (Hex)	WORD	Bit	ITEM	STATUS	
				1	0
8005	AOCE 6 (W 52)	B0	↑	MSB	
		B1			
		B2			
		B3	BC ANS		
		B4			
		B5			
		B6			
		B7	↓	LSB	
8006	AOCE 7 (W 53)	B0	COMRAM A ENA/DIS	ENA	DIS
		B1	COMRAM B ED/DS	ENA	DIS
		B2	S PORT A ENA/DIS	ENA	DIS
		B3	S PORT B ENA/DIS	ENA	DIS
		B4	BUS A ENA/DIS	ENA	DIS
		B5	BUS B ENA/DIS	ENA	DIS
		B6	CM A ENA/DIS	ENA	DIS
		B7	CD B ENA/DIS	ENA	DIS
8007	AOCE 8 (W 54)	B0	SSAS ON/OFF	ON	OFF
		B1	TSAS ON/OFF	ON	OFF
		B2	RG A ON/OFF	ON	OFF
		B3	RGB-B ON/OFF	ON	OFF
		B4	ACM-A ON/OFF	ON	OFF
		B5	ACM-B ON/OFF	ON	OFF
		B6	ACM-C ON/OFF	ON	OFF
		B7	ACM-D ON/OFF	ON	OFF
8015	AOCE 9 (W 55)	B0	HLV	OPN	CLS
		B1	LV-1	OPN	CLS
		B2	LV-2	OPN	CLS
		B3	LV-3	OPN	CLS
		B4	LV-4	OPN	CLS
		B5	LV-5	OPN	CLS
		B6	LV-6	OPN	CLS
		B7	LV-M	OPN	CLS
8009	AOCE 10 (W 56)	B0	SPARE		
		B1	SPARE		
		B2	GATE SIG SELE	SP2	SP1
		B3	DELAY LOGIC INPUT SIG	GATE OUT SIG	TSAS-Y
		B4	IP CENTER INPUT	MSB	11: NO SEL 10: TSAS-X
		B5	SIG SELECT	LSB	01: DL LOG OUT 00: SSAS
		B6	IP PLS SELECT	P CENTER OUT	IP CENTER IN
		B7	SPARE		
800A	AOCE 11 (W 57)	B0	RFU 7		
		B1	RFU 6		
		B2	RFU 5		
		B3	RFU 4		
		B4	RFU 3		
		B5	RFU 2		
		B6	RFU 1		
		B7	RFU 0		
800B	AOCE 12 (W 58)	B0	MRM-A ON/OFF	ON	OFF
		B1	MRM-B ON/OFF	ON	OFF
		B2	AACP MODE	MSB	11: B/A 10: DUPLEX
		B3		LSB	01: SIMPLEX 00: MANU
		B4	CM-A	SEL	MON
		B5	CM-B	SEL	MON
		B6	EM-A	ERR	NML
		B7	EM-B	ERR	NML
800C	AOCE 13 (W 59)	B0	RFU 1		
		B1	RFU 2		
		B2	RFU 3		
		B3	RFU 4		
		B4	RFU 5		
		B5	RFU 6		
		B6	RFU 7		
		B7	RFU 8		
800D	AOCE 14 (W 60)	B0	CPU-A ON/OFF	ON	OFF
		B1	CLK-A ERR	ERR	NML
		B2	BUSA-A TIMEOUT	TIME OUT	NML
		B3	BUSA-B TIMEOUT	TIME OUT	NML
		B4	LECC-A EVEN2 ERR	ERR	NML
		B5	LECC-A ODD2 ERR	ERR	NML
		B6	LECC-A EVEN1 ERR	ERR	NML
		B7	LECC-A ODD1 ERR	ERR	NML
800E	AOCE 15 (W 61)	B0	WDT-A OVF	OVF	NML
		B1	SW-A CHKERR	ERR	NML
		B2	CPU-A CHK OK	OK	NON
		B3	SPARE		
		B4	SPARE		
		B5	SPARE		
		B6	SPARE		
		B7	CPU OFF ENA/DIS	ENA	DIS
800F	AOCE 16 (W 62)	B0	CPU-B ON/OFF	ON	OFF
		B1	CLK-B ERR	ERR	NML
		B2	BUSA-B TIMEOUT	TIME OUT	NML
		B3	BUSB-B TIMEOUT	TIME OUT	NML
		B4	LECC-B EVEN2 ERR	ERR	NML
		B5	LECC-B ODD2 ERR	ERR	NML
		B6	LECC-B EVEN1 ERR	ERR	NML
		B7	LECC-B ODD1 ERR	ERR	NML
8010	AOCE 17 (W 63)	B0	WDT-B OVF	OVF	NML
		B1	SW-B CHKERR	ERR	NML
		B2	CPU-B CHK OK	OK	NON
		B3	SPARE		
		B4	SPARE		
		B5	SPARE		
		B6	SPARE		
		B7	CPU OFF ENA/DIS	ENA	DIS
8011	AOCE 18 (W 64)	B0	COM RAM-A SEL		
		B1	CECC-A EVEN2 ERR	ERR	NML
		B2	CECC-A ODD2 ERR	ERR	NML
		B3	CECC-A EVEN1 ERR	ERR	NML
		B4	CECC-A ODD1 ERR	ERR	NML
		B5	SPARE		
		B6	SPARE		
		B7	SPARE		
8012	AOCE 19 (W 65)	B0	BUS-A SEL	SEL	NON
		B1	SPARE		
		B2	SPARE		
		B3	SPARE		
		B4	SPORT-A SEL	SEL	NON
		B5	SPARE		
		B6	SPARE		
		B7	SPARE		
8013	AOCE 20 (W 66)	B0	COM RAM-B SEL		
		B1	CECC-B EVEN2 ERR	ERR	NML
		B2	CECC-B ODD2 ERR	ERR	NML
		B3	CECC-B EVEN1 ERR	ERR	NML
		B4	CECC-B ODD1 ERR	ERR	NML
		B5	SPARE		
		B6	SPARE		
		B7	SPARE		
8014	AOCE 21 (W 67)	B0	BUS-B SEL	SEL	NON
		B1	SPARE		
		B2	SPARE		
		B3	SPARE		
		B4	SPORT-B SEL	SEL	NON
		B5	SPARE		
		B6	SPARE		
		B7	SPARE		

Table B-2 Bilevel Data List (5/11)

ADRS (Hex)	WORD	Bit	ITEM	STATUS	
				1	0
8016	AOCE22 (w 68)	B0	TLMRFU7		
		B1	TLMRFU6		
		B2	TLMRFU5		
		B3	TLMRFU4		
		B4	TLMRFU3		
		B5	TLMRFU2		
		B6	TLMRFU1		
		B7	TLMRFU0		
		B0			
		B1			
		B2			
		B3			
		B4			
		B5			
		B6			
		B7			
		B0			
		B1			
		B2			
		B3			
		B4			
		B5			
		B6			
		B7			
		B0			
		B1			
		B2			
		B3			
		B4			
		B5			
		B6			
		B7			

Table B-2 Bilevel Data List (6/11)

ADRS (Hex)	WORD	Bit	ITEM	STATUS	
				1	0
8000	TCI 1 (w 69)	B0	SSW-A	A	B
		B1	SSW-B	HGA	LGA-B
		B2	SBR-A SQ	ON	OFF
		B3	SBR-B SQ	ON	OFF
		B4	SPARE		
		B5	CMD LOCK ON/OFF	ON	OFF
		B6	DATA ERR	ERR	NO-ERR
		B7	RE-TRNS	RE-TRNS	NO RE-TRNS
8001	TCI 2 (w 70)	B0	MSB		
		B1			
		B2	CMD TRANS.		
		B3	FLAME No		
		B4			
		B5			
		B6			
		B7	LSB		
8002	AOCE 3 (w 71)	B0	TMS	ON	OFF
		B1	TMS PWR	HIGH	LOW
		B2	TMS COH	COH	NCOH
		B3	S AUTO COH	COH ENA	COH DIS
		B4	S RNG	RNG A	RNG B
		B5	S RNG ON/OFF	ON	OFF
		B6	SPARE		
		B7	SPARE		
8003	AOCE 4 (w 72)	B0	TMX	ON	OFF
		B1	TMX PWR	HIGH	LOW
		B2	TMX COH	COH	NCOH
		B3	X AUTO COH	COH ENA	COH DIS
		B4	X RNG	RNG A	RNG B
		B5	X RNG ON/OFF	ON	OFF
		B6	XPA	ON	OFF
		B7	SPARE		
8004	TCI 5 (w 73)	B0	KM NZL EXT	EXT	NO EXT
		B1	EXT MEC SEP	SEP	NO SEP
		B2	SA SEP	SEP	NO SEP
		B3	SPARE		
		B4	SPARE		
		B5	SPARE		
		B6	SPARE		
		B7	SPARE		
8005	TCI 6 (w 74)	B0	EPTSQ23	MSB	
		B1	EPTSQ22		
		B2	EPTSQ21		
		B3	EPTSQ20	LSB	
		B4	EPTCLK	PWR ON	PWR OFF
		B5	EPTARM1	ARMING ON	ARMING OFF
		B6	EPTARM2	ARMING ON	ARMING OFF
		B7	EPTARM3	ARMING ON	ARMING OFF
8000	HCE 1 (w 75)	B0	H TNK HTR PRI	ON	OFF
		B1	H TNK HTR SEC	ON	OFF
		B2	N TNK HTR PRI	ON	OFF
		B3	N TNK HTR SEC	ON	OFF
		B4	G TNK HTR PRI	ON	OFF
		B5	G TNK HTR SEC	ON	OFF
		B6	PIPE A HTR	ON	OFF
		B7	PIPE B HTR	ON	OFF
8001	HCE 2 (w 76)	B0	PIPE C HTR	ON	OFF
		B1	PIPE D HTR	ON	OFF
		B2	PIPE E HTR	ON	OFF
		B3	VLV M A HTR	ON	OFF
		B4	VLV M B HTR	ON	OFF
		B5	VLV M C HTR	ON	OFF
		B6	OME HTR PRI	ON	OFF
		B7	OME HTR SEC	ON	OFF
8002	HCE 3 (w 77)	B0	EM A PRI	ON	OFF
		B1	EM A SEC	ON	OFF
		B2	EM B PRI	ON	OFF
		B3	EM B SEC	ON	OFF
		B4	TH BED AXI	ON	OFF
		B5	TH BED RAD	ON	OFF
		B6	TH BED TAN	ON	OFF
		B7	OME INJ	ON	OFF
8003	HCE 4 (w 78)	B0	BAT A1 HTR	ON	OFF
		B1	BAT A2 HTR	ON	OFF
		B2	BAT B1 HTR	ON	OFF
		B3	BAT B2 HTR	ON	OFF
		B4	SSC HTR	ON	OFF
		B5	XPA HTR	ON	OFF
		B6	MIC HTR	ON	OFF
		B7	REPLACE 1	ON	OFF
8004	HCE 5 (w 79)	B0	REPLACE 2	ON	OFF
		B1	REPLACE 3	ON	OFF
		B2	REPLACE 4	ON	OFF
		B3	SPARE		
		B4	H TNK HTR PRI	AUTO	MANU
		B5	H TNK HTR SEC	AUTO	MANU
		B6	N TNK HTR PRI	AUTO	MANU
		B7	N TNK HTR SEC	AUTO	MANU
8005	HCE 6 (w 80)	B0	G TNK HTR PRI	AUTO	MANU
		B1	G TNK HTR SEC	AUTO	MANU
		B2	PIPE A HTR	AUTO	MANU
		B3	PIPE B HTR	AUTO	MANU
		B4	PIPE C HTR	AUTO	MANU
		B5	PIPE D HTR	AUTO	MANU
		B6	PIPE E HTR	AUTO	MANU
		B7	VLV M A HTR	AUTO	MANU
8006	HCE 7 (w 81)	B0	VLV M B HTR	AUTO	MANU
		B1	VLV M C HTR	AUTO	MANU
		B2	OME HTR PRI	AUTO	MANU
		B3	OME HTR SEC	AUTO	MANU
		B4	EM A PRI	AUTO	MANU
		B5	EM A SEC	AUTO	MANU
		B6	EM B PRI	AUTO	MANU
		B7	EM B SEC	AUTO	MANU
8007	HCE 8 (w 82)	B0	BAT A1 HTR	AUTO	MANU
		B1	BAT A2 HTR	AUTO	MANU
		B2	BAT B1 HTR	AUTO	MANU
		B3	BAT B2 HTR	AUTO	MANU
		B4	SSC HTR	AUTO	MANU
		B5	XPA HTR	AUTO	MANU
		B6	MIC HTR	AUTO	MANU
		B7	REPLACE 1	AUTO	MANU
8008	HCE 9 (w 83)	B0	REPLACE 2	AUTO	MANU
		B1	REPLACE 3	AUTO	MANU
		B2	REPLACE 4	AUTO	MANU
		B3	SPARE		
		B4	SPARE		
		B5	SPARE		
		B6	SPARE		
		B7	SPARE		
8009	HCE 10 (w 84)	B0	SPARE		
		B1	SPARE		
		B2	SPARE		
		B3	SPARE		
		B4	SPARE		
		B5	SPARE		
		B6	SPARE		
		B7	SPARE		

Table B-2 Bilevel Data List (7/11)

ADRS (Hex)	WORD	Bit	ITEM	STATUS	
				1	0
8000	PCD 1 (w 85)	B0	▲	MSB	
		B1			
		B2			
		B3	BAT A C/D		
		B4	COUNT DATA		
		B5			
		B6			
		B7	▼	LSB	
8001	PCD 2 (w 86)	B0	▲	MSB	
		B1			
		B2			
		B3	BAT B C/D		
		B4	COUNT DATA		
		B5			
		B6			
		B7	▼	LSB	
8002	PCD 3 (w 87)	B0	DIST(RF) ON/OFF	ON	OFF
		B1	DIST(AOCE) ON/OFF	ON	OFF
		B2	DIST(DHU) ON/OFF	ON	OFF
		B3	DIST(I/D/B) ON/OFF	ON	OFF
		B4	DIST(PSA) ON/OFF	ON	OFF
		B5	DIST(PWA) ON/OFF	ON	OFF
		B6	DIST(MPM) ON/OFF	ON	OFF
		B7	DIST(MIC) ON/OFF	ON	OFF
8003	PCD 4 (w 88)	B0	DIST(TPA) ON/OFF	ON	OFF
		B1	DIST(IMD) ON/OFF	ON	OFF
		B2	DIST(NMS) ON/OFF	ON	OFF
		B3	DIST(MDC) ON/OFF	ON	OFF
		B4	DIST OFF ENA/DIS	OF ENA	OF DIS
		B5	SPARE		
		B6	S/P CHG	S-CHG	P-CHG
		B7	K SET	110	120

ADRS (Hex)	WORD	Bit	ITEM	STATUS	
				1	0
8004	PCD 5 (w 89)	B0	BAT A INT/EXT	INT	EXT
		B1	BAT A CHG A/M	AUTO	MANU
		B2	BAT A CHG F/T	FULL	TRK
		B3	BAT A CD F/T	FULL	TRK
		B4	BAT A UVC ENA/DIS	ENA	DIS
		B5	BAT A UVS HIS	ON	OFF
		B6	BAT A Q SET	ENA	DIS
		B7	BAT A RCN	ON	OFF
8005	PCD 6 (w 90)	B0	BAT B INT/EXT	INT	EXT
		B1	BAT B CHG A/M	AUTO	MANU
		B2	BAT B CHG F/T	FULL	TRK
		B3	BAT B CD F/T	FULL	TRK
		B4	BAT B UVC ENA/DIS	ENA	DIS
		B5	BAT B UVS HIS	ON	OFF
		B6	BAT B Q SET	ENA	DIS
		B7	BAT B RCN	ON	OFF
8006	PCD 7 (w 91)	B0	A UVC LVL STS1		
		B1	A UVC LVL STS2		
		B2	SPARE		
		B3	SPARE		
		B4	B UVC LVL STS1		
		B5	B UVC LVL STS2		
		B6	SPARE		
		B7	SPARE		
8000	DR 1 (w 92)	B0	MEM BLOCK0 ON/OFF	ON	OFF
		B1	MEM BLOCK1 ON/OFF	ON	OFF
		B2	MEM BLOCK2 ON/OFF	ON	OFF
		B3	MEM BLOCK3 ON/OFF	ON	OFF
		B4	SPARE		
		B5	SPARE		
		B6	SPARE		
		B7	DR ON/OFF	ON	OFF

ADRS (Hex)	WORD	Bit	ITEM	STATUS	
				1	0
F800	DR 2 (w 93)	B0	DR RST	ACK	---
		B1	DR BC	ACK	---
		B2	DR REC MODE	MODE	---
		B3	DR REPRO MODE	MODE	---
		B4	DR STBY MODE	MODE	---
		B5	DR CHECK MODE	MODE	---
		B6	DR CHECK ENA/DIS	ENA	DIS
		B7	WDI RST	RST	---
F801	DR 3 (w 94)	B0	DR OVWR MODE	ON	OFF
		B1	ECC ON/OFF	ON	OFF
		B2	HEC ON/OFF	ON	OFF
		B3	N/A		
		B4	LATCH UP MB0	L UP0	---
		B5	LATCH UP MB1	L UP1	---
		B6	LATCH UP MB2	L UP2	---
		B7	LATCH UP MB3	L UP3	---
F802	DR 4 (w 95)	B0	▲	MSB	
		B1			
		B2			
		B3	WR ADDRESS		
		B4			
		B5			
		B6			
		B7	▼	LSB	
F803	DR 5 (w 96)	B0	▲	MSB	
		B1			
		B2			
		B3	RD ADDRESS		
		B4			
		B5			
		B6			
		B7	▼	LSB	

ADRS (Hex)	WORD	Bit	ITEM	STATUS	
				1	0
F804	DR 6 (w 97)	B0	▲	MSB	
		B1			
		B2			
		B3	1 BIT ERROR		
		B4			
		B5			
		B6			
		B7	▼	LSB	
F805	DR 7 (w 98)	B0	▲	MSB	
		B1			
		B2			
		B3	2 BIT ERROR		
		B4			
		B5			
		B6			
		B7	▼	LSB	
F810	DR 8 (w 99)	B0	HARD ERR MB0	HER 0	---
		B1	HARD ERR MB1	HER 1	---
		B2	HARD ERR MB2	HER 2	---
		B3	HARD ERR MB3	HER 3	---
		B4	N/A		
		B5	N/A		
		B6	N/A		
		B7	N/A		

Table B-2 Bilevel Data List (8/11)

ADRS (Hex)	WORD	Bit	ITEMS	STATUS	
				1	0
8000	PSA 1 (W 100)	B0	PSA ECC 2BIT ERR	ACT	NON
		B1	PSA ECC 1BIT ERR	ACT	NON
		B2	PSA ECC ENA/DIS	ENA	DIS
		B3	PSA HTR ENA/DIS	ENA	DIS
		B4	PSA WDT ERR	ACT	NON
		B5	PSA WDT ENA/DIS	ENA	DIS
		B6	PSA CPU RUN/RST	RUN	RST
		B7	PSA CPU ON/OFF	ON	OFF
F800	PSA 2 (W 101)	B0	EIS ON/OFF	ON	OFF
		B1	EIS SSD HV ENA/DIS	ENA	DIS
		B2	EIS MCP HV ENA/DIS	ENA	DIS
		B3	EIS SSD HV ON/OFF	ON	OFF
		B4	EIS MCP HV ON/OFF	ON	OFF
		B5	ADD ONE ENA/DIS	ENA	DIS
		B6	ANTI ENA/DIS	ENA	DIS
		B7	EIS CAL ON/OFF	ON	OFF
F801	PSA 3 (W 102)	B0	PAX ON/OFF	ON	OFF
		B1	H32 RUN/RST	H32 RUN	H32 RST
		B2	H32 RUN/HLT	H32 RUN	H32 HALT
		B3	H32 ENA/FLT	ENA	FLOAT
		B4	H32 ECC 1BIT ERR	ACT	NON
		B5	H32 ECC 2BIT ERR	ACT	NON
		B6	SF ENA/DIS	ENA	DIS
		B7	H32 ON/OFF	ON	OFF
F802	PSA 4 (W 103)	B0	ESA MCP ENA/DIS	ENA	DIS
		B1	ESA MCP ON/OFF	ON	OFF
		B2	ESA SV ENA/DIS	ENA	DIS
		B3	ESA SV ON/OFF	ON	OFF
		B4	ISA MCP ENA/DIS	ENA	DIS
		B5	ISA MCP ON/OFF	ON	OFF
		B6	ISA SV ENA/DIS	ENA	DIS
		B7	ISA SV ON/OFF	ON	OFF

ADRS (Hex)	WORD	Bit	ITEMS	STATUS	
				1	0
F803	PSA 5 (W 104)	B0	XUV MCP ENA/DIS	ENA	DIS
		B1	XUV MCP ON/OFF	ON	OFF
		B2	ESA CAL ON/OFF	ON	OFF
		B3	ESA MODE PHA/PD	MODE PHA	MODE PD
		B4	ISA CAL ON/OFF	ON	OFF
		B5	ISA MODE PHA/PD	MODE PHA	MODE PD
		B6	SPARE		
		B7	SPARE		
0000	(W 105)	B0	SPARE		
		B1	SPARE		
		B2	SPARE		
		B3	SPARE		
		B4	SPARE		
		B5	SPARE		
		B6	SPARE		
		B7	SPARE		
8000	MIC 1 (W 106)	B0	MIC ECC 2BIT ERR	ACT	NON
		B1	MIC ECC 1BIT ERR	ACT	NON
		B2	MIC ECC ENA/DIS	ENA	DIS
		B3	MIC HTR ENA/DIS	ENA	DIS
		B4	MIC WDT ERR	ACT	NON
		B5	MIC WDT ENA/DIS	ENA	DIS
		B6	MIC CPU RUN/RST	RUN	RST
		B7	MIC CPU ON/OFF	ON	OFF
F800	MIC 2 (W 107)	B0	MIC PWR ON/OFF	ON	OFF
		B1	SOFT MODE0	ON	OFF
		B2	SOFT MODE1	ON	OFF
		B3	CMP-PARAME0	ON	OFF
		B4	CMP-PARAME1	ON	OFF
		B5	P-WAIT1	ON	OFF
		B6	P-WAIT2	ON	OFF
		B7	P-TAKING	ON	OFF

ADRS (Hex)	WORD	Bit	ITEMS	STATUS	
				1	0
F801	MIC 3 (W 108)	B0	MODE0 B1B0-	00:AUTO	01:COMMAND
		B1	MODE1	10:ONESHOT	11:ENDLESS
		B2	GAIN0 B3B2-	00:LOW	01:NML
		B3	GAIN1	10:HIGH	11:N/A
		B4	THRESHOLD0 B5B4-	00:LEVEL0	01:LEVEL1
		B5	THRESHOLD1	10:LEVEL2	11:N/A
		B6	COLOR0 B7B6-	00:RED	01:GREEN
		B7	COLOR1	10:BLUE	11:FUL COLOR
F802	MIC 4 (W 109)	B0	AZIMUTH0		
		B1	AZIMUTH1		
		B2	AZIMUTH2		
		B3	AZIMUTH3		
		B4	ELEVATION0		
		B5	ELEVATION1		
		B6	ELEVATION2		
		B7	ELEVATION3		
F803	MIC 5 (W 110)	B0	SA0	↑ MSB	
		B1	SA1		
		B2	SA2		
		B3	SA3	START ANGLE	
		B4	SA4		
		B5	SA5		
		B6	SA6	↓ LSB	
		B7	FIXED TO 0		
F804	MIC 6 (W 111)	B0	SP0	↑ MSB	
		B1	SP1		
		B2	SP2	START PICKSEL	
		B3	SP3		
		B4	SP4	↓ LSB	
		B5	FIXED TO 0		0
		B6	COMMAND ERR 0	ERR	NON
		B7	COMMAND ERR 1	ERR	NON

ADRS (Hex)	WORD	Bit	ITEMS	STATUS	
				1	0
F800	IMI 1 (W 112)	B0	IMI CPU ON/OFF	ON	OFF
		B1	IMI HEATER ON/OFF	ON	OFF
		B2	TBD		
		B3	IMI HV ENA/DIS	ENA	DIS
		B4	IMI HV ON/OFF	ON	OFF
		B5	TBD		
		B6	TBD		
		B7	TBD		
F801	IMI 2 (W 113)	B0	IMI HV1 ON/OFF	ON	OFF
		B1	IMI HV2 ON/OFF	ON	OFF
		B2	IMI HV3 ON/OFF	ON	OFF
		B3	IMI HV4 ON/OFF	ON	OFF
		B4	IMI HV1 ENA/DIS	ENA	DIS
		B5	IMI HV2 ENA/DIS	ENA	DIS
		B6	IMI HV3 ENA/DIS	ENA	DIS
		B7	IMI HV4 ENA/DIS	ENA	DIS
F802	IMI 3 (W 114)	B0	TBD		
		B1	TBD		
		B2	TBD		
		B3	TBD		
		B4	TBD		
		B5	TBD		
		B6	TBD		
		B7	TBD		
0000	(W 115)	B0	SPARE		
		B1	SPARE		
		B2	SPARE		
		B3	SPARE		
		B4	SPARE		
		B5	SPARE		
		B6	SPARE		
		B7	SPARE		

Table B-2 Bilevel Data List (9/11)

ADRS (Hex)	WORD	Bit	ITEMS	STATUS	
				1	0
8000	MPM 1 (W 116)	B0	MPM ECC 2BIT ERR	ACT	NON
		B1	MPM ECC 1BIT ERR	ACT	NON
		B2	MPM ECC ENA/DIS	ENA	DIS
		B3	MPM HIR ENA/DIS	ENA	DIS
		B4	MPM WDT ERR	ACT	NON
		B5	MPM WDT ENA/DIS	ENA	DIS
		B6	MPM CPU RUN/RST	RUN	RST
		B7	MPM CPU ON/OFF	ON	OFF
F800	MPM 2 (W 117)	B0	MGF/PEF ON/OFF	ON	OFF
		B1	MGF SENSE NOR/REV	REV	NOR
		B2	MGF RNG BC/AUTO	BC	AUTO
		B3	PET CAL ON/OFF	ON	OFF
		B4	UV HV ENA/DIS	ENA	DIS
		B5	UV HV ON/OFF	ON	OFF
		B6	PM HV ENA/DIS	ENA	DIS
		B7	PM HV ON/OFF	ON	OFF
F801	MPM 3 (W 118)	B0	UVS ON/OFF	ON	OFF
		B1	PM H FIL ON/OFF	ON	OFF
		B2	PMD FIL ON/OFF	ON	OFF
		B3	UV MCP GAIN B1	▲ MCP GAIN	
		B4	UV MCP GAIN B0	▼ SET	
		B5	PM GAIN B1	▲ PHOTO METER	
		B6	PM GAIN B0	▼ GAIN SET	
		B7	SPARE		
F802	MPM 4 (W 119)	B0	UVS OBS MODE ID0	OBSERVATION MODE SET	
		B1	UVS OBS MODE ID1		
		B2	UVS OBS MODE ID2		
		B3	UVS OBS MODE ID3		
		B4	UVS OBS MODE ID4		
		B5	UVS OBS MODE ID5		
		B6	UVS OBS MODE ID6		
		B7	UVS OBS MODE ID7		
F803	MPM 5 (W 120)	B0	MST STBY	ON	OFF
		B1	MST HIR CONT	ON	OFF
		B2	MST EXT MODE	EXT MODE	—
		B3	MST RET MODE	RET MODE	—
		B4	MST DRV	ON	OFF
		B5	MST OVLD	OVLD	—
		B6	MST RET	RET FUL	—
		B7	MST STRAP TNT	ON	OFF
0000	(W 121)	B0	SPARE		
		B1	SPARE		
		B2	SPARE		
		B3	SPARE		
		B4	SPARE		
		B5	SPARE		
		B6	SPARE		
		B7	SPARE		
F800	MDC 1 (W 122)	B0	TEMP OUT OF RNG	OUT	—
		B1	HV OUT OF RNG	OUT	—
		B2	ANALOG V OUT OF RNG	OUT	—
		B3	DIGITAL V OUT OF RNG	OUT	—
		B4	MDC CPU RUN/RST	RUN	RST
		B5	MDC DC TEST PROC HDL		
		B6	NOISE ALARM	ALARM	
		B7	SPARE		
F801	MDC 2 (W 123)	B0	HV ON/OFF	ON	OFF
		B1	HV ENA/DIS	ENA	DIS
		B2	SPARE		
		B3	SPARE		
		B4	SPARE		
		B5	SPARE		
		B6	SPARE		
		B7	SPARE		

ADRS (Hex)	WORD	Bit	ITEMS	STATUS	
				1	0
0000	(W 124)	B0	SPARE		
		B1	SPARE		
		B2	SPARE		
		B3	SPARE		
		B4	SPARE		
		B5	SPARE		
		B6	SPARE		
		B7	SPARE		
F800	NMS 1 (W 125)	B0	T.B.D.		
		B1	T.B.D.		
		B2	T.B.D.		
		B3	T.B.D.		
		B4	T.B.D.		
		B5	T.B.D.		
		B6	T.B.D.		
		B7	T.B.D.		
F801	NMS 2 (W 126)	B0	T.B.D.		
		B1	T.B.D.		
		B2	T.B.D.		
		B3	T.B.D.		
		B4	T.B.D.		
		B5	T.B.D.		
		B6	T.B.D.		
		B7	T.B.D.		
F802	NMS 3 (W 127)	B0	T.B.D.		
		B1	T.B.D.		
		B2	T.B.D.		
		B3	T.B.D.		
		B4	T.B.D.		
		B5	T.B.D.		
		B6	T.B.D.		
		B7	T.B.D.		

Table B-2 Bilevel Data List (10/11)

ADRS (Hex)	WORD	Bit	ITEMS	STATUS	
				1	0
8000	PWA 1 (W 128)	B0	PWA ECC 2BIT ERR	ACT	NON
		B1	PWA ECC 1BIT ERR	ACT	NON
		B2	PWA ECC ENA/DIS	ENA	DIS
		B3	PWA HTR ENA/DIS	ENA	DIS
		B4	PWA WDT ERR	ACT	NON
		B5	PWA WDT ENA/DIS	ENA	DIS
		B6	PWA CPU RUN/RST	RUN	RST
		B7	PWA CPU ON/OFF	ON	OFF
		B8	LFA ON/OFF	ON	OFF
		B9	LFA CAL ON/OFF	ON	OFF
F800	PWA 2 (W 129)	B0	WFCM BIAS ON/OFF	ON	OFF
		B1	LFA GAIN H/L	HIGH	LOW
		B2	WFCM GAIN H/M/L B1	HIGH	LOW
		B3	WFCM GAIN H/M/L B1	RSB6=10=HIGH	RSB6=01=MTD
		B4	WFCM GAIN H/M/L B2	RSB6=00=LOW	
		B5	OFA ANT EX/EY	EX	EY
		B6	LFA DSP ON/OFF	ON	OFF
		B7	DSP RUN/HLD/RST B1	R1B2=10=RUN	R1B2=01=HLD
		B8	DSP RUN/HLD/RST B2	R1B2=00=SET	
		B9	LFA DSP WDT ENA/DIS	ENA	DIS
F801	PWA 3 (W 130)	B0	LFA WDT ERR/NOR	ERR	NOR
		B1	LFA FIFO FL/NOR	FUL	NOR
		B2	LFA FIFO EM/NOR	EMP	NOR
		B3	LFA FIFO HF/NOR	FUL	NOR
		B4	WFCM CAL ON/OFF	ON	OFF
		B5	LFA ADC CLK LFA/PWS	LFA	PWS
		B6	WFCM SPB/DPB	SPB	DPB
		B7	SPARE		
		B8	WFCM BANK SET MSB	SET	
		B9	WFCM BANK SET B2	SET	
F802	PWA 4 (W 131)	B0	WFCM BANK SET B3	SET	
		B1	WFCM BANK SET LSB	SET	
		B2	SPARE		
		B3	WFCM BANK SET MSB	SET	
		B4	WFCM BANK SET B2	SET	
		B5	WFCM BANK SET B3	SET	
		B6	WFCM BANK SET LSB	SET	
		B7	SPARE		
		B8	WFCM BANK SET MSB	SET	
		B9	WFCM BANK SET B2	SET	
F803	PWA 5 (W 132)	B0	SPARE		
		B1	SPARE		
		B2	SPARE		
		B3	LFA IP/PC ADR MSB	SET	
		B4	LFA IP/PC ADR B11	SET	
		B5	LFA IP/PC ADR B10	SET	
		B6	LFA IP/PC ADR B9	SET	
		B7	LFA IP/PC ADR B8	SET	
		B8	LFA IP/PC ADR B7	SET	
		B9	LFA IP/PC ADR B6	SET	
F804	PWA 6 (W 133)	B0	LFA IP/PC ADR B5	SET	
		B1	LFA IP/PC ADR B4	SET	
		B2	LFA IP/PC ADR B3	SET	
		B3	LFA IP/PC ADR B2	SET	
		B4	LFA IP/PC ADR B1	SET	
		B5	LFA IP/PC ADR LSB	SET	
		B6	WFCM BIAS SET +/-	SET +	SET -
		B7	WFCM BIAS SET MSB	SET	
		B8	WFCM BIAS SET B65	SET	
		B9	WFCM BIAS SET B4	SET	
F805	PWA 7 (W 134)	B0	WFCM BIAS SET B3	SET	
		B1	WFCM BIAS SET B2	SET	
		B2	WFCM BIAS SET B1	SET	
		B3	WFCM BIAS SET LSB	SET	
		B4	PWS CAL SET	SET	
		B5	PWS ANT SET	SET	
		B6	PWS MODE SET	SET	
		B7	PWS LOCAL SET	SET	
		B8	PWS PARA SET	SET	
		B9	PWS AMP SET	SET	
F806	PWA 8 (W 135)	B0	PWS DATA SET	SET	
		B1	OBS TIME SET	SET	
		B2	SPARE		
		B3	SPARE		
		B4	SPARE		
		B5	SPARE		
		B6	SPARE		
		B7	SPARE		
		B8	SPARE		
		B9	SPARE		
F807	PWA 9 (W 136)	B0	PWS ON/OFF	ON	OFF
		B1	PWS DCDC ON/OFF	ON	OFF
		B2	POWER AMP ON/OFF	ON	OFF
		B3	NEI ON/OFF	ON	OFF
		B4	CAL/MES	CAL	MES
		B5	CAL AUTO/MAN	AUTO	MAN
		B6	GND CAL ON/OFF	ON	OFF
		B7	LEVEL CAL ON/OFF	ON	OFF
		B8	PHASE CAL ON/OFF	ON	OFF
		B9	SPW CAL ON/OFF	ON	OFF
F808	PWA10 (W 137)	B0	NEI CAL ON/OFF	ON	OFF
		B1	RX GAIN CONT H/L	HIGH	LOW
		B2	NPW FIX/SWEEP	FIX	SWEEP
		B3	SPW NOR/HIGH	NOR	HIGH
		B4	SPW FIX/SWEEP	FIX	SWEEP
		B5	NEI FIX/SWEEP	FIX	SWEEP
		B6	POWER CONT H/L	HIGH	LOW
		B7	WANT SET NOR/REV	NOR	REV
		B8	C-BANK1 ON/OFF	ON	OFF
		B9	C-BANK2 ON/OFF	ON	OFF
F809	PWA11 (W 138)	B0	C-BANK3 ON/OFF	ON	OFF
		B1	C-BANK4 ON/OFF	ON	OFF
		B2	LOAD 4/3	LOAD4	LOAD3
		B3	CENTER ON/OFF	ON	OFF
		B4	COMP MODE I/T	I	T
		B5	SPW GAIN MSB H/L		
		B6	SPW GAIN LSB H/L		
		B7	SPW PEDEST MSB H/L		
		B8	SPW PEDEST LSB H/L		
		B9	SPW MODE SPW/ALT	SPW	ALT
F80A	PWA12 (W 139)	B0	ALT FIX/SWEEP	SWEEP	FIX
		B1	WANT SET NOR/REV	NOR	REV
		B2	SPARE		
		B3	SPARE		
		B4	SPARE		
		B5	SPARE		
		B6	SPARE		
		B7	SPARE		
		B8	SPARE		
		B9	SPARE		
F80B	PWA13 (W 140)	B0	PWS/LFA BC ANS		
		B1	PWS LOCAL		
		B2	PWS MODE		
		B3	PWS OBS TIME		
		B4	WANT PRE ON/OFF		
		B5	SPARE		
		B6	SPARE		
		B7	SPARE		
		B8	WANT STBY	ON	OFF
		B9	WANT EXT/RET	EXT	RET
F80C	PWA14 (W 141)	B0	WANT MONI	ON	OFF
		B1	WANT LIMIT	ENA	DIS
		B2	WANT-1 SELECT	ON	OFF
		B3	WANT-2 SELECT	ON	OFF
		B4	WANT-3 SELECT	ON	OFF
		B5	WANT-4 SELECT	ON	OFF
		B6	WANT-1 EXT FULL	FUL	NOT FUL
		B7	WANT-1 RET FULL	FUL	NOT FUL
		B8	WANT-2 EXT FULL	FUL	NOT FUL
		B9	WANT-2 RET FULL	FUL	NOT FUL
F80D	PWA15 (W 142)	B0	WANT-3 EXT FULL	FUL	NOT FUL
		B1	WANT-3 RET FULL	FUL	NOT FUL
		B2	WANT-4 EXT FULL	FUL	NOT FUL
		B3	WANT-4 RET FULL	FUL	NOT FUL
		B4	WANT DRV	ON	OFF
		B5	SPARE		
		B6	SPARE		
		B7	SPARE		
		B8	SPARE		
		B9	SPARE		
F80E	PWA16 (W 143)	B0	SPARE		
		B1	SPARE		
		B2	SPARE		
		B3	SPARE		
		B4	SPARE		
		B5	SPARE		
		B6	SPARE		
		B7	SPARE		
		B8	SPARE		
		B9	SPARE		

Table B-2 Bilevel Data List (11/11)

ADRS (Hex)	WORD	Bit	ITEMS	STATUS	
				1	0
F800	TPA 1 (W 144)	B0	SLEEP STATE	YES	NO
		B1	ARM	YES	NO
		B2	DEPLOY PRIMARY	YES	NO
		B3	DEPLOY REDUNDANT	YES	NO
		B4	WDT ERR	YES	NO
		B5	PIM I/F ERR	YES	NO
		B6	TPA-E-U MEM MAP	NVM1	NVM0
		B7	BOOT	BOOT	NML
F801	TPA 2 (W 145)	B0	PIM S0	HI	LO
		B1	PIM S1	HI	LO
		B2	SPARE		
		B3	SPARE		
		B4	HVPS RST	RST	NO RST
		B5	SENSOR HTR	ENA	DIS
		B6	SENSOR POWER	ON	OFF
		B7	HVPS POWER	ON	OFF
F802	TPA 3 (W 146)	B0	HV-1(VSA)	ACT	INACT
		B1	HV-2(VGD)	ACT	INACT
		B2	HV-3(VCF)	ACT	INACT
		B3	HV-4(VAN)	ACT	INACT
		B4	MED V-1(VEA)	ACT	INACT
		B5	SPARE		
		B6	MED V-3(VES)	ACT	INACT
		B7	MED V-4(VIFS)	ACT	INACT
F803	TPA 4 (W 147)	B0	TPA-E-S ERR CODE BIT0	0000h=NO ERR	
		B1	TPA-E-S ERR CODE BIT1		
		B2	TPA-E-S ERR CODE BIT2		
		B3	TPA-E-S ERR CODE BIT3		
		B4	SPARE		
		B5	SPARE		
		B6	SPARE		
		B7	SPARE		

Table B-3 Analog Data List (1/5)

S/S NAME	WORD	ADRS (Hex)	SYMBOL	ITEM	UNIT	RANGE		CONVERSION SYSTEM	
						MINIMUM	MAXIMUM	(y=ax+b)	
								a	b
PCD	212	8007	SCP-I	SCP total current	A				
	213	8008	LOAD-I	Spacecraft total current	A				
	214	8009	BATA-I	BAT-A current	A				
	215	800A	BATB-I	BAT-B current	A				
	216	800B	DHU-I	DHU current	A				
	217	800C	AOCE-I	AOCE current	A				
	218	800D	RF-I	TMS/TMX/XPA/SBR/CMD total current	A				
	219	800E	PSU CI-I	TC/HCE/DR/EPT-SA/INS-SA total current	A				
	220	800F	HTR-I	HEATER current	A				
	221	8010	MPM-I	MPM current	A				
	222	8011	PSA-I	PSA current	A				
	223	8012	PWA-I	PWA current	A				
	224	8013	MIC-I	MIC current	A				
	225	8014	TPA-I	TPA current	A				
	226	8015	IMI-I	IMI current	A				
	227	8016	MDC-I	MDC current	A				
	228	8017	NMS-I	NMS current	A				
	229	8018	SPARE						
	230	8019	BUS-V	Primary voltage	V				
	231	801A	BATA-V	BAT-A voltage	V				
	232	801B	BATB-V	BAT-B voltage	V				
	233	801C	PCD+5V	PCU +5 voltage	V				
	234	801D	PCD+12V	PCU +12 voltage	V				
	235	801E	PCD-12V	PCU -12 voltage	V				
	236	801F	SPARE						
HCE	237	8010	B PNL1-T	STRUCTURE base panel temperature 1	°C				
	238	8011	B PNL2-T	STRUCTURE base panel temperature 2	°C				
	239	8012	B PNL3-T	STRUCTURE base panel temperature 3	°C				
	240	8013	B PNL4-T	STRUCTURE base panel temperature 4	°C				
	241	8014	U PNL1-T	STRUCTURE upper panel temperature 1	°C				
	242	8015	U PNL2-T	STRUCTURE upper panel temperature 2	°C				
	243	8016	L SHLD1-T	STRUCTURE lower shield temperature 1	°C				
	244	8017	L SHLD2-T	STRUCTURE lower shield temperature 2	°C				
	245	8018	PDL1-T	Solar cell paddle temperature 1	°C				
	246	8019	PDL2-T	Solar cell paddle temperature 2	°C				
	247	801A	BATA1-T	BAT A cell temperature 1	°C				
	248	801B	BATA2-T	BAT A case temperature 2	°C				
	249	801C	BATB1-T	BAT B cell temperature 1	°C				
	250	801D	BATB2-T	BAT B case temperature 2	°C				
	251	801E	SHNT-T	SHUNT temperature	°C				
	252	801F	SSCBLK-T	SSC bracket temperature	°C				
	253	8020	SSC-T	SSC temperature	°C				
	254	8021	SSAS-T	SSAS temperature	°C				
	255	8022	TSAS-T	TSAS temperature	°C				
	256	8023	HTNK1-T	N2H4 TANK temperature 1	°C				
	257	8024	HTNK2-T	N2H4 TANK temperature 2	°C				
	258	8025	NTNK1-T	NTO TANK temperature 1	°C				
	259	8026	NTNK2-T	NTO TANK temperature 2	°C				

Table B-3 Analog Data List (2/5)

S/S NAME	WORD	ADRS (Hex)	SYMBOL	ITEM	UNIT	RANGE		CONVERSION SYSTEM (y=ax+b)	
						MINIMUM	MAXIMUM	a	b
HCE (continue)	260	8027	GTNK1-T	GHe TANK temperature 1	°C				
	261	8028	GTNK2-T	GHe TANK temperature 2	°C				
	262	8029	RCSP1P1-T	RCS PIPE temperature 1	°C				
	263	802A	RCSP1P2-T	RCS PIPE temperature 2	°C				
	264	802B	RCSP1P3-T	RCS PIPE temperature 3	°C				
	265	802C	RCSP1P4-T	RCS PIPE temperature 4	°C				
	266	802D	RCSP1P5-T	RCS PIPE temperature 5	°C				
	267	802E	OMSP1P1-T	OMS PIPE temperature 1	°C				
	268	802F	OMSP1P2-T	OMS PIPE temperature 2	°C				
	269	8030	VLVMA-T	Valve Module A temperature	°C				
	270	8031	VLVMB-T	Valve Module B temperature	°C				
	271	8032	VLVMC-T	Valve Module C temperature	°C				
	272	8033	OME1-T	OME temperature 1	°C				
	273	8034	OME2-T	OME temperature 2	°C				
	274	8035	EMA1-T	Engine Module A temperature 1	°C				
	275	8036	EMA2-T	Engine Module A temperature 2	°C				
	276	8037	EMB1-T	Engine Module B temperature 1	°C				
	277	8038	EMB2-T	Engine Module B temperature 2	°C				
	278	8039	THRA1-T	RCS A1 THRUSTER temperature	°C				
	279	803A	THRA2-T	RCS A2 THRUSTER temperature	°C				
	280	803B	THRA3-T	RCS A3 THRUSTER temperature	°C				
	281	803C	THRA4-T	RCS A4 THRUSTER temperature	°C				
	282	803D	THRT1-T	RCS T1 THRUSTER temperature	°C				
	283	803E	THRT2-T	RCS T2 THRUSTER temperature	°C				
	284	803F	THRT3-T	RCS T3 THRUSTER temperature	°C				
	285	8040	THRT4-T	RCS T4 THRUSTER temperature	°C				
	286	8041	THRR1-T	RCS R1 THRUSTER temperature	°C				
	287	8042	THRR2-T	RCS R2 THRUSTER temperature	°C				
	288	8043	XPA-T	XPA temperature	°C				
	289	8044	HTNK_SET-T	N2H4 TANK set temperature	°C				
	290	8045	NTNK_SET-T	NTO TANK set temperature	°C				
	291	8046	GTNK_SET-T	GHe TANK set temperature	°C				
	292	8047	PIP_SET-T	PIPE set temperature	°C				
	293	8048	VLV_SET-T	Valve Module set temperature	°C				
	294	8049	OME_SET-T	OME set temperature	°C				
	295	804A	BATA_SET-T	BAT-A set temperature	°C				
	296	804B	BATB_SET-T	BAT-B set temperature	°C				
	297	804C	SSC_SET-T	SSC set temperature	°C				
	298	804D	XPA_SET-T	XPA set temperature	°C				
	299	804E	SPARE						
	300	804F	HTNK-P	N2H4 TANK pressure					
	301	8050	NTNK-P	NTO TANK pressure					
	302	8051	GTNK-P	GHe TANK pressure					
	303	8052	RCSLIN1-P	RCS LINE pressure 1					
	304	8053	RCSLIN2-P	RCS LINE pressure 2					
	305	8054	OMSLIN1-P	OMS LINE pressure 1					
	306	8055	OMSLIN2-P	OMS LINE pressure 2					
	307	8056	SPARE						

Table B-3 Analog Data List (3/5)

S/S NAME	WORD	ADRS (Hex)	SYMBOL	ITEM	UNIT	RANGE		CONVERSION SYSTEM (y=ax+b)	
						MINIMUM	MAXIMUM	a	b
TCI	308	8010	RF+5V	RF +5 voltage	V				
	309	8011	RF+12V	RF +12 voltage	V				
	310	8012	RF-12V	RF -12 voltage	V				
	311	8013	DHU+5V	DHU +5 voltage	V				
	312	8014	DHU+12V	DHU +12 voltage	V				
	313	8015	SPARE						
	314	8016	SBRA-T	SBR-A temperature	°C				
	315	8017	CMD-T	CMD temperature	°C				
	316	8018	TMS-T	TMS temperature	°C				
	317	8019	TMX-T	TMX temperature	°C				
	318	801A	XPA-T	XPA temperature	°C				
	319	801B	SBRA AGC	SBR-A AGC level	dBm				
	320	801C	SBRA LPS	SBR-A Loop stress	Hz				
	321	801D	SBRB AGC	SBR-B AGC level	dBm				
	322	801E	SBRB LPS	SBR-B Loop stress	Hz				
	323	801F	THDB+5V	THDB +5 voltage	V				
	324	8020	THDB+12V	THDB +12 voltage	V				
	325	8021	THDB-12V	THDB -12 voltage	V				
	326	8022	SPARE						
AOCE	327	8020	ACMA-T	ACM-A temperature	°C				
	328	8021	ACMB-T	ACM-B temperature	°C				
	329	8022	ACMC-T	ACM-C temperature	°C				
	330	8023	ACMD-T	ACM-D temperature	°C				
	331	8024	AOCE+5V	AOCE +5 voltage	V				
	332	8025	AOCE+12V	AOCE +12 voltage	V				
	333	8026	AOCE-12V	AOCE -12 voltage	V				
	334	8027	AOCE+15V	AOCE +15 voltage	V				
	335	8028	AOCE+29V	AOCE +29 voltage	V				
	336	8029	SPARE						
PSA	337	802A	SPARE						
	338	8010	PSA-E-T	PSA-E temperature	°C	-50	+70		
	339	8011	ESA-S-T	ESA-S temperature	°C	-50	+70		
	340	8012	ISA-S-T	ISA-S temperature	°C	-50	+70		
	341	8013	XUV-S-T	XUV-S temperature	°C	-50	+70		
	342	8014	XUV-MCP-T	XUV MCP temperature	°C	-50	+70		
	343	8015	ESA-HVIN	ESA input High voltage	V	0	+500		
	344	8016	ESA-MESH		V	0	-15		
	345	8017	ESA-HVOUT	ESA output High voltage	V	0	+5000		
	346	8018	ISA-HV	ISA High voltage	V	0	-5000		
	347	8019	XUV-HV	XUV High voltage	V	0	-5000		
	348	801A	EIS-S-T	EIS-S temperature	°C	-50	+70		
	349	801B	EIS+5V	EIS +5 voltage	V	0	+10		
	350	801C	EIS+12V	EIS +12 voltage	V	0	+15		
	351	801D	EIS-12V	EIS -12 voltage	V	-15	0		
	352	801E	EIS-MCP	EIS MCP High voltage	V	0	+5000		
	353	801F	EIS-SSD	EIS SSD High voltage	V	0	+250		
PWA	354	8010	LFA-E-T	LFA-E temperature	°C	-50	+80		
	355	8011	PWS-RX-T	PWS-RX temperature	°C	-50	+80		

Table B-3 Analog Data List (4/5)

S/S NAME	WORD	ADRS (Hex)	SYMBOL	ITEM	UNIT	RANGE		CONVERSION SYSTEM (y=ax+b)	
						MINIMUM	MAXIMUM	a	b
PWA (continue)	366	8012	SPW-AMP-T	SPW amplifier temperature	°C	-60	+80		
	357	8013	SPARE						
	358	8014	W-PRE1-T	WANT Preamplifier 1 Temperature	°C	-50	+80		
	359	8015	W-PRE2-T	WANT Preamplifier 2 Temperature	°C	-50	+80		
	360	8016	W-PRE3-T	WANT Preamplifier 3 Temperature	°C	-50	+80		
	361	8017	W-PRE4-T	WANT Preamplifier 4 Temperature	°C	-50	+80		
	362	8018	WANT1-T	WANT 1 Temperature	°C	-50	+80		
	363	8019	WANT2-T	WANT 2 Temperature	°C	-50	+80		
	364	801A	WANT3-T	WANT 3 Temperature	°C	-50	+80		
	365	801B	WANT4-T	WANT 4 Temperature	°C	-50	+80		
	366	801C	PWA+5V	PWA +5 voltage	V	0	+8		
	367	801D	PWA+12V	PWA +12 voltage	V	0	+15		
	368	801E	PWA-12V	PWA -12 voltage	V	0	-15		
	369	801F	PWA+29V	PWA +29 voltage	V	0	+35		
MPM	370	8010	MGF-E-T	MGF E temperature	°C	-60	+80		
	371	8011	MGF-S-T	MGF S temperature	°C	-70	+80		
	372	8012	PET-T	PET VF temperature	°C	T.B.D.			
	373	8013	MST-T	MST motor temperature	°C	-50	+80		
	374	8014	UV-T	UV temperature	°C	-50	+80		
	375	8015	PMH-T	PHOTOMETER H cell temperature	°C	-50	+80		
	376	8016	PMD-T	PHOTOMETER D cell temperature	°C	-50	+80		
	377	8017	PM-T	PHOTOMETER temperature	°C	-50	+80		
	378	8018	MCPHV	MCP high voltage	V				
	379	8019	PMHV	PHOTOMETER high voltage	V				
	380	801A	DHIL	Filament D voltage	V				
	381	801B	HFIL	Filament H voltage	V				
	382	801C	MPM+5V	MPM +5 voltage	V				
	383	801D	MPM+12V	MPM +12 voltage	V				
	384	801E	MPM-12V	MPM -12 voltage	V				
	385	801F	MPM+29V	MPM +29 voltage	V				
MIC	386	8010	LENS-T	Lens temperature	°C				
	387	8011	CCD-T	CCD temperature	°C				
	388	8012	FPGA-T	FPGA temperature	°C				
	389	8013	MIC-T	MIC temperature	°C				
	390	8014	CLUMP-V	Clump voltage	V				
	391	8015	REF-V	Reference voltage	V				
	392	8016	THR-V	Threshold voltage	V				
	393	8017	MIC+5V	MIC +5 voltage	V				
	394	8018	MIC+12V	MIC +12 voltage	V				
	395	8019	MIC-12V	MIC -12 voltage	V				
	396	801A	SPARE						
	397	801B	SPARE						
TPA	398	F804	TPA-PCU-T	TPA PCU Temperature	°C	-55	100	1.76	
	399	F805	TPA-S-T	TPA Sensor Temperature	°C	-55	100	1.76	
	400	F806	CREADLE-T	TPA Cradle Temperature	°C	-70	100	1.76	
	401	F807	BOOM C RES	BOOM - CRADLE resistance	ohm	0	13500	52.73	

Table B-3 Analog Data List (5/5)

S/S NAME	WORD	ADRS (Hex)	SYMBOL	ITEM	UNIT	RANGE		CONVERSION SYSTEM (y=ax+h)	
						MINIMUM	MAXIMUM	a	b
IMI	402	F8F0	IMI-T	IMI Temperature	°C				
	403	F8F1	IMI HV1	IMI HV1 Voltage	V				
	404	F8F2	IMI HV2	IMI HV2 Voltage	V				
	405	F8F3	IMI HV3	IMI HV3 Voltage	V				
	406	F8F4	IMI HV4	IMI HV4 Voltage	V				
	407	F8F5	IMI T1-T	IMI T1 Temperature	°C				
	408	F8F6	IMI T2-T	IMI T2 Temperature	°C				
	409	F8F7	IMI-I	IMI Current	mA				
	410	F8F8	T.B.D.						
	411	F8F9	T.B.D.						
	412	F8FA	T.B.D.						
	413	F8FB	T.B.D.						
MDC	414	F802	MDC+200V	MDC HV +200V	V				
	415	F803	MDC-200V	MDC HV -200V	V				
	416	F804	MDC-T	MDC Temperature	°C				
	417	F805	MDC-TCC	Command/Status Count					
	418	F806	MDC-IMPC	Impact Count					
	419	F807	MDC-NC1	Noise Count					
	420	F808	MDC-NC2	Noise Count					
	421	F809	MDC-NC3	Noise Count					
	422	F80A	MDC-EC	Event/Reject Count					
NMS	423	F803	T.B.D.						
	424	F804	T.B.D.						
	425	F805	T.B.D.						
	426	F806	T.B.D.						
	427	F807	T.B.D.						
	428	F808	T.B.D.						
	429	F809	T.B.D.						
	430	F80A	T.B.D.						
	431	F80B	T.B.D.						
	432	F80C	T.B.D.						
	433	0000	SPARE						
	434	0000	SPARE						
	435	0000	SPARE						

Appendix-C : Command Items

Table C-1 Discrete Command List (1/15)

PIM ID	SUBSYSTEM
01	DHU

CODE X Y	COMMAND NAME	FUNCTION	TELEMETRY LOCATION				
			PACKET ID No(Hex)	2nd Header	W (dec)	B	STATUS
2 0	BUS ACC ENA	BUS ACCESS ENABLE	01	N/A	16	7	1
2 1	BUS ACC DIS	BUS ACCESS DISABLE	01	N/A	16	7	0
2 2	MODE CHNG	MODE CHANGE	01	N/A	6-8	-	-
2 3	DMP PRM SET	DUMP PARAMETER SET	01	N/A	43-46	-	-
2 4	TLM ROM UD	TLM-ROM UPDATE	01	N/A	20-21,30	-	-
2 5	TLM ROM A ON	TLM-ROM A ON	01	N/A	8	0	0
2 6	TLM ROM B ON	TLM-ROM B ON	01	N/A	8	0	1
2 7	S REP ON	S-TLM REP ON/X-TLM REP OFF	01	N/A	9	6	1
2 8	X REP ON	X-TLM REP ON/S-TLM REP OFF	01	N/A	9	4	1
2 9	REP OFF	REPRODUCE OFF	01	N/A	9	4,6	0,0
2 A	REC DATA OUTPUT ON	RECORD DATA OUTPUT ON	01	N/A	9	3	1
2 B	REC DATA OUTPUT OFF	RECORD DATA OUTPUT OFF	01	N/A	9	3	0
2 C	S TLM ON	S TLM DATA OUTPUT ON	01	N/A	9	7	1
2 D	S TLM OFF	S TLM DATA OUTPUT OFF	01	N/A	9	7	0
2 E	X TLM ON	X TLM DATA OUTPUT ON	01	N/A	9	5	1
2 F	X TLM OFF	X TLM DATA OUTPUT OFF	01	N/A	9	5	0
4 0	BUS A ON	CONTROL BUS A ON /B OFF	01	N/A	19	2,3	10
4 1	BUS B ON	CONTROL BUS B ON /A OFF	01	N/A	19	2,3	01
4 2	CLK-A STOP	CONTROL BUS MASTER CLOCK-A STOP	01	N/A	19	4	0
4 3	CLK-B STOP	CONTROL BUS MASTER CLOCK-B STOP	01	N/A	19	5	0
4 4	CLK-A OUT	CONTROL BUS MASTER CLOCK-A ON	01	N/A	19	4	1
4 5	CLK-B OUT	CONTROL BUS MASTER CLOCK-B ON	01	N/A	19	5	1
4 6	R-BUS A ENA	RESPONSE-BUS A ENABLE	01	N/A	19	6	1
4 7	R-BUS A DIS	RESPONSE-BUS A DISABLE	01	N/A	19	6	0
4 8	R-BUS B ENA	RESPONSE-BUS B ENABLE	01	N/A	19	7	1
4 9	R-BUS B DIS	RESPONSE-BUS B DISABLE	01	N/A	19	7	0
6 0	TI DLVRY	TIME INDICATOR BROAD CASTING	01	N/A	27	-	-
6 1	TI_ABS_CAL	TIME INDICATOR ABSOLUTE CALIBRATION	01	N/A	4,5	-	-
6 2	TI_DIF_CAL	TIME DIFFERENTIAL CALIBRATION	N/A				
7 0	DHU-PRG RUN	DHU-PROGRAM RUN	01	N/A	24	6,7	10
7 1	DHU-PRG AP IPL	DHU-PROGRAM APPLICATION IPL	01	N/A	24	6,7	01
7 2	DHU-PRG OS IPL	DHU-PROGRAM OS IPL	01	N/A	24	6,7	01
7 3	DHU-PRG ROM UD	DHU-PROGRAM ROM UPDATE	01	N/A	20,21	-	-
7 4	DHU-PRG RAM WRI	DHU-PROGRAM RAM WRITE	01	N/A	20,21	-	-
7 5	DHU-PRG AP CHK	DHU-PROGRAM APPLICATION CHECK	01	N/A	29,30	-	-
7 6	DHU-PRG OS CHK	DHU-PROGRAM OS CHECK	01	N/A	29,30	-	-
7 7	BFM UPDATE	BFM UPDATE	01	N/A	20-21	-	-
7 8	USR-PRG CHK	USER-PROGRAM CHECK	01	N/A	22	6	0
7 9	USR-PRG IPL	USER-PROGRAM IPL	01	N/A	20-21	-	-
7 A	USR-PRG RAM WRI	USER-PROGRAM RAM WRITE	01	N/A	20-21	-	-

Table C-1 Discrete Command List (2/15)

PIM ID	SUBSYSTEM
01	DHU

[illegible]

Table C-1 Discrete Command List (3/15)

PIM ID	SUBSYSTEM
02	AOCE

CODE X Y	COMMAND NAME	FUNCTION	TELEMETRY LOCATION				
			PACKET ID No(Hex)	2nd Header	W (deci)	B	STATUS
0 1	AOCE ON	AOCE ON	01	N/A	47	0	1
2 5	AOCE OFF ENA	AOCE OFF ENABLE	01	N/A	48	0	1
2 6	AOCE OFF	AOCE OFF	01	N/A	47	0	0
2 7	AOCE RST ENA	AOCE RESET ENABLE	01	N/A	48	2	1
2 8	AOCE RST	AOCE RESET	01	N/A	48	2	0
2 9	BC EXE	BC EXECUTE	N/A				
2 A	BC DIS	BC DISABLE	01	N/A	49	2	0
2 B	ENACMD_RST	ENABLE CMD RESET	01	N/A	48	0-7	ALL 0
					49	1,2	00
2 C	DE ENA	DATA ERROR ENABLE	01	N/A	49	5	1
2 D	DE DIS	DATA ERROR DISABLE	01	N/A	49	5	0
2 E	EE ENA	EXTERNAL ERROR ENABLE	01	N/A	49	6	1
2 F	EE DIS	EXTERNAL ERROR DISABLE	01	N/A	49	6	0
3 0	MRM-A_ON	MONITOR AND RECONFIGURATION MODULE A ON	01	N/A	58	0	1
3 1	MRM-B_ON	MONITOR AND RECONFIGURATION MODULE B ON	01	N/A	58	1	1
3 2	MRM_OFF_ENA	MONITOR AND RECONFIGURATION MODULE OFF ENABLE					
3 3	MRM-A_OFF	MONITOR AND RECONFIGURATION MODULE A OFF	01	N/A	58	0	0
3 4	MRM-B_OFF	MONITOR AND RECONFIGURATION MODULE B OFF	01	N/A	58	1	0
3 5	CONFIG BC_ENA	CONFIGURATION BC ENABLE	01	N/A	49	2	1
A 0	CPU-A_ON	CPU-A ON	01	N/A	60	0	1
A 1	CPU-B_ON	CPU-B ON	01	N/A	62	0	1
A 2	CPU OFF ENA	CPU OFF ENABLE	01	N/A	61	7	1
A 3	CPU-A OFF	CPU-A POWER OFF	01	N/A	60	0	0
A 4	CPU-B OFF	CPU-B POWER OFF	01	N/A	62	0	0
A 5	MANUAL_MODE	MONITOR AND RECONFIGURATION MODULE MANUAL MODE	01	N/A	58	2,3	00
A 6	SIMPLEX_MODE	MONITOR AND RECONFIGURATION MODULE SIMPLEX MODE	01	N/A	58	2,3	01
A 7	DUPLEX_MODE	MONITOR AND RECONFIGURATION MODULE DUPLEX MODE	01	N/A	58	2,3	10
A 8	EM-A SET	ERROR MARK-A FLAG SET	01	N/A			
A 9	EM-A RST	ERROR MARK-A FLAG RESET	01	N/A			
A A	EM-B SET	ERROR MARK-B FLAG SET	01	N/A			
A B	EM-B RST	ERROR MARK-B FLAG RESET	01	N/A			
A C	FLG CLR	FLAG CLEAR	01	N/A			
D 0	SYNC	SYNCHRONIZATION FOR BOTH OF CPU'S	01	N/A			
D 1	NML-A	CPU-A NORMAL MODE	01	N/A			
D 2	NML-B	CPU-B NORMAL MODE	01	N/A			
D 3	STBY-A	OBS STANDBY ROM MODE	01	N/A			
D 4	STBY-B	OBS STANDBY ROM MODE	01	N/A			
D 5	CHK-A	CPU-A OBS CHECK	01	N/A	61	2	-
D 6	CHK-B	CPU-B OBS CHECK	01	N/A	63	2	-
D 7	DMP-A	CPU-A OBS TLM DUMP	01	N/A			

Table C-1 Discrete Command List (4/15)

PIM ID	SUBSYSTEM
02	AOCE

CODE X Y	COMMAND NAME	FUNCTION	TELEMETRY LOCATION				
			PACKET ID No(Hex)	2nd Header	W (dec)	B	STATUS
D 8	DMP-B	CPU-B OBS TLM DUMP	01	N/A			
D 9	AACP BC ENA	AACP BC ENABLE	01	N/A			
D A	CPU-A PRG ENA	CPU-A PROGRAM ENABLE	01	N/A			
D B	CPU-B PRG ENA	CPU-B PROGRAM ENABLE	01	N/A			
D C	CPU-A ADR ENA	CPU-A ADDRESS ENABLE	01	N/A			
D D	CPU-B ADR ENA	CPU-B ADDRESS ENABLE	01	N/A			
7 0	CMD FLG0 ENA	AOCI PORT-CMD FLG0 ON	01	N/A			
7 1	CMD FLG1 ENA	AOCI PORT-CMD FLG1 ON	01	N/A			
7 2	CMD FLG2 ENA	AOCI PORT-CMD FLG2 ON	01	N/A			
7 3	CMD FLG3 ENA	AOCI PORT-CMD FLG3 ON	01	N/A			
7 4	CMD FLG4 ENA	AOCI PORT-CMD FLG4 ON	01	N/A			
7 5	CMD FLG5 ENA	AOCI PORT-CMD FLG5 ON	01	N/A			
7 6	CMD FLG6 ENA	AOCI PORT-CMD FLG6 ON	01	N/A			
7 7	CMD FLG7 ENA	AOCI PORT-CMD FLG7 ON	01	N/A			
7 8	CMD FLG8 ENA	AOCI PORT-CMD FLG8 ON	01	N/A			
7 9	CMD FLG9 ENA	AOCI PORT-CMD FLG9 ON	01	N/A			
8 0	CMD FLG0 DIS	AOCI PORT-CMD FLG0 OFF	01	N/A			
8 1	CMD FLG1 DIS	AOCI PORT-CMD FLG1 OFF	01	N/A			
8 2	CMD FLG2 DIS	AOCI PORT-CMD FLG2 OFF	01	N/A			
8 3	CMD FLG3 DIS	AOCI PORT-CMD FLG3 OFF	01	N/A			
8 4	CMD FLG4 DIS	AOCI PORT-CMD FLG4 OFF	01	N/A			
8 5	CMD FLG5 DIS	AOCI PORT-CMD FLG5 OFF	01	N/A			
8 6	CMD FLG6 DIS	AOCI PORT-CMD FLG6 OFF	01	N/A			
8 7	CMD FLG7 DIS	AOCI PORT-CMD FLG7 OFF	01	N/A			
8 8	CMD FLG8 DIS	AOCI PORT-CMD FLG8 OFF	01	N/A			
8 9	CMD FLG9 DIS	AOCI PORT-CMD FLG9 OFF	01	N/A			
4 0	SSAS ON	SSAS ON	01	N/A	54	0	1
4 1	SSAS OFF ENA	SSAS OFF ENABLE	01	N/A	48	3	1
4 2	SSAS OFF	SSAS OFF	01	N/A	54	0	0
4 3	TSAS ON	TSAS ON	01	N/A	54	1	1
4 4	TSAS OFF ENA	TSAS OFF ENABLE	01	N/A	48	4	1
4 5	TSAS OFF	TSAS OFF	01	N/A	54	1	0
C 0	TSAS CAL ON	TSAS CAL ON	01	N/A			
C 1	TSAS CAL OFF	TSAS CAL OFF	01	N/A			
4 6	SSC ON	SSC ON	01	N/A	47	2	1
4 7	SSC OFF ENA	SSC OFF ENABLE	01	N/A	48	5	1
4 8	SSC OFF	SSC OFF	01	N/A	47	2	0
4 9	SSC CAL ON	SSC CAL ON	01	N/A	47	3	1
4 A	SSC CAL OFF	SSC CAL OFF	01	N/A	47	3	0
C 2	SSC BC AUTO	SSC BC AUTO	01	N/A			
C 3	SSC BC MANU	SSC BC MANU	01	N/A			
C 4	SSC FILTR ENA	SSC FILTER ENABLE	01	N/A			
C 5	SSC FILTR DIS	SSC FILTER DISABLE	01	N/A			
C C	DATA SAVE ENA	SSC,TSAS,SSAS DATA SAVE START	01	N/A			
C D	DATA SAVE DIS	SSC,TSAS,SSAS DATA SAVE END	01	N/A			

Table C-1 Discrete Command List (5/15)

PIM ID	SUBSYSTEM
02	AOCE

CODE X Y	COMMAND NAME	FUNCTION	TELEMETRY LOCATION				
			PACKET ID No(Hex)	2nd Header	W (deci)	B	STATUS
3 6	ACM-A ON	ACM-A ON	01	N/A	54	2	1
3 7	ACM-B ON	ACM-B ON	01	N/A	54	3	1
3 8	ACM-C ON	ACM-C ON	01	N/A	54	4	1
3 9	ACM-D ON	ACM-D ON	01	N/A	54	5	1
3 A	ACM OFF ENA	ACM OFF ENABLE	01	N/A	48	7	1
3 B	ACM OFF	ACM OFF	01	N/A	48	7	0
					54	4-7	ALL 0
C 6	INTEG ENA	INTEG ENABLE	01	N/A			
C 7	INTEG DIS	INTEG DISABLE	01	N/A			
C 8	ACM BIAS ENA	ACM BIAS ENABLE	01	N/A			
C 9	ACM BIAS DIS	ACM BIAS DISABLE	01	N/A			
C A	AD TEMP ENA	AD-CONVERTER TEMPERATURE ENA	01	N/A			
C B	AD TEMP DIS	AD-CONVERTER TEMPERATURE DIS	01	N/A			
3 C	RGA-A ON	RGA-A ON	01	N/A	54	2	1
3 D	RGA-B ON	RGA-B ON	01	N/A	54	3	1
3 E	RGA OFF ENA	RGA OFF ENABLE	01	N/A	48	6	1
3 F	RGA OFF	RGA OFF	01	N/A	48	6	0
					54	2,3	00
5 0	RCSPWR ON	RCS DRIVE POWER ON	01	N/A	50	0	1
5 1	RCSPWR OF ENA	RCS DRIVE POWER OF ENABLE	01	N/A	49	0	1
5 2	RCSPWR OFF	RCS DRIVE POWER OFF	01	N/A	50	0	0
5 3	RCS ENA	RCS ENABLE	01	N/A	50	3	1
E 0	RCS GO	RCS GO					
5 4	RCS STOP	RCS STOP					
5 5	RCS PRITY ENA	RCS PARITY ENABLE	01	N/A	50	1	1
5 6	RCS PRITY DIS	RCS PARITY DISABLE	01	N/A	50	1	0
5 7	RCS WDT ENA	RCS WATCHDOG TIMER ENABLE	01	N/A	50	2	1
5 8	RCS WDT DIS	RCS WATCHDOG TIMER DISABLE	01	N/A	50	2	0
5 9	RCS CNTIN ENA	RCS CONTINUATION ENABLE	01	N/A	50	4	1
5 A	RCS_CNTIN_DIS	RCS CONTINUATION DISABLE	01	N/A	50	4	0
6 A	HLV OPEN	HIGH PRESSURE VALVE OPEN	01	N/A	55	0	1
7 A	HLV CLOSE	HIGH PRESSURE VALVE CLOSE	01	N/A	55	0	0
6 B	LV-1 OPEN	LATCHING VALVE-1 OPEN	01	N/A	55	1	1
7 B	LV-1 CLOSE	LATCHING VALVE-1 CLOSE	01	N/A	55	1	0
6 C	LV-2 OPEN	LATCHING VALVE-2 OPEN	01	N/A	55	2	1
7 C	LV-2 CLOSE	LATCHING VALVE-2 CLOSE	01	N/A	55	2	0
6 D	LV-3 OPEN	LATCHING VALVE-3 OPEN	01	N/A	55	3	1
7 D	LV-3 CLOSE	LATCHING VALVE-3 CLOSE	01	N/A	55	3	0
6 E	LV-4 OPEN	LATCHING VALVE-4 OPEN	01	N/A	55	4	1
7 E	LV-4 CLOSE	LATCHING VALVE-4 CLOSE	01	N/A	55	4	0
6 F	LV-5 OPEN	LATCHING VALVE-5 OPEN	01	N/A	55	5	1
7 F	LV-5 CLOSE	LATCHING VALVE-5 CLOSE	01	N/A	55	5	0
8 A	LV-6 OPEN	LATCHING VALVE-6 OPEN	01	N/A	55	6	1
8 A	LV-6 CLOSE	LATCHING VALVE-6 CLOSE	01	N/A	55	6	0
8 B	LV-M OPEN	LATCHING VALVE-M OPEN	01	N/A	55	7	1
8 B	LV-M CLOSE	LATCHING VALVE-M CLOSE	01	N/A	55	7	0

Table C-1 Discrete Command List (6/15)

PIM ID	SUBSYSTEM
02	AOCE

[illegible]

Table C-1 Discrete Command List (7/15)

PIM ID	SUBSYSTEM
06	DR

[illegible]

Table C-1 Discrete Command List (8/15)

PIM ID	SUBSYSTEM
07	PSA

CODE X Y	COMMAND NAME	FUNCTION	TELEMETRY LOCATION				
			PACKET ID No(Hex)	2nd Header	W (deci)	B	STATUS
0 1	PSA CPU ON	PSA SI-CPU ON	01	N/A	100	7	1
0 2	PSA CPU OFF	PSA SI-CPU OFF	01	N/A	100	7	0
1 0	PSA HTR ENA	PSA HEATER ENABLE	01	N/A	100	3	1
1 1	PSA HTR DIS	PSA HEATER DISABLE	01	N/A	100	3	0
1 2	PSA ECC ENA	PSA ECC ENABLE	01	N/A	100	2	1
1 3	PSA ECC DIS	PSA ECC DISABLE	01	N/A	100	2	0
1 4	PSA WDT ENA	PSA WATCHDOG TIMER ENABLE	01	N/A	100	5	1
1 5	PSA WDT DIS	PSA WATCHDOG TIMER DISABLE	01	N/A	100	5	0
1 6	PSA CPU RUN	PSA SI-CPU RUN	01	N/A	100	6	1
1 7	PSA CPU RST	PSA SI-CPU RESET	01	N/A	100	6	0
1 8	PSA ADRS SET	PSA ADDRESS SET					
2 0	PSA BUS ACC ENA	PSA BUS ACCESS ENABLE					
2 1	PSA BUS ACC DIS	PSA BUS ACCESS DISABLE					
2 2	PSA MODE CHNG	PSA MODE CHANGE					
8 0	EIS ON	EIS SYSTEM CONTROL POWER ON	01	N/A	101	0	1
A 0	EIS OFF	EIS SYSTEM CONTROL POWER OFF	01	N/A	101	0	0
8 2	EIS HV ENA SET	EIS HV "ON" ENABLE	01	N/A	101	1,2	-
A 2	EIS HV DIS SET	EIS HV "ON" DISABLE	01	N/A	101	1,2	-
8 4	EIS HV ON SET	EIS HV ON	01	N/A	101	3,4	-
A 4	EIS HV OFF SET	EIS HV OFF	01	N/A	101	3,4	-
8 E	EIS HV CTL SET	EIS HV OUTPUT VOLTAGE CONTROL					
8 6	EIS CAL ON	EIS CAL ON	01	N/A	101	7	1
A 6	EIS CAL OFF	EIS CAL OFF	01	N/A	101	7	0
8 8	EIS ANTI ENA	EIS ANTICOINCIDENCE ENABLE	01	N/A	101	6	1
A 8	EIS ANTI DIS	EIS ANTICOINCIDENCE DISABLE	01	N/A	101	6	0
9 0	EIS CTL SET	EIS SYSTEM CONTROL					
8 C	EIS DISC SET	EIS DISCRIMINATION LEVEL SET					
8 A	ADD ONE ENA	ADD ONE ENABLE	01	N/A	101	5	1
A A	ADD ONE DIS	ADD ONE DISABLE	01	N/A	101	5	0
3 0	PAX ON	ESA,ISA,XUV CONTROL POWER ON	01	N/A	102	0	1
3 1	PAX OFF	ESA,ISA,XUV CONTROL POWER OFF	01	N/A	102	0	0
4 0	PAX HV ENA SET	ESA,ISA,XUV HV "ON" ENABLE	01	N/A	103,104		-
4 2	PAX HV ON SET	ESA,ISA,XUV HV ON	01	N/A	103,104		-
4 4	PAX HV OFF SET	ESA,ISA,XUV HV OFF	01	N/A	103,104		-
6 0	PAX_HV_SET	ESA,ISA,XUV HV OUTPUT VOLTAGE CONTROL	01	N/A	103,104		-
6 1	PAX CTL SET	ESA,ISA,XUV SYSTEM CONTROL					
4 6	H32 CTL SET	H32 CONTROL	01	N/A	102	-	-
4 A	H32 ST ADRS SET	H32 START ADDRESS SET					
6 2	ESA CTL SET	ESA SYSTEM CONTROL	01	N/A	104	2,3	-
6 3	ISA CTL SET	ISA SYSTEM CONTROL	01	N/A	104	4,5	-
6 4	XUV FOV SET	XUV FIELD OF VIEW SET					
3 2	H32 ON	H32 POWER ON	01	N/A	102	7	1
3 3	H32 OFF	H32 POWER OFF	01	N/A	102	7	0

Table C-1 Discrete Command List (9/15)

PIM ID	SUBSYSTEM
08	PWA

CODE X Y	COMMAND NAME	FUNCTION	TELEMETRY LOCATION				
			PACKET ID No(Hex)	2nd Header	W (deci)	B	STATUS
0 1	PWA CPU ON	PWA SI-CPU ON	01	N/A	128	7	1
0 2	PWA CPU OFF	PWA SI-CPU OFF	01	N/A	128	7	0
1 0	PWA HTR ENA	PWA HEATER ENABLE	01	N/A	128	3	1
1 1	PWA HTR DIS	PWA HEATER DISABLE	01	N/A	128	3	0
1 2	PWA ECC ENA	PWA ECC ENABLE	01	N/A	128	2	1
1 3	PWA ECC DIS	PWA ECC DISABLE	01	N/A	128	2	0
1 4	PWA WDT ENA	PWA WATCHDOG TIMER ENABLE	01	N/A	128	5	1
1 5	PWA WDT DIS	PWA WATCHDOG TIMER DISABLE	01	N/A	128	5	0
1 6	PWA CPU RUN	PWA SI-CPU RUN	01	N/A	128	6	1
1 7	PWA CPU RST	PWA SI-CPU RESET	01	N/A	128	6	0
1 8	PWA ADRS SET	PWA ADDRESS SET					
2 0	PWA BUS ACC ENA	PWA BUS ACCESS ENABLE					
2 1	PWA BUS ACC DIS	PWA BUS ACCESS DISABLE					
2 2	PWA MODE CHNG	PWA MODE CHANGE					
7 0	WANT PRE ON	WANT PRE-AMP POWER ON	01	N/A	140	4	TBD
7 2	WANT PRE OFF	WANT PRE-AMP POWER OFF	01	N/A	140	4	TBD
3 0	LFA ON SET	LFA ON MODE SET	01	N/A	129,131		-
3 2	LFA OFF SET	LFA OFF MODE SET	01	N/A	129,131		-
3 4	WFCD BIAS SET	WFCD BIAS PARAMETER SET	01	N/A	134	0-7	-
3 6	WFCD BANK SET	WFCD MEMORY BANK SET	01	N/A	134	4-7	-
3 8	WFCD GAIN SET	LFA GAIN AND OFA ANTENNA SET	01	N/A	129,131		-
3 A	LFA DSP SET	LFA DSP SET	01	N/A	130	-	-
8 0	PWS ON	PWS POWER ON	01	N/A	136	0	1
8 2	PWS OFF	PWS POWER OFF	01	N/A	136	0	0
8 4	PWS DC/DC ON	DC/DC CONVERTER ON	01	N/A	136	1	1
8 6	PWS DC/DC OFF	DC/DC CONVERTER OFF	01	N/A	136	1	0
8 8	POWER AMP ON	POWER AMP ON	01	N/A	136	2	1
8 A	POWER AMP OFF	POWER AMP OFF	01	N/A	136	2	0
8 C	NEI ON	NEI POWER ON	01	N/A	136	3	1
8 E	NEI OFF	NEI POWER OFF	01	N/A	136	3	0
TBD	PWS CAL ON SET	PWS CAL PARAMETER ON SET	01	N/A	136,137		-
TBD	PWS CAL OFF SET	PWS CAL PARAMETER OFF SET	01	N/A	136,137		-
9 2	PWS ANT SET	PWS ANTENNA PARAMETER SET	01	N/A	135	1	1
9 4	PWS MODE SET	PWS OBS MODE SET	01	N/A	135	2	1
9 6	PWS LOCAL SET	PWS LOCAL-OSC PARAMETER SET	01	N/A	135	3	1
TBD	PWS GAIN SET	PWS GAIN SET	01	N/A	139	1-2	-
9 8	PWS PARA SET	PWS SWEEP MODE SET	01	N/A	135	4	1
TBD	POWER AMP ON SET	PWS POWER AMP PARAMETER ON SET	01	N/A	138	-	-
TBD	POWER AMP OFF SET	PWS POWER AMP PARAMETER OFF SET	01	N/A	138	-	-
9 C	PWS DATA SET	PWS DATA REDUCTION SET	01	N/A	135	6	1
9 E	OBS TIME SET	PWS OBS TIME SET	01	N/A	135	7	1
C 0	WANT ON SET	WANT STBY.ANT.MONLLIM.SEL1-4 ON SET	01	N/A	141	0-7	-
C 2	WANT OFF SET	WANT STBY.ANT.MONLLIM.SEL1-4 OFF SET	01	N/A	141	0-7	-
C 4	WANT DRV ON	WANT 1-4 DRIVE ON	01	N/A	143	0	1
C 6	WANT DRV OFF	WANT 1-4 DRIVE/STAND-BY OFF	01	N/A	143	0	0

Table C-1 Discrete Command List (10/15).

PIM ID	SUBSYSTEM
09	MPM

[illegible]

Table C-1 Discrete Command List (11/15)

PIM ID	SUBSYSTEM
09	MPM

[illegible]

Table C-1 Discrete Command List (12/15)

PIM ID	SUBSYSTEM
0A	MIC

[illegible]

Table C-1 Discrete Command List (13/15)

PIM ID	SUBSYSTEM
0B	IMI

[illegible]

Table C-1 Discrete Command List (14/15)

PIM ID	SUBSYSTEM
0C	MDC

[illegible]

Table C-1 Discrete Command List (15/15)

PIM ID	SUBSYSTEM
0D	TPA

[illegible]

Table C-2 Block Command List (1/7)

S/S NAME	DC NAME	BC NAME	BC SIZE (byte)	CODE		BC BIT MAP								TELEMETRY			STATUS				
				DC (HEX)	BC (HEX)	MSB				LSB				PACKET ID(HEX)	WORD	BIT					
						B0	B1	B2	B3	B4	B5	B6	B7								
DHU	MODE_CHNG		3	22	•	0	0	0	FORMAT No.				01	8	3~7	•					
					•	0	0	0	0	EDITION RATE			01	6	4~7	•					
					•	X BIT RATE				S BIT RATE			01	7	ALL	•					
	DUMP_PRG_SET		4	23	•	MEM DMP UPPER ADR															
					•	0	MEM DMP LOWER ADR														
					•	MEM DMP BLOCK COUNT															
					•	0	LOOP CNT				PIM ID										
					•	0	0	0	FORMAT												

S/S NAME	DC NAME	BC NAME	BC SIZE (byte)	CODE		BC BIT MAP								TELEMETRY			STATUS	
				DC	BC	MSB				LSB				PACKET ID(HEX)	WORD	BIT		
				(HEX)	(HEX)	B0	B1	B2	B3	B4	B5	B6	B7					
AOCE			2			• AOCP ADDRESS SET												
						• AOCP ADDRESS SET												
			3-5			• AOCP DATA IDENTIFICATION WORD												
						• AOCP DATA IDENTIFICATION WORD												
						• AOCP DATA IDENTIFICATION WORD (1-3 Bytes)												
			N/A			• AOCP PROGRAM												
			2			• Time set :Upper 8 bits 0-2047.5sec LSB=0.5sec												
						• Time set :Lower 4 bits N/A												
					• AOCP ADDRESS SET													
					• AOCP ADDRESS SET													

S/S NAME	DC NAME	BC NAME	BC SIZE (byte)	CODE		BC BIT MAP								TELEMETRY			STATUS				
				DC (HEX)	BC (HEX)	MSB				LSB				PACKET ID(HEX)	WORD	BIT					
						B0	B1	B2	B3	B4	B5	B6	B7								
DR	DR-MB-ON		1	60	*	Each bit number = each memory block number								01	91	0-3	-				
	DR-MB-OFF		1	61	*	Each bit number = each memory block number								01	91	0-3	-				
	DR-MSK-SET		2	62	*	Each bit number = each memory block number															
					*	Mask bit address															
	DR-MSK-RSET		2	63	*	Each bit number = each memory block number															
					*	Address of mask cancellation bit															

Table C-2 Block Command List (2/7)

S/S NAME	DC NAME	BC NAME	BC SIZE (byte)	CODE		BC BIT MAP										TELEMETRY			STATUS
				DC (HEX)	BC (HEX)	MSB	B0	B1	B2	B3	B4	B5	B6	B7	LSB	PACKET ID(HEX)	WORD	BIT	
PSA	EIS_HV_ENA_SET	EIS SSD HV ENA	1	82	01										0 1	01	101	1	1
		EIS MCP HV ENA	1	82	02										1 0	01	101	2	1
	EIS_HV_DIS_SET	EIS SSD HV DIS	1	A2	01										0 1	01	101	1	0
		EIS MCP HV DIS	1	A2	02										1 0	01	101	2	0
	EIS_HV_ON_SET	EIS SSD HV ON	1	84	01										0 1	01	101	3	1
		EIS MCP HV ON	1	84	02										1 0	01	101	4	1
	EIS_HV_OFF_SET	EIS SSD HV OFF	1	A4	01										0 1	01	101	3	0
		EIS MCP HV OFF	1	A4	02										1 0	01	101	4	0
	EIS_HV_CTL_SET	EIS SSD HV SEL	2	8E	01										0 1				
					*														
		EIS MCP HV SEL	2	8E	02										CNT DATA				
					*														
	EIS_DISC_SET	EIS SSD DL SET	1	8C	*		*	*		SSD3 DL	SSD2 DL	SSD1 DL							
		EIS +1 TABLE DUMP	8	90	01					NOT USE	0	0	0	1					
					*					EIS CHA TBL DATA									
					*					EIS CHA INT DATA									
					*					EIS CHA DTC DATA									
					*					EIS SFT ETBL DATA 1									
					*					EIS SFT ETBL DATA 2									
					*					EIS SFT TTBL DATA 1									
					*					EIS SFT TTBL DATA 2									
		EIS AUT INT	8	90	02					NOT USE	0	0	1	0					
					*					EIS CHA TBL DATA									
					*					EIS CHA INT DATA									
					*					EIS CHA DTC DATA									
					*					EIS SFT ETBL DATA 1									
	EIS S3-A FIX				*					EIS SFT ETBL DATA 2									
					*					EIS SFT TTBL DATA 1									
					*					EIS SFT TTBL DATA 2									
		EIS S3-A FIX	8	90	08					NOT USE	1	0	0	0					
					*					EIS CHA TBL DATA									
					*					EIS CHA INT DATA									
	EIS S3-B FIX				*					EIS CHA DTC DATA									
					*					EIS SFT ETBL DATA 1									
					*					EIS SFT ETBL DATA 2									
					*					EIS SFT TTBL DATA 1									
					*					EIS SFT TTBL DATA 2									
					*					EIS SFT TTBL DATA 1									
PAX	PAX_HV_ENA_SET	XUV HV MCP ENA	1	40	*					NOT USE	*	*	*	*	1	01	104	0	1
		ISA HV SV ENA	1	40	*					NOT USE	*	*	*	1	*	01	103	6	1
		ISA HV MCP ENA	1	40	*					NOT USE	*	*	1	*	*	01	103	4	1
		ESA HV SV ENA	1	40	*					NOT USE	*	1	*	*	*	01	103	2	1
	PAX_HV_ON_SET	ESA HV MCP ENA	1	40	*					NOT USE	1	*	*	*	*	01	103	0	1
		XUV HV MCP ON	1	42	*					NOT USE	*	*	*	*	1	01	104	1	1
		ISA HV SV ON	1	42	*					NOT USE	*	*	*	1	*	01	103	7	1
		ISA HV MCP ON	1	42	*					NOT USE	*	*	1	*	*	01	103	5	1
	PAX_HV_OFF_SET	ESA HV SV ON	1	42	*					NOT USE	*	1	*	*	*	01	103	3	1
		ESA HV MCP ON	1	42	*					NOT USE	1	*	*	*	*	01	103	1	1
		XUV HV MCP OFF	1	44	*					NOT USE	*	*	*	*	1	01	104	1	0
		ISA HV SV OFF	1	44	*					NOT USE	*	*	*	1	*	01	103	7	0
PAX	PAX_HV_ON_SET	ISA HV MCP OFF	1	44	*					NOT USE	*	*	1	*	*	01	103	5	0
		ESA HV SV OFF	1	44	*					NOT USE	*	1	*	*	*	01	103	3	0
		ESA HV MCP OFF	1	44	*					NOT USE	1	*	*	*	*	01	103	1	0
		XUV HV MCP SEL	2	60	01					NOT USE	0	0	0	0	1				
	PAX_HV_SET				*					CNT DATA									
		ISA HV SV SEL	2	60	02					NOT USE	0	0	0	1	0				
					*					NOT USE					CNT DATA				
		ISA HV MCP SEL	2	60	04					NOT USE	0	0	1	0	0				
	PAX_HV_OFF_SET				*					CNT DATA									
		ESA HV SV SEL	2	60	08					NOT USE	0	1	0	0	0				
					*					NOT USE					CNT DATA				
		ESA HV MCP SEL	2	60	10					NOT USE	1	0	0	0	0				
					*					CNT DATA									

Table C-2 Block Command List (3/7)

S/S NAME	DC NAME	BC NAME	BC SIZE (byte)	CODE		BC BIT MAP								TELEMETRY			STATUS
				DC (HEX)	BC (HEX)	MSB							LSB	PACKET ID(HEX)	WORD	BIT	
				B0	B1	B2	B3	B4	B5	B6	B7						
PSA	PAX_CTL_SET		2	61	*	CNT DATA											
					*	CNT DATA											
	H32_CTL_SET	H32 BUS ENABLE	1	46	*	*	NOT USE				*	1					
		H32 BUS FLOAT	1	46	*	*	NOT USE				*	0					
		H32 STATUS	1	46	83	1	NOT USE				1	1					
		H32 STATUS	1	46	81	1	NOT USE				0	1					
		H32 STATUS	1	46	83	1	NOT USE				1	1					
		H32 STATUS	1	46	03	0	NOT USE				1	1					
	H32_ST_ADRS_SET		4	4A	*	H32 ADDRESS 0-7											
					*	H32 ADDRESS 8-15											
					*	H32 ADDRESS 16-23											
					*	H32 ADDRESS 24-32											
	ESA_CTL_SET	ESA CAL ON	1	62	*	1	*	CNT DATA						01	104	2	1
		ESA CAL OFF	1	62	*	0	*	CNT DATA						01	104	2	0
		ESA MODE PHA	1	62	*	*	1	CNT DATA						01	104	3	1
		ESA MODE PD	1	62	*	*	0	CNT DATA						01	104	3	0
	ISA_CTL_SET	ISA CAL ON	1	63	*	1	*	CNT DATA						01	104	4	1
		ISA CAL OFF	1	63	*	0	*	CNT DATA						01	104	4	0
		ISA MODE PHA	1	63	*	*	1	CNT DATA						01	104	5	1
		ISA MODE PD	1	63	*	*	0	CNT DATA						01	104	5	0
	XUV_FOV_SET	XUV_FOV	1	64	*	NOT USE						CNT DATA					

Table C-2 Block Command List (4/7)

S/S NAME	DC NAME	BC NAME	BC SIZE (byte)	CODE		BC BIT MAP										TELEMETRY			STATUS		
				DC (HEX)	BC (HEX)	MSB	B0	B1	B2	B3	B4	B5	B6	B7	LSB	PACKET ID(HEX)	WORD	BIT			
PWA	LFA_ON_SET	LFA ON	1	30	*	1	*	*	*	*	*	*	*	NOT USE	01	129	0	1			
		CAL ON	1	30	*	*	1	*	*	*	*	*	*	NOT USE	01	129	1	1			
		DCAL ON	1	30	*	*	*	*	1	*	*	*	*	NOT USE							
		BIAS ON	1	30	*	*	*	*	*	1	*	*	*	NOT USE	01	129	2	1			
	CLK PWS	1	30	*	*	*	*	*	*	1	*	*	NOT USE	01	131	1	0				
	LFA_OFF_SET	LFA OFF	1	32	*	1	*	*	*	*	*	*	*	NOT USE	01	129	0	0			
		CAL OFF	1	32	*	*	1	*	*	*	*	*	*	NOT USE	01	129	1	0			
		DCAL OFF	1	32	*	*	*	*	1	*	*	*	*	NOT USE							
		BIAS OFF	1	32	*	*	*	*	*	1	*	*	*	NOT USE	01	129	2	0			
	CLK LFA	1	32	*	*	*	*	*	*	1	*	*	NOT USE	01	131	1	1				
	WPCD_BIAS_SET	(SIGN +)	1	34	*	1	MSB							LSB		01	134	0~7	*		
		(SIGN -)	1	34	*	0															
	WPCD_BANK_SET		1	36	*	NOT USE					MSB					LSB		01	131	4~7	*
	LFA_GAIN_ANT_SET	WPCD SPB	1	38	*	NOT USE	1	*	*	*	*	*	*	*	01	131	2	1			
		WPCD DPB	1	38	*	NOT USE	0	*	*	*	*	*	*	*	01	131	2	0			
		OFA EX	1	38	*	NOT USE	*	1	*	*	*	*	*	*	01	129	7	1			
		OFA EY	1	38	*	NOT USE	*	0	*	*	*	*	*	*	01	129	7	0			
		WFCM HIGH	1	38	*	NOT USE	*	*	1	0	*	*	*	*	01	129	5,6	1,0			
		WFCM MID	1	38	*	NOT USE	*	*	0	1	*	*	*	*	01	129	5,6	0,1			
		WFCM LOW	1	38	*	NOT USE	*	*	0	0	*	*	*	*	01	129	5,6	0,0			
		WPCD HIGH	1	38	*	NOT USE	*	*	*	*	1	*	*	*	01	129	4	1			
		WPCD LOW	1	38	*	NOT USE	*	*	*	*	0	*	*	*	01	129	4	0			
		OFA HIGH	1	38	*	NOT USE	*	*	*	*	*	1	*	*	01	129	3	1			
		OFA LOW	1	38	*	NOT USE	*	*	*	*	*	0	*	*	01	129	3	0			
	LFA_DSP_SET	FTFO_RST	1	3A	*	1	*	*	*	*	*	*	*	*							
		ADC CAL	1	3A	*	*	1	*	*	*	*	*	*	*							
		DSP INT	1	3A	*	*	*	1	*	*	*	*	*	*							
		WDT ENA	1	3A	*	*	*	*	1	*	*	*	*	*	01	130	3	1			
		WDT DIS	1	3A	*	*	*	*	0	*	*	*	*	*	01	130	3	0			
		RUN	1	3A	*	*	*	*	*	1	*	*	*	*	01	130	1,2	1,0			
		HLD	1	3A	*	*	*	*	*	*	1	*	*	*	01	130	1,2	0,1			
		RST	1	3A	*	*	*	*	*	*	*	1	*	*	01	130	1,2	0,0			
	DSP CLK OFF	1	3A	*	*	*	*	*	*	*	*	1	*								
	PWS_CAL_ON_SET	CAL	1	*	*	1	*	*	*	*	*	*	*	*	01	136	4	1			
		CAL AUTO	1	*	*	*	1	*	*	*	*	*	*	*	01	136	5	1			
		GND ON	1	*	*	*	*	1	*	*	*	*	*	*	01	136	6	1			
		LEVE ON	1	*	*	*	*	*	1	*	*	*	*	*	01	136	7	1			
		PHAS ON	1	*	*	*	*	*	*	1	*	*	*	*	01	137	0	1			
		SPW ON	1	*	*	*	*	*	*	*	1	*	*	*	01	137	1	1			
	NEI ON	1	*	*	*	*	*	*	*	*	1	*	*	01	137	2	1				
	PWS_CAL_OFF_SET	CAL MES	1	*	*	1	*	*	*	*	*	*	*	*	01	136	4	0			
		CAL MAN	1	*	*	*	1	*	*	*	*	*	*	*	01	136	5	0			
		GND OFF	1	*	*	*	*	1	*	*	*	*	*	*	01	136	6	0			
		LEVE OFF	1	*	*	*	*	*	1	*	*	*	*	*	01	136	7	0			
		PHAS OFF	1	*	*	*	*	*	*	1	*	*	*	*	01	137	0	0			
		SPW OFF	1	*	*	*	*	*	*	*	1	*	*	*	01	137	1	0			
	NEI OFF	1	*	*	*	*	*	*	*	*	1	*	*	01	137	2	0				
	PWS_ANT_SET	ANT REV	1	92	01	NOT USE										1	01	138	1	0	
		ANT NOR	1	92	00	NOT USE										0	01	138	1	1	
	PWS_MODE_SET		1	94	*																
	PWS_LOCAL_SET		1	96	*																
	PWS_GAIN_SET	GAIN LOW	1		01	NOT USE										1	01	139	TBD	TBD	
		GAIN HIGH	1		00	NOT USE										0	01	139	TBD	TBD	
	PWS_PARA_SET	NPW FIX	1	98	*	NOT USE					1	*	*	*	*	01	137	4	1		
		NPW SWP	1	98	*	NOT USE					0	*	*	*	*	01	137	4	0		
		SPW HIGH	1	98	*	NOT USE					*	1	*	*	*	01	137	5	0		
		SPW NOR	1	98	*	NOT USE					*	0	*	*	*	01	137	5	1		
		SPW FIX	1	98	*	NOT USE					*	*	1	*	*	01	137	6	1		
		SPW SWP	1	98	*	NOT USE					*	*	0	*	*	01	137	6	0		
		NEI FIX	1	98	*	NOT USE					*	*	*	1	*	01	137	7	1		
		NEI SWP		1	98	*	NOT USE					*	*	*	0	*	01	137	7	0	
	POWER_AMP_ON_SET	CENT ON	1	*	*	-	1	*	*	*	*	*	*	*	01	138	7	1			
		LOAD 4	1	*	*	-	*	1	*	*	*	*	*	*	01	138	6	1			
		PWR HIGH	1	*	*	-	*	*	1	*	*	*	*	*	01	138	0	1			
		CB4 ON	1	*	*	-	*	*	*	1	*	*	*	*	01	138	5	1			
		CB3 ON	1	*	*	-	*	*	*	*	1	*	*	*	01	138	4	1			
		CB2 ON	1	*	*	-	*	*	*	*	*	1	*	*	01	138	3	1			
	CB1 ON	1	*	*	-	*	*	*	*	*	*	1	*	01	138	2	1				

Table C-2 Block Command List (5/7)

S/S NAME	DC NAME	BC NAME	BC SIZE (byte)	CODE		BC BIT MAP								TELEMETRY			STATUS	
				DC (HEX)	BC (HEX)	MSB	B0	B1	B2	B3	B4	B5	B6	LSB	PACKET ID(HEX)	WORD		BIT
PWA	POWER_AMP_OFF_SET	CENT OFF	1	*	*	-	1	*	*	*	*	*	*	01	08	7	0	
		LOAD 3	1	*	*	-	*	1	*	*	*	*	*	01	08	0	0	
		PWR LOW	1	*	*	-	*	*	1	*	*	*	*	01	08	0	0	
		CB4 OFF	1	*	*	-	*	*	*	1	*	*	*	01	08	5	0	
		CB3 OFF	1	*	*	-	*	*	*	*	1	*	*	01	08	4	0	
		CB2 OFF	1	*	*	-	*	*	*	*	*	1	*	01	08	3	0	
		CB1 OFF	1	*	*	-	*	*	*	*	*	*	1	01	08	2	0	
	PWS_DATA_SET	COMP 1	1	9C	*	1	NOT USE				*	*	TBD					
		COMP T	1	9C	*	0	NOT USE				*	*	TBD					
		LSET 8	1	9C	*	*	NOT USE				1	1	TBD					
		LSET 7	1	9C	*	*	NOT USE				1	0	TBD					
		LSET 6	1	9C	*	*	NOT USE				0	1	TBD					
		LSET 5	1	9C	*	*	NOT USE				0	0	TBD					
		Nr SET	1	9C	*	*	NOT USE				*	*	TBD					
	OBS TIME SET		1	9E	*	MSB								LSB				
	WANT_ON_SET	STBY ON	1	C0	*	1	*	*	*	*	*	*	*	01	141	0	1	
		ANT EXT	1	C0	*	*	1	*	*	*	*	*	*	01	141	1	1	
		MONI ON	1	C0	*	*	*	1	*	*	*	*	*	01	141	2	1	
		LIM DIS	1	C0	*	*	*	*	1	*	*	*	*	01	141	3	0	
		SEL1 ON	1	C0	*	*	*	*	*	1	*	*	*	01	141	4	1	
		SEL2 ON	1	C0	*	*	*	*	*	*	1	*	*	01	141	5	1	
SEL3 ON		1	C0	*	*	*	*	*	*	*	1	*	01	141	6	1		
SEL4 ON		1	C0	*	*	*	*	*	*	*	*	1	01	141	7	1		
WANT_OFF_SET	STBY OFF	1	C2	*	1	*	*	*	*	*	*	*	01	141	0	0		
	ANT RET	1	C2	*	*	1	*	*	*	*	*	*	01	141	1	0		
	MONI OFF	1	C2	*	*	*	1	*	*	*	*	*	01	141	2	0		
	LIM ENA	1	C2	*	*	*	*	1	*	*	*	*	01	141	3	1		
	SEL1 OFF	1	C2	*	*	*	*	*	1	*	*	*	01	141	4	0		
	SEL2 OFF	1	C2	*	*	*	*	*	*	1	*	*	01	141	5	0		
	SEL3 OFF	1	C2	*	*	*	*	*	*	*	1	*	01	141	6	0		
SEL4 OFF	1	C2	*	*	*	*	*	*	*	*	1	01	141	7	0			

Table C-2 Block Command List (6/7)

S/S NAME	DC NAME	BC NAME	BC SIZE (byte)	CODE		BC BIT MAP								TELEMETRY			STATUS	
				DC (HEX)	BC (HEX)	MSB	B0	B1	B2	B3	B4	B5	B6	B7	LSB	PACKET ID(HEX)		WORD	BIT
MPM	MPM_ADDR_SET		2	18	*													
	MGP_RNG_SET	X	1	38	*	-	1	*	*	-	-	*	*					
		Y	1	38	*	-	*	1	*	-	-	*	*					
		Z	1	38	*	-	*	*	1	-	-	*	*					
		RNG B0	1	38	*	-	*	*	*	-	-	1	*					
		RNG B1	1	38	*	-	*	*	*	-	-	*	1					
	MEG/PET_MODE_SET	REV	1	39	*	1	*	*	*	*	*	*	*	01	116	1	1	
		NOR	1	39	*	0	*	*	*	*	*	*	*	01	116	1	0	
		BC	1	39	*	*	1	*	*	*	*	*	*	01	116	2	1	
		AUTO	1	39	*	*	0	*	*	*	*	*	*	01	116	2	0	
		RNG B0	1	39	*	*	*	1	*	*	*	*	*					
		RNG B1	1	39	*	*	*	*	1	*	*	*	*					
		OBSERVATION MODE	1	39	*	*	*	*	*	1	1	1	1					
	UV_DATA_SET		1	54	*	MCP GAIN SELE B0 B1	MCP DISC SELE B0 B1	MCP AmpGain SELE B0 B1	LIS AmpGain SELE B0 B1									
	UVS OBS MODE SET		1	42	*	MODE ID								10	118	0~7	*	
	PM_DATA_SET		1	67	*	PM GAIN SELE B0 B1	PM DISC SELE B0 B1	PM AmpGain SELE B0 B1	BOS Gain SELE B0 B1									
	PM_H_FIL_DATA_SET		1	68	*	NOT USE		H FIL TEMP SELE B0 B1	H FIL SELE B0 B1 B2 B3									
	PM_D_FIL_DATA_SET		1	69	*	NOT USE		D FIL TEMP SELE B0 B1	D FIL SELE B0 B1 B2 B3									
	UV_CAL DATA SET		1	55	*	UVS WAVE LENGTH SET DATA												
	UV_MCP_GAIN_SET		1	56	*	NOT USE						MCP GAIN B0 B1	01	117	3,4	*		
	UV_MCP_DISC_SET		1	57	*	NOT USE						MCP DISC B0 B1						
	UV_MCP_AMP_GAIN_SET		1	58	*	NOT USE						MCP AMP GAIN B0 B1						
	UV_LIS_AMP_GAIN_SET		1	59	*	NOT USE						LIS AMP GAIN B0 B1						
	PM_GAIN_SET		1	6A	*	NOT USE						PM GAIN B0 B1	01	117	5,6	*		
	PM_DISC_SET		1	6B	*	NOT USE						PM DISC B0 B1						
	PM_AMP_GAIN_SET		1	6C	*	NOT USE						PM AMP GAIN B0 B1						
	PM_BOS_GAIN_SET		1	6D	*	NOT USE						BOS GAIN B0 B1						
	PM_H_FIL_TEMP_SET		1	6E	*	NOT USE						H FIL TEMP B0 B1						
	PM_H_FIL_SEL_SET		1	6F	*	NOT USE				H FIL SEL B0 B1 B2 B3								
PM_D_FIL_TEMP_SET		1	70	*	NOT USE						D FIL TEMP B0 B1							
PM_D_FIL_SEL_SET		1	71	*	NOT USE				D FIL SEL B0 B1 B2 B3									

Table C-2 Block Command List (7/7)

S/S NAME	DC NAME	BC NAME	BC SIZE (byte)	CODE		BC BIT MAP										TELEMETRY			STATUS
				DC (HEX)	BC (HEX)	MSB	B0	B1	B2	B3	B4	B5	B6	B7	LSB	PACKET ID(HEX)	WORD	BIT	
MIC	MODE SET		4		*	Color	Threshold			AMP. Gain			Mode	01	108	0-7	-		
						00:RED	00:LVLO	00:N/A			00:Auto								
						01:GREEN	01:LVLI	01:			01:Command								
						10:BLUE	10:LVLI	Nominal			10:One								
						11:Color	11:N/A	10:High			10:shoot								
								11:N/A			11:Endless								
			Elevation				Azimuth	01	109	0-7	-								
			00:256				00:256												
			pickcell				line												
		NOT USE	01:512	NOT USE			01:512												
			pickcell				10:1024												
			10:1024				11:8												
			11:2560																
					Start Angle							01	110	0-6	-				
					01H: 1×128 = 128 line														
					7FH: 128×128 = 16256 line														
					00H: 128×128 = 16384 line														

S/S NAME	DC NAME	BC NAME	BC SIZE (byte)	CODE		BC BIT MAP								TELEMETRY			STATUS
				DC (HEX)	BC (HEX)	MSB	LSB						PACKET ID(HEX)	WORD	BIT		
TPA	EEPROM UPLOAD		1		*	B0	B1	B2	B3	B4	B5	B6	B7				

S/S NAME	DC NAME	BC NAME	BC SIZE (byte)	CODE		BC BIT MAP								TELEMETRY			STATUS
				DC (HEX)	BC (HEX)	MSB						LSB		PACKET ID(HEX)	WORD	BIT	
						B0	B1	B2	B3	B4	B5	B6	B7				
MDC	FCALL	RESET	3	30	03	0	0	0	0	0	0	1	1	01	122	4	
					00	0	0	0	0	0	0	0	0				
					02	0	0	0	0	0	0	1	0				
		CLEAR	3	30	03	0	0	0	0	0	0	1	1	01	122	4	
					00	0	0	0	0	0	0	0	0				
					04	0	0	0	0	0	1	0	0				
		TEST	3	30	03	0	0	0	0	0	0	1	1	01	122	7	
					00	0	0	0	0	0	0	0	0				
					06	0	0	0	0	0	1	1	0				
		PWSN	3	30	03	0	0	0	0	0	0	1	1				
					00	0	0	0	0	0	0	0	0				
					08	0	0	0	0	1	0	0	0				
		PWSOFF	3	30	03	0	0	0	0	0	0	1	1				
					00	0	0	0	0	0	0	0	0				
					0A	0	0	0	0	1	0	1	0				

Appendix-D

Special Abbreviations, Acronyms and Nomenclature

Acronyms Meaning

ACM	Accelerometer
ACP	Autonomous Control Program
A/D	Analog-to-Digital Converter
ADRS	Address
AGC	Automatic Gain Control
ALT	Altimeter
AMP	Amplifier
ANT	Antenna
AOCE	Attitude and Orbit Control Electronics
AOCP	Attitude and Orbit Control Processor
AOCS	Attitude and Orbit Control System
AOS	Advanced Orbiting Systems
AU	Astronomical Unit
BAT	Battery
BC	Block Command
BCCU	Battery Charge Control Unit
BCNT	Bus Control Module
BER	Bit Error Rate
BFM	Back-up File Memory
BiØ-L	Bi Phase L
BLK	Block
BPF	Band Pass Filter
bps	Bits per second
BRR	Blue Red Reflective
BUF	Buffer
CAB	Command Answer Back
CAL	Calibration
CCCG	Conductive Coating Cover Glass
CCSDS	Consultative Committee for Space Data Systems
C&DH	Command and Data Handling
CE	Command Element
CFRP	Carbon Fiber Reinforced Plastics
CG	Cover Glass
CHK	Check
CHNG	Change
CI	Common Instrument
CLCW	Command Link Control Word
CLK	Clock
CLS	Close
CM	Command
CMD	Command Decoder
CMDIF	Command Interface Module
CNCL	Cancel
CNESS	Centre Narinal d'Etudes Spatiales
Co-I	Co-Investigator
COMP	Compare
CPM	CPU Module
CPU	Central Processing Unit
CRM	Clamp Release Mechanism
CTL	Control
CV	Check Valve
DC	Discrete Command
DHS	Data Handling System
DHU	Data Handling Unit
DIS	Disable
DISC	Discrimination
DLM	Deploy Mechanism
DMA	Direct Memory Access
DMP	Dump

Acronyms Meaning

DOD	Degree of Discharge
DPB	Double Probe
DPLY	Deploy
DPRAM	Dual Port RAM
DPU	Data Processing Unit
DR	Data Recorder
DRV	Drive
DSP	Digital Signal Processor
ECC	Error Correction Circuit
ECW	End of Command Writing
EGM	Engine Module
EIS	Electron and Ion Spectrometer
EIC	Electrical Interface Compatibility
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
ENA	Enable
EPS	Electrical Power System
EPT-SA	Electrical Programmable Timer - Satellite
ERR	Error
ESA	Electron Spectrum Analyzer
eV	Electron Volt
EXT	Extension
FIFO	First-In First-Out
FMT	Format
FOV	Field of View
FPGA	Field Programmable Gate Array
FUL	Full
GDP	Guard Pulse
GHe	Gas Helium
GRS	Gas Rate Sensor
HCE	Heater Control Electronics
HGA	High Gain Antenna
HK	Housekeeping
HTR	Heater
HTR	Heater
HV	High Voltage
IC	Identification Number
ICD	Interface Control Document
ICM	Image Compression Module
IMI	Ion Mass Imager
INIT	Initialization
INS-SA	Instrument - Satellite
INT	Interrupt
INTRPT	Interrupt
I/O	Input/Output
IP	Index Pulse
	Internet Protocol
ISA	Ion Spectrum Analyzer
ISACS	Intelligent Satellite Control Software System
ISAS	Institute of Space and Astronautical Science
kbps	Kilobits per second
keV	Kilo-Electron Volt
KSC	Kagoshima Space Center
LBSF	Localized Back Surface Field
LEO	Low Earth Orbit

Acronyms Meaning

LFA	Low Frequency Wave Analyzer
LGA	Low Gain Antenna
LPF	Low Pass Filter
LV	Latching Valve
MANU	Manual
MGF	Magnetic Field Measurement
MDC	Mars Dust Counter
MEM	Memory
MeV	Mega-Electron Volt
MIC	Mars Imaging Camera
MINT	Mechanical Integration
MONI	Monitor
MPM	MGF/PET/MST/UVS
MPX	Multiplexer
MST	Mast
ND	Nutation Damper
NEI	Number Density of Electron by Impedance Probe
NiMH	Nickel Metal Hydride
NML	Normal
NMS	Neutral Gas Mass Spectrometer
NPW	Natural Plasma Wave
NRS	Non-Reflective Surface
OFA	Onboard Frequency Analyzer
OG	Organized Command
OGE	OG Element
OMS	Orbital Maneuvering System
OP	Operation Program
OPN	Open
OVC	Over Voltage Control
OVF	Overflow
PC	Phase Clock, Personal Computer
PCD	Power Controller and Distributor
PCS	Power Control System
PCM	Pulse Code Modulation
PCU	Power Control Unit
PDL	Paddle
PET	Probe for Electron Temperature
PI	Principal Investigator
PIM	Peripheral Interface Module
PLS	Pulse
PM	Phase Modulation, Proto Model, Photomultiplier
PRE	Pre-Amplifier
PRIM	Primary
PROG	Program
PSA	Particle Spectrum Analyzer
PSK	Phase Shift Keying
PSU	Power Supply Unit
PWA	Plasma Wave Analyzer
PWR	Power
PWS	Plasma Wave and Sounder Experiment
RAM	Random Access Memory
RARR	Range and Rate
RCS	Reaction Control System
REP	Reproduce
RET	Retraction
RF	Radio Frequency
RGA	Rate Gyro Assembly
RNG	Ranging
ROM	Read Only Memory
RPM	Revolutions per minute

Acronyms Meaning

RS	Reed Solomon
RST	Reset
RV	Relief Valve
SAS	Sun Aspect Sensor
SBR	S-Band Receiver
SCP	Solar Cell Paddle
SDIP	S-Band Diplexer
SECND	Secondary
SEL	Select
SEQ	Sequence
S/H	Sample Holder
SHNT	Shunt Dissipater
SI	Scientific Instrument
SIG	Signal
SPB	Single Probe
SPW	Stimulated Plasma Wave
S/S	Sub-System
SSAS	Spin-Type Sun Aspect Sensor
SSC	Star Scanner
SSOC	Sagamihara Spacecraft Operation Center
SSW	S-Band Switch
STBY	Standby
STR	Structure
TBD	To be Determined
TBS	To be Studied, To be Supplied
TBV	To be Verified
TCI	Telemetry Command Interface
TCM	Trajectory Control Maneuvers
TCP	Transfer Control Protocol
TCS	Thermal Control System
TCXO	Temperature Control Crystal Oscillator
THR	Thruster
TI	Time Indicator
TIC	TI Counter
TINT	Thermal Integration
TLM	Telemeter
TLMP	Telemetry Processor Module
TMS	S-Band Transmitter
TMX	X-Band Transmitter
TNK	Tank
TPA	Thermal Plasma Analyzer
TSAS	Two-Dimensional Sun Aspect Sensor
TT&C	Tracking, Telemetry, and Command
UD	Update
UDSC	Usuda Deep Space Center
UVC	Under Voltage Control
UVS	Ultraviolet Imaging Spectrometer
VCO	Voltage Control Oscillator
VLF	Very Low Frequency
VM	Valve Module
WANT	Wire Antenna
WDT	Watch Dog Timer
WFC	Wave Form Capture
WFC-D	Direct-Mode WFC
WFC-M	Memory-Mode WFC
WHN	Wire Harness
XPA	X-Band Power Amplifier
XUV	Extremely Ultraviolet Imager

