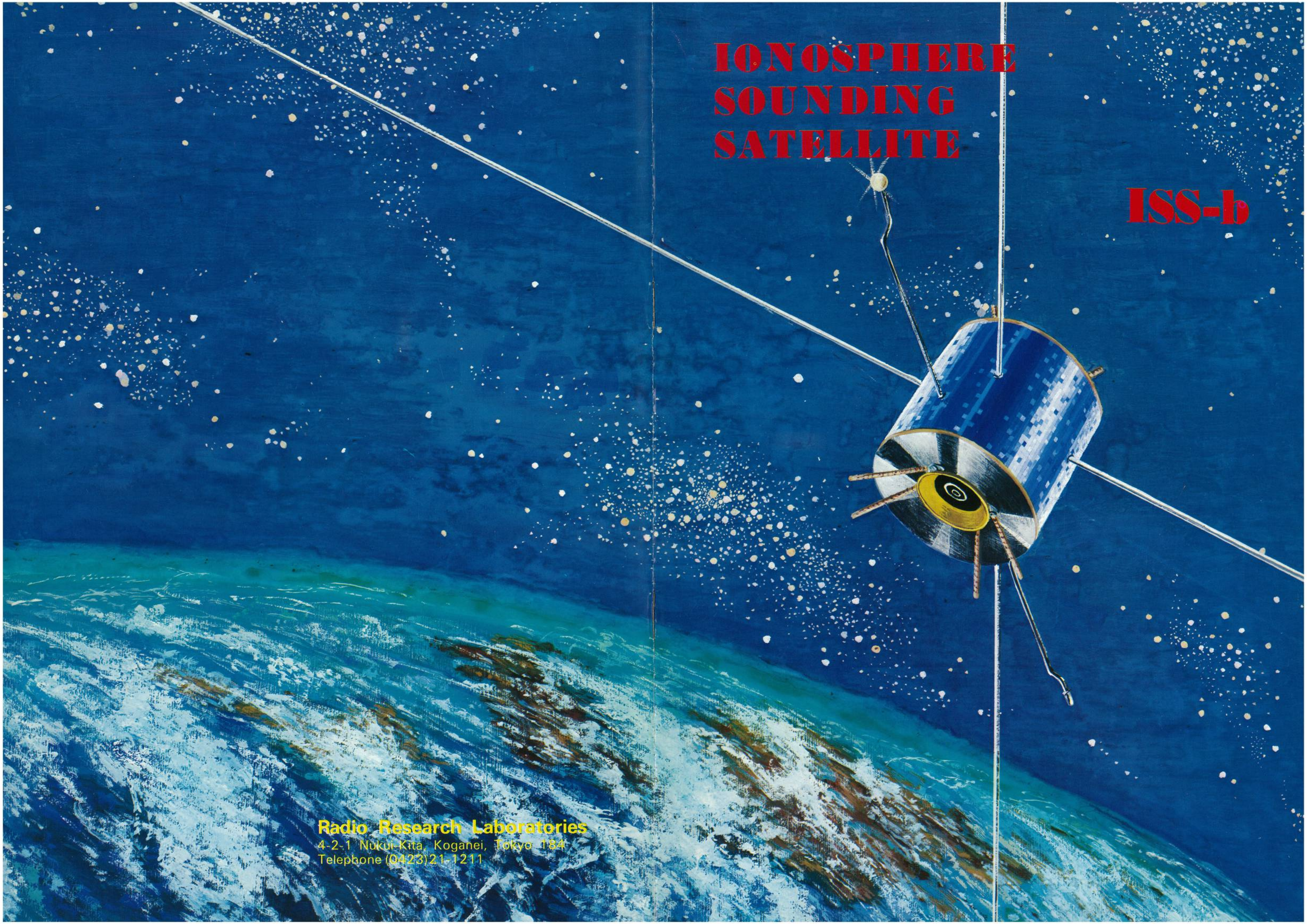


IONOSPHERE SOUNDING SATELLITE

ISS-b

Radio Research Laboratories
4-2-1 Nukui-Kita, Koganei, Tokyo 184
Telephone (0423)21-1211

The internationally coordinated project, the IGY (International Geophysical Year, 1957–1958), was carried on about twenty years ago in order to make a global investigation of the physical status of the earth's environment such as the solid earth, ocean, atmosphere, ionosphere and its far surroundings. During the IGY, the programme of the artificial satellite has been brought to fruition with the birth of Sputnik (1957) and Explorer (1958).

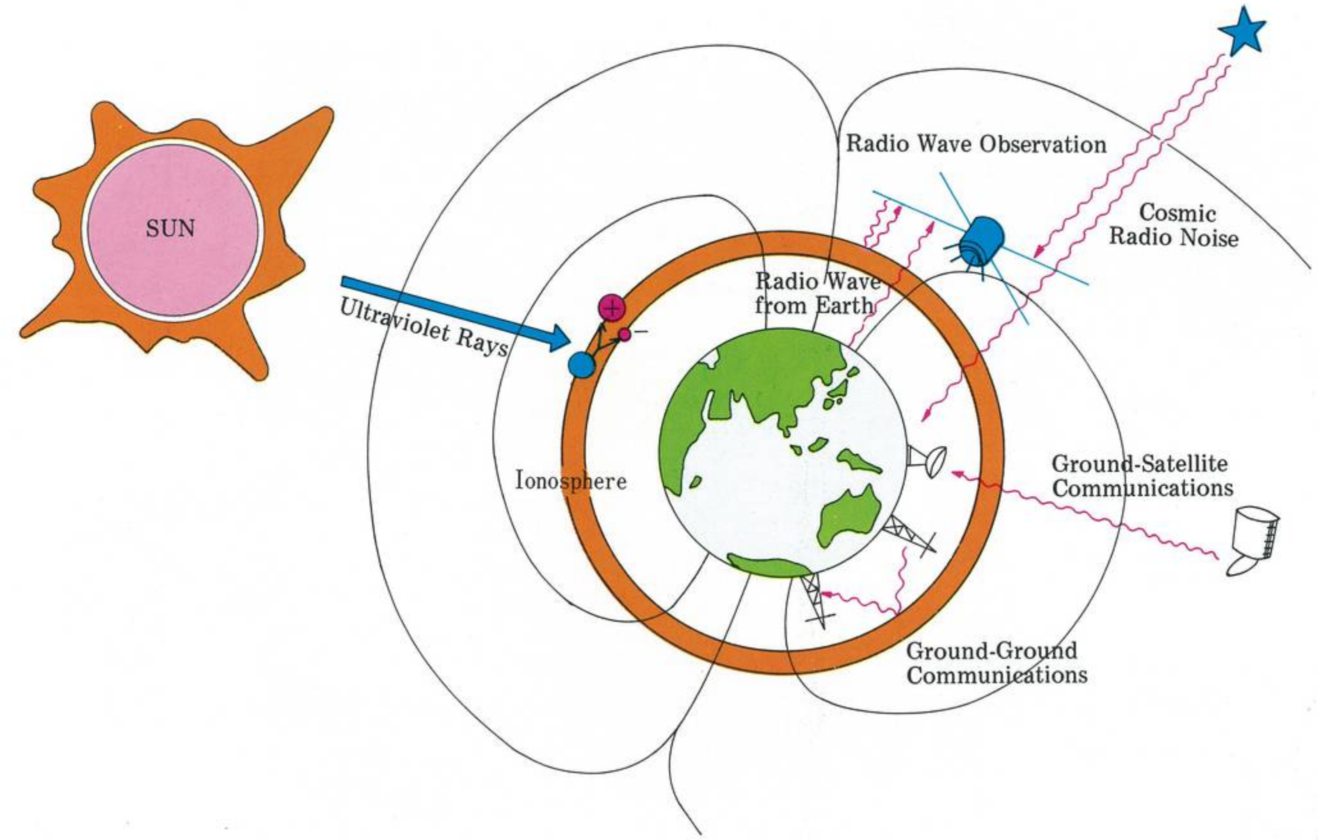
Progress in space activities has been steadily expanding the fields of space utilization for the progress of mankind. The Ionosphere Sounding Satellite (ISS) to be introduced in this article belongs to the field of surveying the earth's environment, particularly observations of world-wide distributions of the ionosphere and radio noises in conjunction with the global survey of the radio wave environment having influence upon the radio communications.

CONTENTS

Ionosphere and Radio Wave

● IONOSPHERE

The extreme ultraviolet rays emitted from the sun collide with particles of the earth's atmosphere, such as oxygen and nitrogen, and resolve them into the electrically charged particles, positive ions and free electrons. The phenomenon, called ionization, takes place mostly in the upper part of the atmosphere where the ionizing solar extreme ultraviolet rays are completely absorbed. The electrically charged particles, plasma, produced through the ionization form the "Ionosphere" at the region above about several tens of kilometers altitude.



Schematic View of the Earth's Ionosphere.

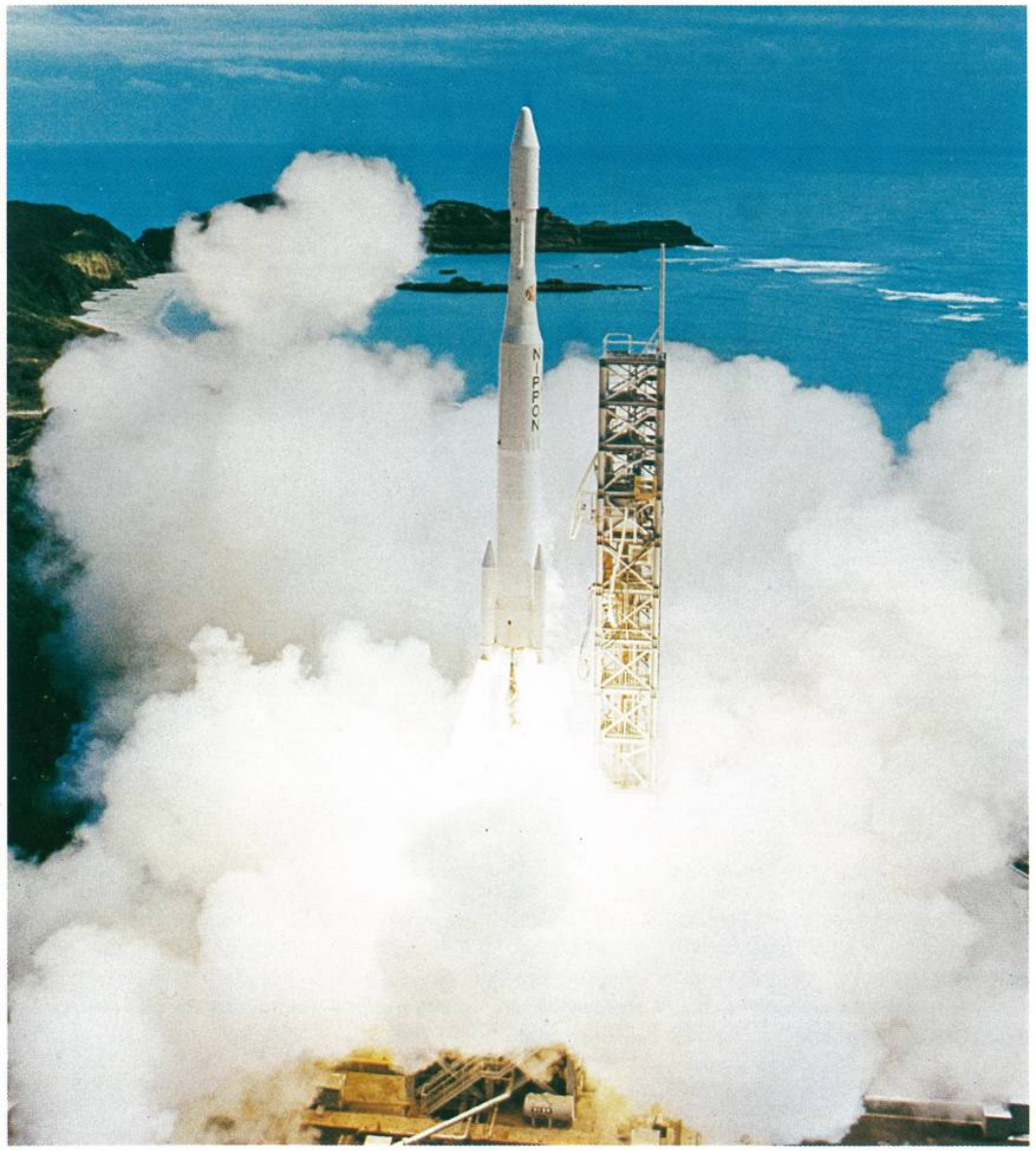
● RADIO WAVE AND IONOSPHERE

The radio waves passing through the ionosphere are influenced by the existence of charged particles, especially the electrons of lighter mass. The radio waves transmitted from the ground or from the outside are reflected or pass through at the ionosphere, depending upon both the wave frequency and the electron density of the ionosphere. Because the electron density of the ionosphere varies in a complex manner both spatially and temporally, observation of the ionosphere is necessary for recognition and forecasting of the conditions of the radio wave environment.

ISS Project

Project of ISS has been promoted under the cooperation of the Ministry of Posts and Telecommunications, the Science and Technology Agency and the National Space Development Agency of Japan (NASDA).

System design and development of satellite-borne mission equipment of ISS have been started at the Radio Research Laboratories (RRL), Ministry of Posts and Telecommunications in 1967. In October 1969, NASDA was established as the central organ for the development of launching vehicles and applications satellites. Accordingly, the work on the development of ISS was transfered to NASDA. The Space Activities Commission established in 1968, in replacing the former National Space Activities Council, decided the first Space Development Program in 1969 in which the launching of ISS is formulated as to be in fiscal 1975 by N–vehicle. Since 1969 RRL has promoted the preparation for the Earth Station at the Kashima Branch and for Data Processing and Analysis System at the Headquarter, RRL.



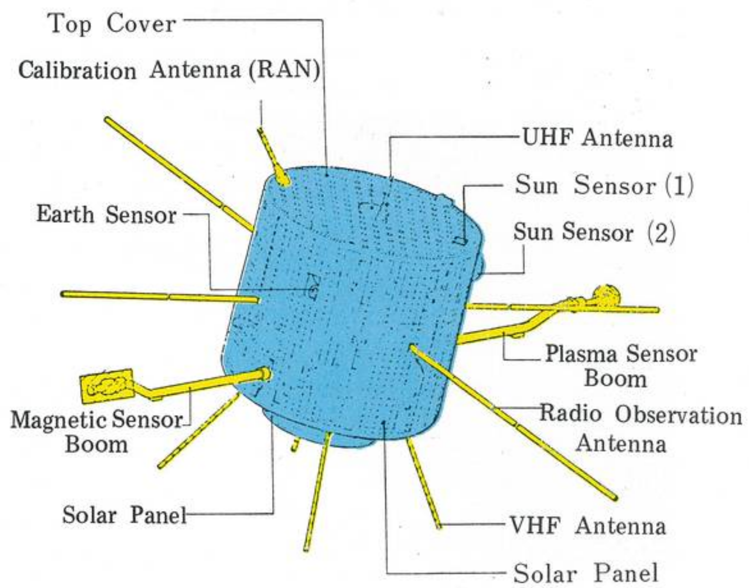
A snapshot of launching ISS [Ume] by N-vehicle on February 29, 1976

ISS was launched on February 29, 1976 from Tanegashima Space Center of NASDA by N-launch vehicle into an almost exact orbit as expected and given an endearing name from"Ume"blossom. At the end of the initial stage operation for the first one month, ISS ceased sending out her signals caused by trouble in the main power supply system. The improved back up flight model, ISS-b, was launched on February 16, 1978.

Brief Description of ISS-b

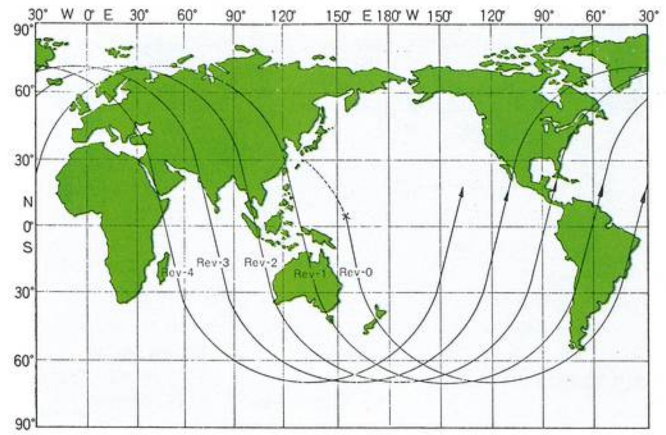
• CONFIGURATION

The main configuration of ISS-b spacecraft is a circular cylinder and approximately 5,000 units of 2cmx2cm solar cells are mounted on the cylindrical surface. A UHF antenna and a calibration antenna are mounted on the top cover, and VHF antennas are stretched downward from the bottom cover. After injection into orbit, two pairs of sounding antennas and two booms for plasma sensor and magnetic sensor are extended and deployed.



Configuration of ISS-b

World Map of ISS-b



• ORBIT

The ISS-b has a nearly circular orbit at altitude of about 1,100 km with orbital period of about 107 minutes and with the inclination angle of about 70 degrees. The orbital plane shifts westward relative to the earth-sun direction with the rate of about 3 degrees per day.

• MISSION

The aim of ISS-b is to carry out the following four missions in order to observe the world distributions of the ionosphere and the radio noises:

(1) Topside Sounding (TOP)
(2) Radio Noise Measurement (RAN)
(3) Plasma Measurement (RPT)
(4) Positive Ion Composition Measurement (PIC)

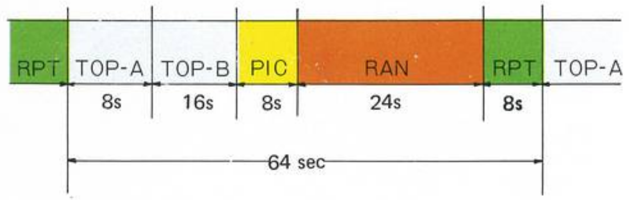
● OPERATIONAL MODE OF ISS-b

Beacon Mode		Radio beacons of VHF and UHF are transmitted without execution of mission.
Observation Mode	Real Time Observation	Four missions are executed and observed PCM data are telemetered in real time by 1,024 bps.
	Recording Observation	Four missions are executed and observed PCM data are stored by on-board tape recorder with recording time up to 115 minutes. Stored data are played back and telemetered by 26,624 bps.
	Recording/ Real Time	Observed PCM data are telemetered in real time by 1,024 bps simultaneously with data storing.
Satellite Check Mode	Real Time Check	Housekeeping PCM data are telemetered in real time by 1,024 bps.
	Recording Check	Housekeeping PCM data are stored by on-board tape recorder with recording time up to 115 minutes. Stored data are played back and telemetered by 26,624 bps.
	Recording/ Real Time	Housekeeping PCM data are telemetered in real time by 1,024 bps simultaneously with data storing.

In observation mode, four missions are executed repeatedly by the sequence as shown in the figure.

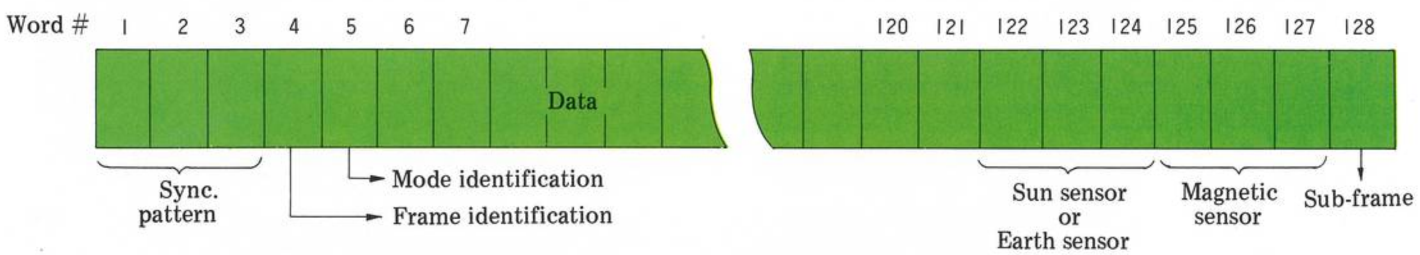
In recording mode, start of the mission execution can be controlled by command with delay of 0, 2, 4 or 6 times of the preset revolution period (105 minutes).

Sequence of Mission



● PCM DATA FORMAT

Main Frame of PCM Data { Word 8 bits/word; Frame 128 words/frame; Sub-frame 128 frames }



In observation mode, observed mission data are encoded in data part and housekeeping data in sub-frame. In satellite check mode, housekeeping data are encoded in data part and blank data in sub-frame.

TECHNICAL FEATURES OF ISS-b

1. Orbit
Perigee 972 km
Apogee 1220 km
Inclination 70 deg
Period 107 min

2. Attitude
Spin stabilized
Initial spin rate 100 rpm
Spin rate after extension of stem antennas 13.7 rpm

3. Shape
Cylindrical
Diameter 94 cm
Height 82 cm

4. Weight 141 kg

5. Mission Subsystem
(a) Topside Sounder (TOP)
(b) Radio Noise Receiver (RAN)
(c) Retarding Potential Trap (RPT)
(d) Ion-Mass Spectrometer (PIC)

6. Attitude Sensors
(a) Sun Sensor
(b) Earth Sensor
(c) Magnetic Sensor (3 axes)

7. Housekeeping Subsystem
Temperatures, Voltages, Currents, Operation Status, etc., 139 items on various parts of subsystems

8. Telemetry Subsystem
(a) Transmitters
Frequency: 136 MHz band
400 MHz band
Modulation: PCM/PM (BPL)
Transmission Rate:
1,024 bps (Real Time)
26,624 bps (Play Back)
Power: Play Back, Real Time Mode 1 W (136 MHz)
0.7 W (400 MHz)
Beacon Mode 0.1 W (136 MHz)
0.07 W (400 MHz)
(b) Tape Recorder
I/O Channel: 1 channel
Record Time: 115 min
Play Back Time: 270 sec
I/O Signal Type: Bi-phase Level
Bit Rate: 1,024 bps (record)
26,624 bps (play back)

9. Command Subsystem
(a) Receivers
Frequency: 148 MHz band
(b) Decoders
Signal Type: Tone Burst
(1 address tone burst, 3 execute tone bursts)
Tone Frequency:
2 address frequencies, 4 execute frequencies
Command Items:
64 items + 8 items (duplicate use)

10. Antennas
(a) Radio Observation Antennas
2 pairs (tip-to-tip length 36.8 m, 11.4 m)
(b) Telemetry-Command VHF Antenna
Turn-style Antenna
(c) Telemetry UHF Antenna
Whip Antenna
(d) RAN Calibration Antenna

11. Power Subsystem
(a) Solar cells: 2 cm x 2 cm, 4940 units
Power Output 60 W
(b) Battery: Nickel-cadmium 5 AH

12. Thermo-control Passive

13. Structure Shell and Honeycomb Sandwich

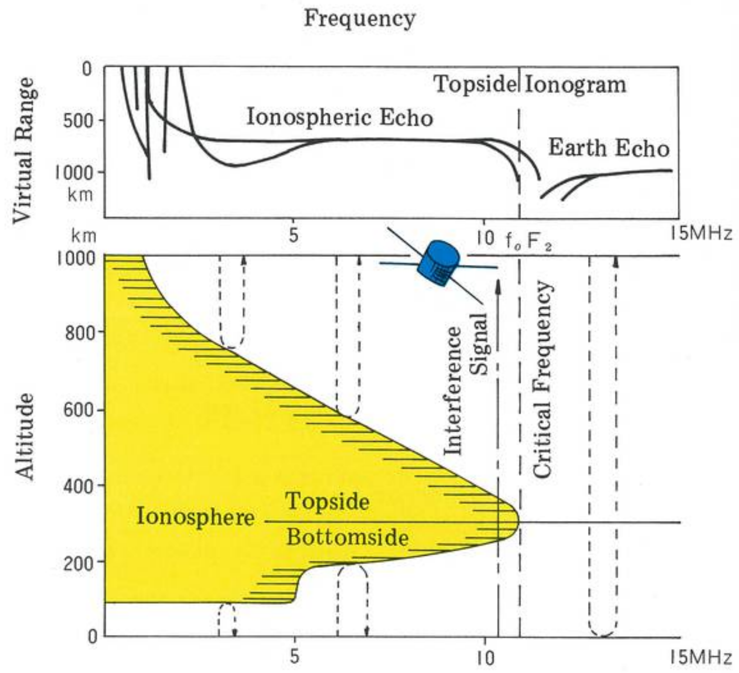
14. Life Survival probability 70% at 1.5 years after launch

15. Launch
(a) N-vehicle
(b) Tanegashima Space Center, NASDA
(c) 04h00m UT, February, 16, 1978

Topside Sounding (TOP)

● TOP MISSION

Topside sounder transmits the pulse radio wave of swept frequency and receives the echo returned to the satellite after reflection at the ionosphere or at the ground. The highest frequency of the echo vertically reflected back at the ionosphere, or the lowest frequency of the radio wave vertically passing through the ionosphere, is called the "critical frequency" of the ionosphere. This frequency gives an important information on the maximum usable frequency for short wave communication. Travel time of the pulse between transmission and reception, i.e., virtual range, versus frequency gives the ionogram data.



Frequency ($\fallingdotseq \sqrt{\text{Electron Density}(cm^{-3})}/111$)

● TOP OBSERVATION ITEMS

TOP-A

(1) Detection of the lowest frequency of the interference signals

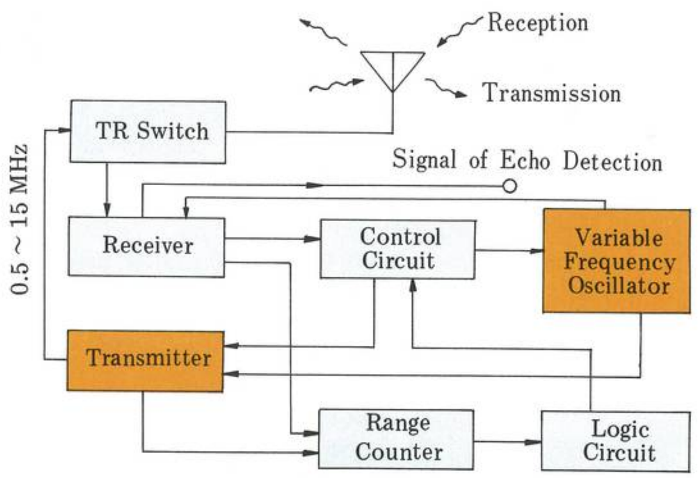
(2) Determination of the critical frequency by on-board logic circuit

TOP-B

(1) Frequency versus virtual range characteristics

(2) Spectrum of cosmic radio noise

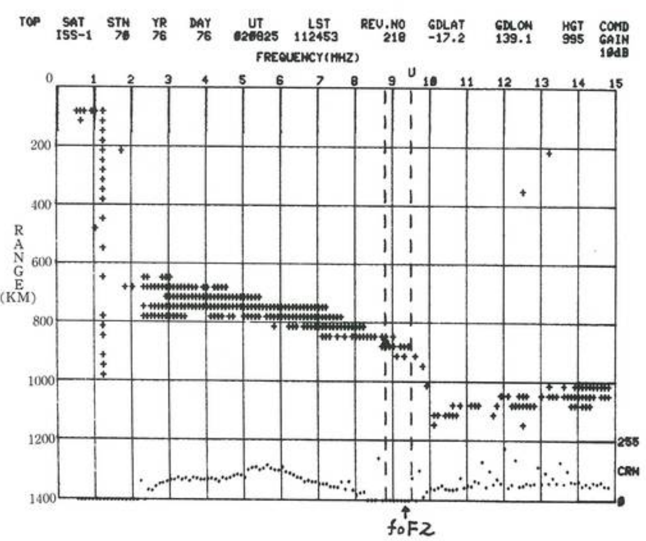
Block Diagram of TOP Equipment



● TOP EQUIPMENT

Frequency range	0.5 ~ 15 MHz
Sweep Frequency Step	100 kHz
Pulse Width	300 μsec
Pulse Peak Power	150 W
Pulse Repetition	64Hz (TOP-A), 9Hz (TOP-B)
Gain Control (command)	0, 5, 10, 15dB

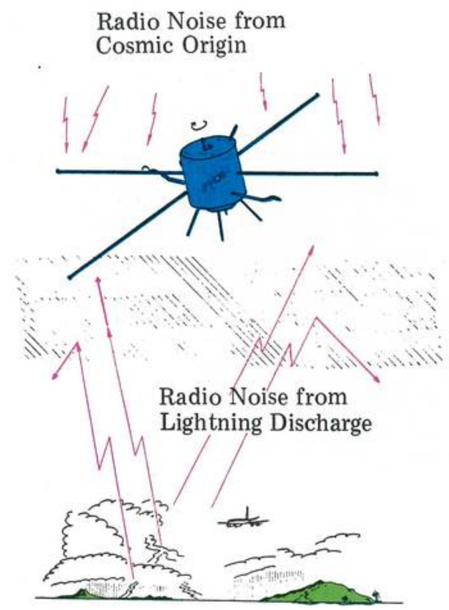
Example of TOP Data from ISS [Ume]



Radio Noise Measurement (RAN)

● RAN MISSION

Radio noise receiver detects the radio noise originating from the lightning discharge and also receives the radio noises from space. In order to avoid the reception of the artificial radio noises, frequency channels of the receiver are selected within the guard bands for the standard radio wave. Four frequency channels are provided so that the position of the source of the atmospheric radio noise may be identified by taking the iris effect of the ionosphere into consideration.



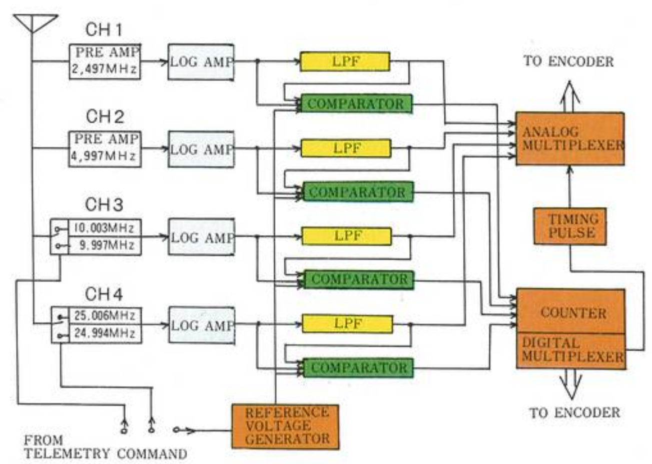
● RAN OBSERVATION ITEMS

RAN observes the following items with respect to all four channels.

(1) Average intensity of radio noise with the sampling rate of 32 samples/sec. channel

(2) Occurrence frequency of impulsive radio noise from lightning discharge with the sampling rate of 1 sample/sec. channel

Block Diagram of RAN Equipment



● RAN EQUIPMENT

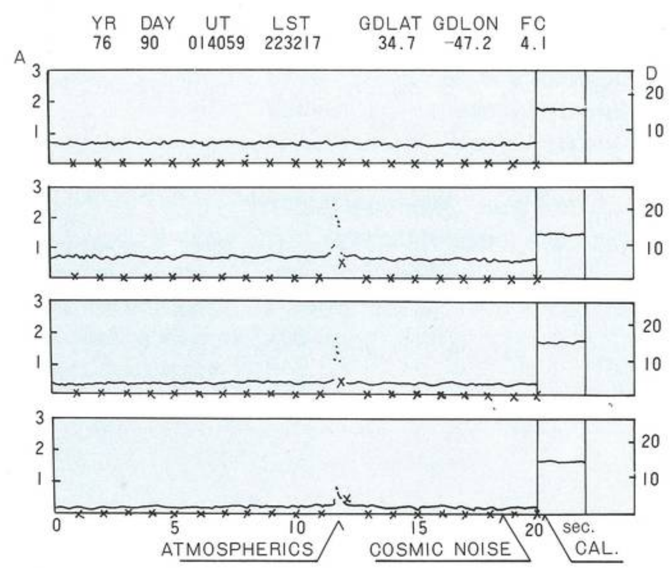
Receiver Dynamic Range

60dB (−120 dBm ~ −60dBm)

Characteristics of Frequency Channel

	Frequency (MHz)	Band Width (KHz)	Slice Level (dB)
CH. 1	2.497	1.250	15 / 20
CH. 2	4.997	1.380	15 / 20
CH. 3	9.997 10.003	1.260	15
CH. 4	24.994 25.006	2.000	15

Example of RAN Data from ISS [Ume]



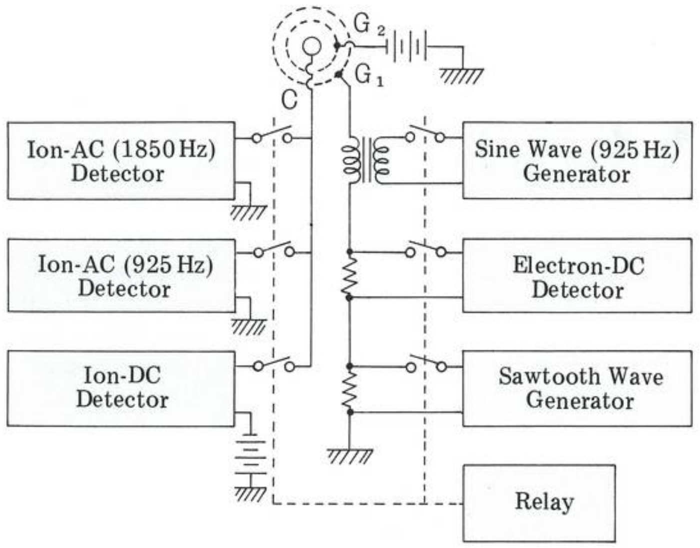
Plasma Measurement (RPT)

● RPT MISSION

Spherical RPT sensor is mounted at the tip of a boom deployed from the spacecraft. Influx of plasma particles, positive ions and electrons, into the RPT sensor from surroundings varies as the electric potential of the RPT sensor is changed. Parameters of the plasma such as density and temperature can be determined by analyzing the characteristics of the influx of the plasma particles, or ion current and electron current, against the changing sensor potential. RPT sensor consists of two concentric spherical grids G_1 and G_2 with diameters of 10 cm and 6 cm, respectively, and central collector C with diameter of 2 cm. Electrons are trapped by the grid G_1 and ions are trapped by the collector C.

RPT Sensor

Block Diagram of RPT Equipment



● RPT OBSERVATION ITEMS

Four kinds of currents, Electron-DC, Ion-DC, Ion-AC(1F) and Ion-AC(2F), are measured sequentially for 2 seconds each, and the following parameters are determined.

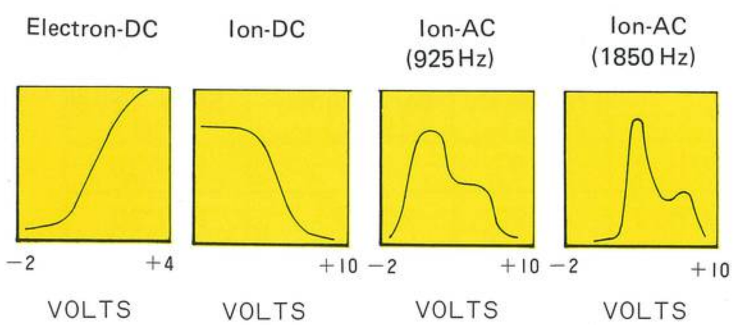
(1) Densities of ions and electrons
($10^3 \sim 10^6$ cm^{-3})

(2) Temperatures of ions and electrons
(500K ~ 5000K)

● RPT EQUIPMENT

Collector Voltage −11V
Grid G_2 Voltage −38V
Grid G_1 Voltage
Sawtooth Wave −2V~+4V, −2V~+10V
Sine Wave 200mVp-p (925Hz)
Detection Range of Currents
(given in the Table)

Wave Forms of Currents



Currents	G_1 Volt	Range of Currents (Amp)			
		Ll	Hl	Lh	Hh
Elec-DC	−2~4	$5\times10^{-6}\sim5\times10^{-4}$	$5\times10^{-7}\sim5\times10^{-5}$	$5\times10^{-7}\sim5\times10^{-5}$	$5\times10^{-8}\sim5\times10^{-6}$
Ion-DC	−2~10	$4\times10^{-8}\sim4\times10^{-6}$	$4\times10^{-9}\sim4\times10^{-7}$	$4\times10^{-9}\sim4\times10^{-7}$	$4\times10^{-10}\sim4\times10^{-8}$
Ion-AC-1F	−2~10	$4\times10^{-9}\sim4\times10^{-7}$	$4\times10^{-10}\sim4\times10^{-8}$	$4\times10^{-10}\sim4\times10^{-8}$	$4\times10^{-11}\sim4\times10^{-9}$
Ion-AC-2F	−2~10	$4\times10^{-10}\sim4\times10^{-8}$		$4\times10^{-11}\sim4\times10^{-9}$	

H, L: High and Low Sensitivity (Command)
h, ℓ: High and Low Sensitivity (Encoder)

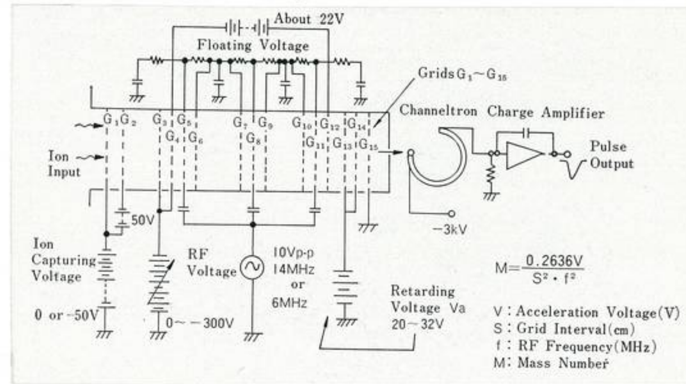
Positive Ion Composition Measurement (PIC)

● PIC MISSION

A PIC sensor is mounted at the center of each cover of the spacecraft with sensor window for ion collection. PIC sensor is an ion-mass spectrometer of Bennett type and it is designed so that ions having a specified mass may be selected and guided to the channeltron detector. The specified mass can be altered continuously by changing the voltage of the ion acceleration grids of the pic sensor. Ions surrounding the satellite are captured partly by the satellite motion and partly by ion capturing voltage of the PIC sensor. The captured ions are accelerated by stepwise acceleration voltage and further modulated by high frequency voltage and also by ion retarding voltage. On the way passing through the various potential barriers, the ions having a specified mass are selected.

PIC Sensor

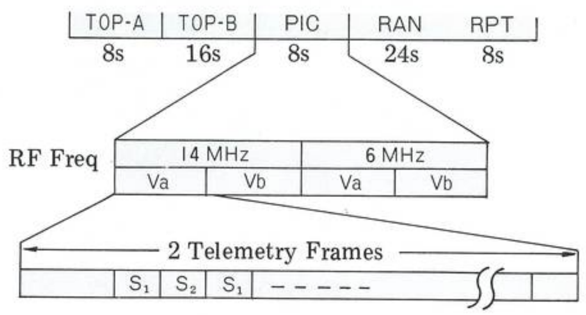
Block Diagram of PIC Equipment



● PIC OBSERVATION ITEM

Composition of the ionospheric positive ions, H^+, He^+, N^+ and O^+, is measured by four kinds of combinations of high frequency and retarding voltages for every 2 seconds.

PIC Observation Sequence



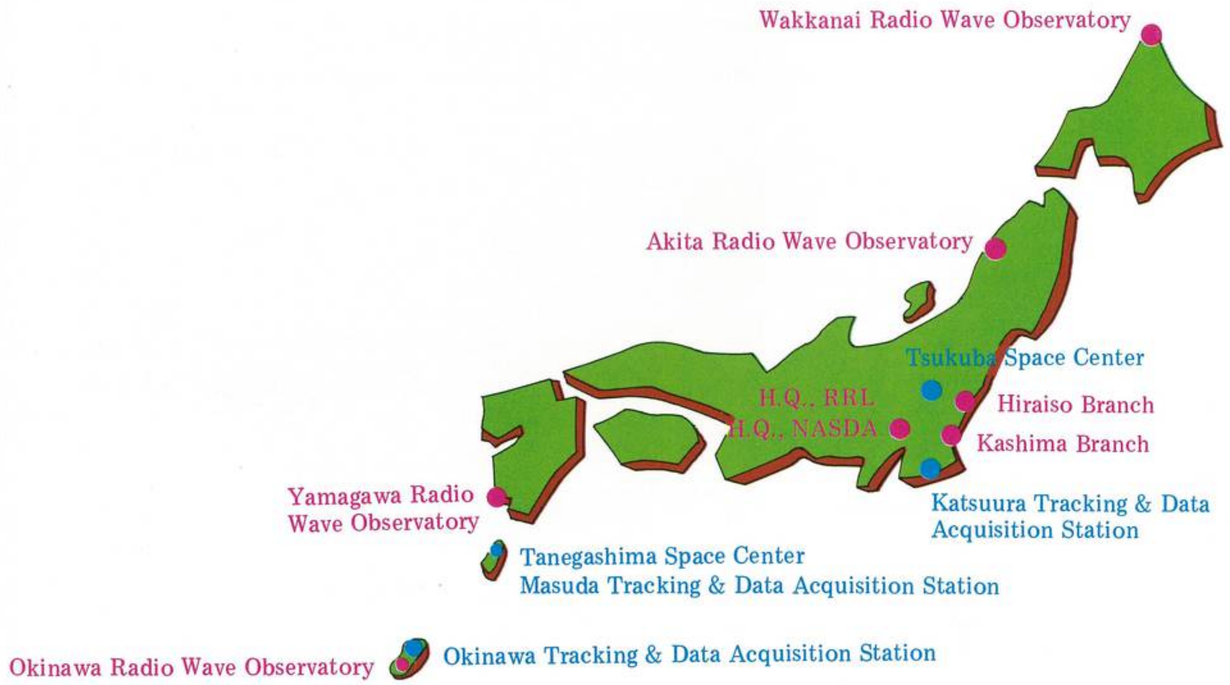
● PIC EQUIPMENT

Type	3 stage, 5–3 cycle Bennett tube	Acceleration Voltage	0 ~ −299 V (sweep)
Mass Range	1 ~ 20 AMU	Retarding Voltage	20 ~ 32 V (command)
Grid Separation	0.3 cm	Capturing Voltage	0, −50 V or −50, −100 V (command)
RF Frequency	14 MHz, 6 MHz	Ion Counting Rate	200 Hz ~ 1.3 MHz
RF Voltage	10 Vp-p	Power Consumption	6 W

Operation of ISS-b

• INITIAL STAGE OPERATION

The initial stage operation of ISS-b for the first about two months after launch is carried on by NASDA in order to check the functions of various subsystems of the satellite. Deployment of the booms, extension of the radio observation antennas and trial runs of mission equipments are performed by turns. Tracking and control of ISS-b are carried out by the Tracking and Data Acquisition Stations, NASDA, at Masuda, Katsuura and Okinawa, and by the Tracking and Control Center of the Tsukuba Space Center, NASDA, RRL supports the initial stage operation through data acquisition and evaluation of the mission data.

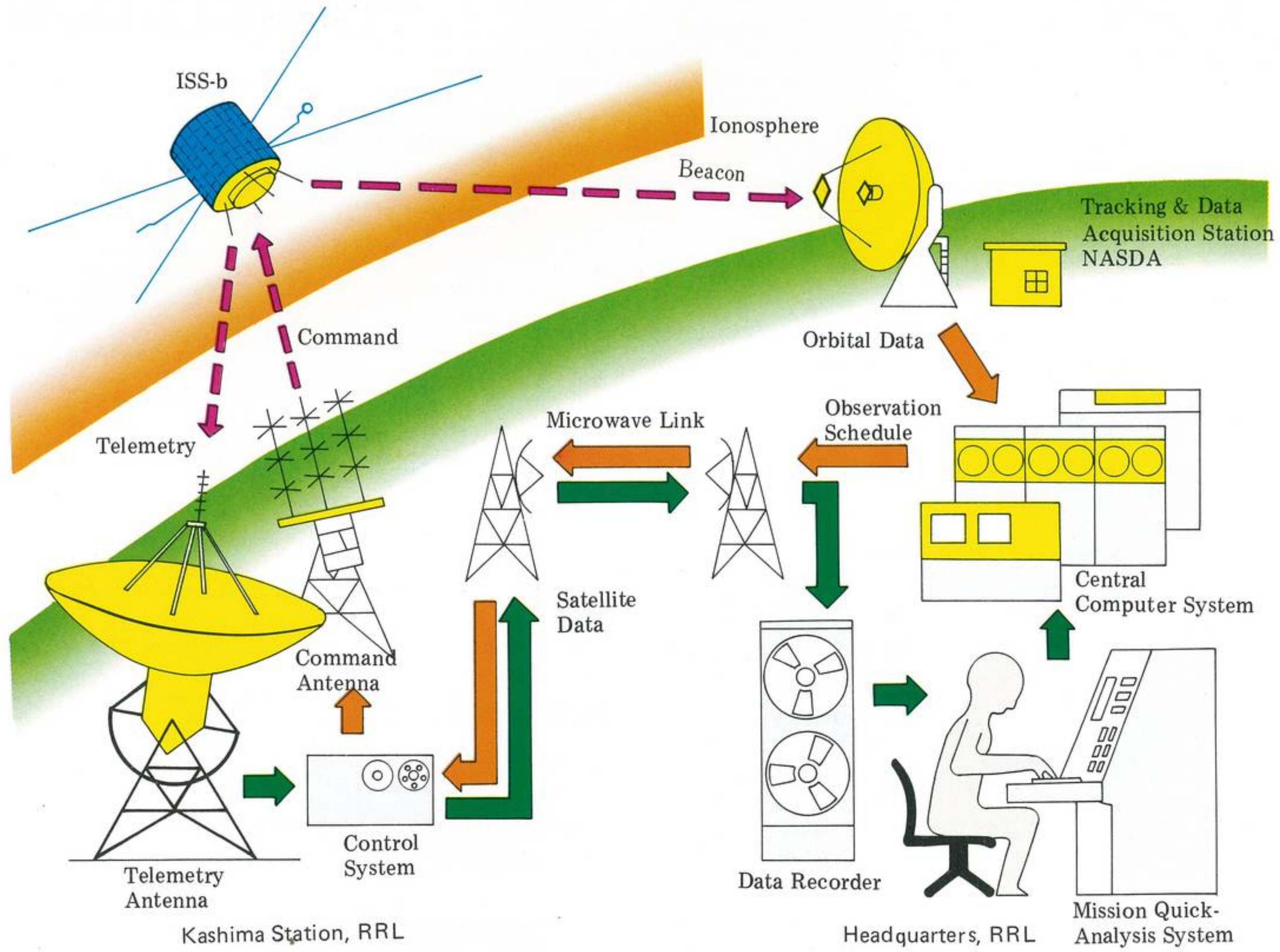


• REGULAR STAGE OPERATION

The regular stage operation of ISS-b after termination of the initial stage is carried on by RRL in order to observe the world-wide distributions of the ionosphere and radio noises. Command, telemetry and quick-look monitoring are performed at the Kashima Branch, RRL. Planning of observation schedule and processing and analysis of the satellite mission data are carried out at the Headquarters, RRL. Operational mode of ISS-b mainly composed of data recording observation by on-board tape recorder with a suitable choice of delay function. The satellite data acquired at the Kashima Station are transferred to H.Q., RRL directly through a microwave link. NASDA is engaged in tracking and keeping of the satellite.

• SYSTEM FOR ISS-b OPERATION

The main operation system in RRL for ISS-b consists of the satellite control system at Kashima Station for telemetry and command, and the computer system for observation planning and data analysis at H.Q., RRL. The observation schedule of ISS-b is fixed after consultation with NASDA in every week. Subsystems for telemetry, command, data quick-look and data recording at Kashima Station are automatically controlled following the weekly schedule stored in the memory of the computer of the control system, except for manual operation in case of emergency.



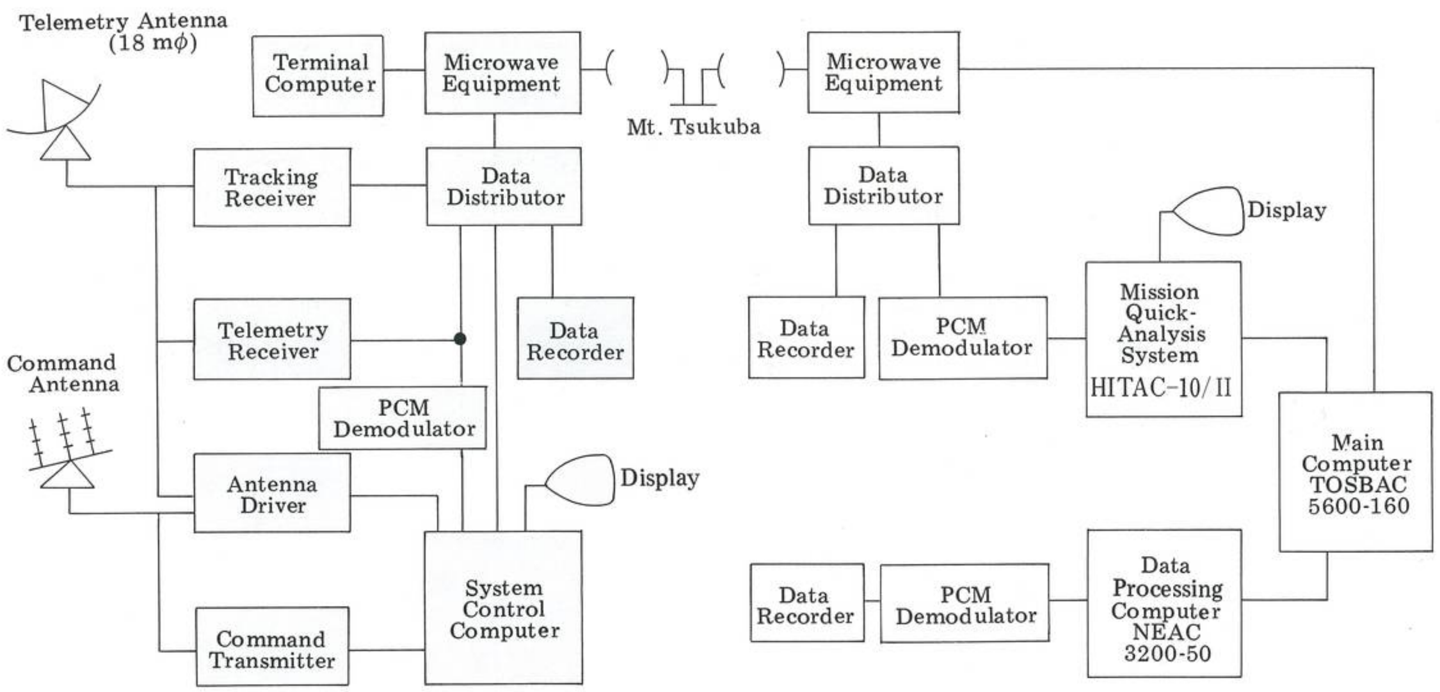
Schematic View of Operation System in RRL for ISS-b

The satellite data acquired at Kashima Station are directly transferred to H.Q., RRL through a microwave link and recorded on the tape recorder by a remote control from Kashima Station. Monitoring of the mission status and analysis for obtaining quick information on the ionosphere are executed with the aid of the Mission Quick-Analysis System. The quick information on the ionosphere is forwarded to the Hiraiso Branch, RRL engaged in the work of radio warning. The satellite data are processed, analyzed and accumulated, and the world-distribution maps of the ionospheric parameters and radio noises are prepared as the basic data for radioforecasts.

Ground Facilities

Satellite Control Center and Telemetry Antenna

Mission Quick-Analysis System



Satellite Control System for ISS-b at Kashima Station

Satellite Operation Planning and Data Analysis System for ISS-b at H.Q., RRL

Satellite Control Panel, Kashima

Central Computer System, H.Q., RRL

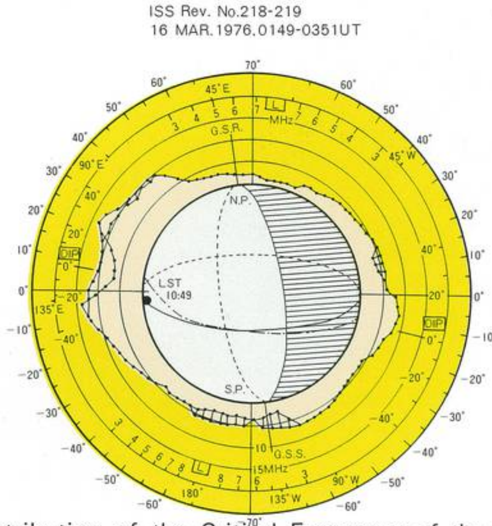
Use of Satellite Data

Satellite technique is the best way to obtain the data of the ionosphere and radio noises above the sea occupying about 2/3 of the earth's surface and sparsely populated area.

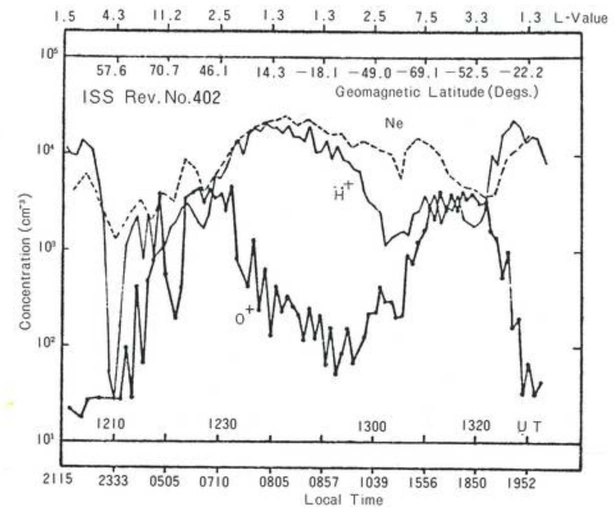
ISS-b gives us the global data of the ionosphere and radio noises by adoption of the on-board data recorder and PCM data format.

The distribution of the critical frequency of the ionosphere around the earth, as an example shown in the figure, gives us a quick information on the status of the ionosphere and are used as a basic data for radio warning service at Hiraiso Branch.

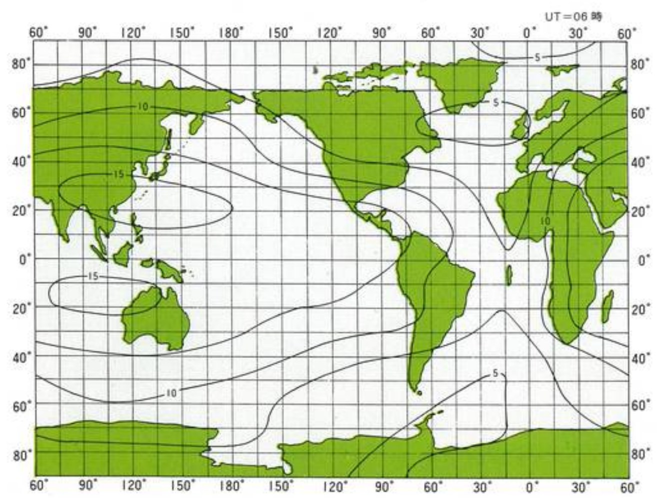
The local time at the subsatellite point of ISS-b on the equator covers from 0h to 24h during two months. Accumulating the data from ISS-b for long term, we can obtain the averaged world distributions of the ionosphere and radio noises and their seasonal, further solar cycle, variations. These data are used as the basic data for long term radio forecasting service.



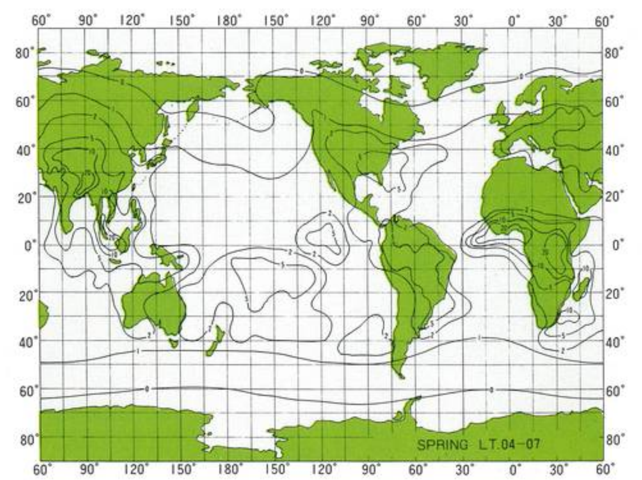
Distribution of the Critical Frequency of the Ionosphere around the Earth from ISS[Ume]



Distributions of Electron Density and Ions from ISS[Ume]



Example of World Distribution of the Ionospheric Critical Frequency



Example of World Distribution of Atmospheric Radio Noise caused by Lightning Discharge