IAF
80-G-286

IAF
31ST INT'L ASTRONAUTICAL
FEDERATION CONGRESS
TOKYO, JAPAN
September 22-28, 1980

A81-18381

XXXI CONGRESS
INTERNATIONAL ASTRONAUTICAL FEDERATION

IAF'80

TOKYO, JAPAN, SEPTEMBER 21-28, 1980

PREPRINT

IAF-80-G-286

Status Report on PLANET-A, Japanese First Interplanetary Flight

R. Akiba *et al., Japan*

This Preprint is for distribution at the Congress only

Published for the
International Astronautical Federation
by
Pergamon Press
Oxford · New York · Toronto · Sydney · Paris · Frankfurt

N

A81-18381

STATUS REPORT ON PLANET-A, JAPANESE FIRST INTERPLANETARY FLIGHT

R. Akiba, T. Hayashi, H. Matsuo,
K. Uesugi and M. Ichikawa

Institute of Space and Aeronautical Science,
University of Tokyo, 4-6-1, Komaba, Meguro-Ku,
Tokyo, Japan

ABSTRACT

Japanese first interplanetary probe PLANET-A is to be launched on the opportunity of next apparition of Halley's Comet in 1986. This paper is a status report on this program. The probe is boosted by use of the improved version of Mu-3S rocket, the newest of ISAS launch vehicles. Technical details are described concerning spacecraft configuration and navigation, control, communication and instrumentation subsystems.

KEYWORDS

Halley's Comet; interplanetary mission; comet encounter; spinning spacecraft; spacecraft subsystem.

INTRODUCTION

Next apparition of Halley's Comet is to occur in 1986. For this opportunity, Japanese first interplanetary probe is to be launched by ISAS (Institute of Space and Aeronautical Science, University of Tokyo) utilizing a national launch vehicle. The program, including Halley's Comet exploration as the primary aim, is named PLANET-A. This paper is a status report on this program.

The probe is boosted by use of Mu-3U rocket which is the improved version of Mu-3S rocket, the newest of ISAS launch vehicles. As shown in Fig. 1, the vehicle is a three-staged solid propellant rocket now under development with a payload capabilit of approx. 670 kg onto 250 km circular orbit.

The spacecraft weighs approx. 125 kg and the main mission is photographing Halley's Comet in UV region and plasma measurement will be carried out en route. According to the demands such as communication and taking pictures, a high gain antenna is despun mechanically, while the camera is mounted on the spinning body. The spin rate of the spacecraft is very low (0.2-0.5 rpm) and the attitude is stabilized by a bias momentum wheel. Solar cell covering the side surface of spacecraft supplies approx. 70 W at 1 AU from the sun. Technical details will be reported concerning navigation, control, communication and instrumentation subsystems.

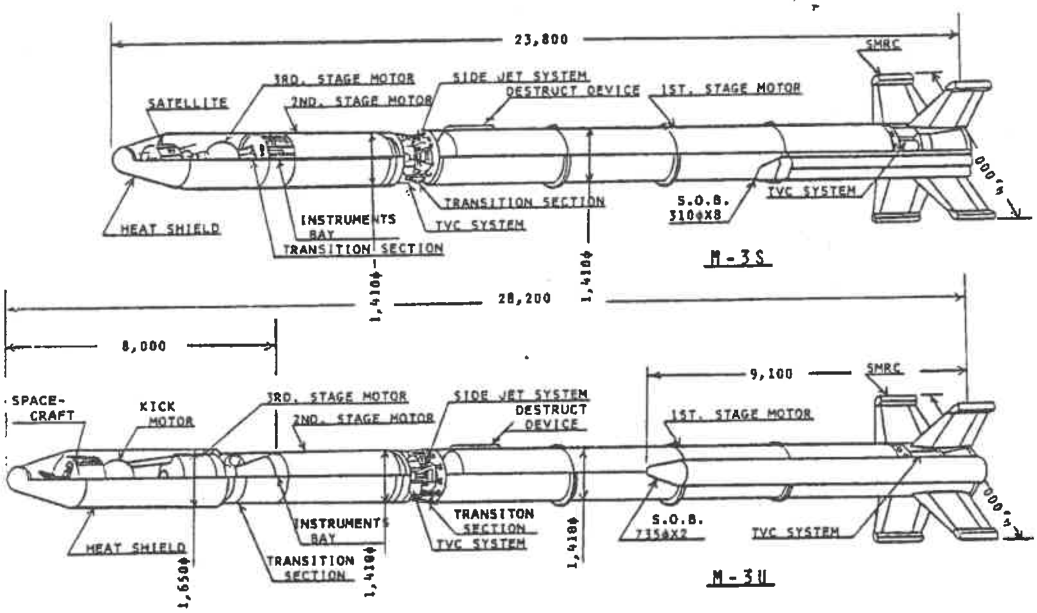

Fig. 1. Mu-3U launch vehicle,
the improved version of Mu-3S rocket

ORBITAL DESIGN

Some flight plans of PLANET-A to Halley's Comet were discussed on 30th IAF congress (R. Akiba and co-workers, 1979). They include pre-perihelion encounter, post-perihelion encounter, the utilization of Venus swing-by, and one round mission which means that spacecraft goes round about the sun before encounter with the Comet. Since this mission is Japanese first interplanetary flight and the payload capability of Mu-3U is not so high, post-perihelion encounter mission, which requires the least launch energy, has been selected. As for the post-perihelion mission, two alternative launch windows exist. In one of the alternatives, the launch time is March in 1985 and spacecraft should carry out the one round mission as shown in Fig. 2. While in the other, spacecraft will be launched in August 1985 and fly directly to a encounter point with the Comet (Fig. 3). In table 1, some essential orbital parameters for both cases are listed. In both cases the probe is injected into a heliocentric orbit directly without parking in order to save fuel for attitude maneuver on parking orbit. To make such a direct escape be possible, the declination of the launch asymptote must be selected carefully.

SCIENTIFIC MISSIONS

Though more than ten scientific missions were proposed by space scientists in Japan, photographing of Halley's Comet in ultraviolet wavelength and plasma measurement were decided to be carried out on board PLANET-A taking consideration of the

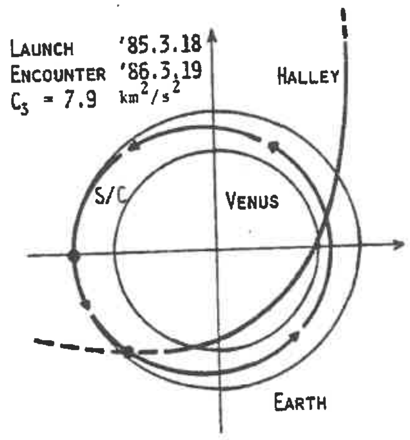

Fig. 2. Flight plan case 1
one-round mission

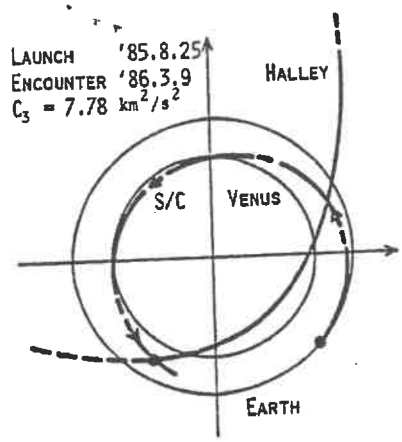

Fig. 3. Flight plan case 2
direct flight mission

TABLE 1 Orbital Parameters

	Case 1	Case 2
Launch Date	1985.03.18.	1985.08.25.
Encounter Date	1986.03.19.	1986.03.09.
Launch Energy C_3 $(km/s)^2$	7.887	7.783
Declination of Launch Asymptote (deg)	-26.63	-27.92
Perihelion (AU)	0.80	0.69
Aphelion (AU)	1.00	1.01
Inclination (deg)	4.357	0.768

payload capability of the launch vehicle. Imaging of Halley's Comet in hydrogen emission (Lyman alpha, 1216 A) is planned to investigate the production rate, outflow mechanism, and loss of hydrogen from this object. Plasma detector for solar wind measurement consists of two separate sensors and common electronics. One sensor is of use for determination of macroscopic properties (density, temperature, bulk velocity). Another is for microscopic phenomena (discontinuity etc.). Total weight of two scientific instruments is expected to be 10 kg.

SPACECRAFT SYSTEM

The mission of photographing of the Comet requires that the camera must be mounted on a fully despun platform or on a spinning body of which spin rate is very low. While a high gain antenna should be oriented to the earth in order to maintain radio communication with the earth station which is to be constructed in Japan. Under such circumstances, spacecraft system was determined as follows. Spacecraft is spun with very low spin rate (0.2-0.5 rpm). The spin axis is controlled to be perpendicular to the ecliptic plane and the attitude is stabilized by a bias momentum wheel. UV camera is mounted on the spinning body, and a high gain antenna is fully despun mechanically by a despun motor. In this section, each subsystem of the spacecraft is discussed briefly.

Communication Subsystem

An S-band communication subsystem carries telemetry to the earth, commands to the spacecraft, and angle-tracking and ranging information for orbit determination. Transmitter frequency has not been finally determined, but an adoption of the coherent system such as 2.28 GHz for downlink and 2.11 GHz for uplink is expected. As for the downlink, assuming the transmitting power (P_0) as 10 W and the gain as 21 dBi, data transmission rate reaches 300 bps at 1.1 AU when a 40 m^{ϕ} ground antenna is available at the time. Figure 4 shows relations between data rate and slant range. Then, for transmitting a picture of which bit density is 256 x 256 and the tone of 7 bits, it takes about 1 hr. in the case of P_0 = 10 W assuming the gain margin as about 4 dB.
As for uplink, the spacecraft command subsystem receives the PCM-PSK data stream from the communication subsystem at the uplink bit rate of 10 bps. Figure 5 shows the omni-antenna can receive 10 bps commands at 1.1 AU if the transmitting power of the earth station (P_T) is greater than 10 kW.
A data processing unit using a microcomputer deals with the observation data from the scientific instruments, house keeping data, and command data from the earth, and a magnetic bubble memory of which capacity is 2 Mbits is to be adopted in order to store these data.

Antennas Subsystem

Antennas subsystem consists of a high gain antenna (HGA), a medium gain antenna (MGA), and one or two omnidirectional low gain antennas (LGA). As for HGA, the mechanical despun antenna (MDA) and the electrical despun antenna (EDA) were investigated and compared with each other. Though EDA is even now very attractive by the advantages of lighter weight and easier operation for pointing antenna toward the earth than those of MDA, its antenna gain is about 5 dB less than that of MDA in the state of art. Then we have tentatively decided to adopt MDA as HGA. An offset parabolic dish antenna was selected as MDA, and the combination of two sun sensors, star scanner and commands from the earth station makes MDA to point toward the earth. The polarization is right-hand circular and the antenna gain of 21 dBi is possible within ±1.5 deg from the plane normal to the spin axis.

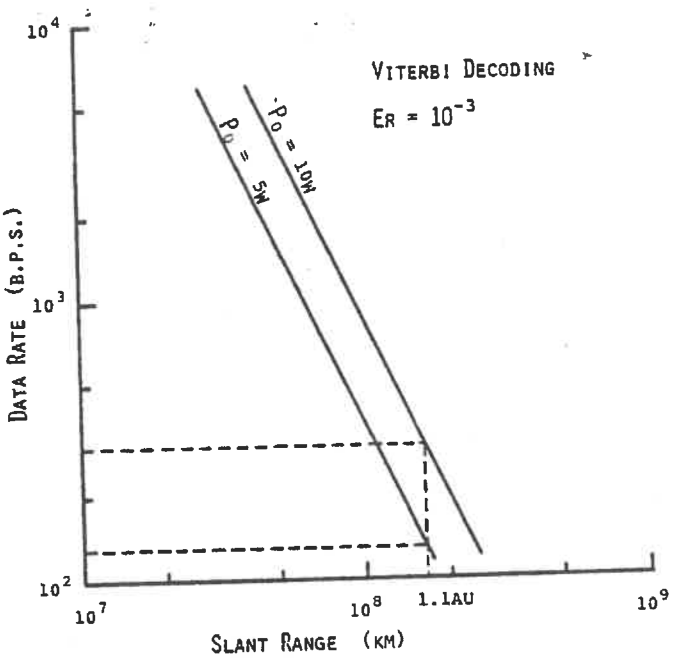

Fig. 4. Downlink data bit rate vs. slant range

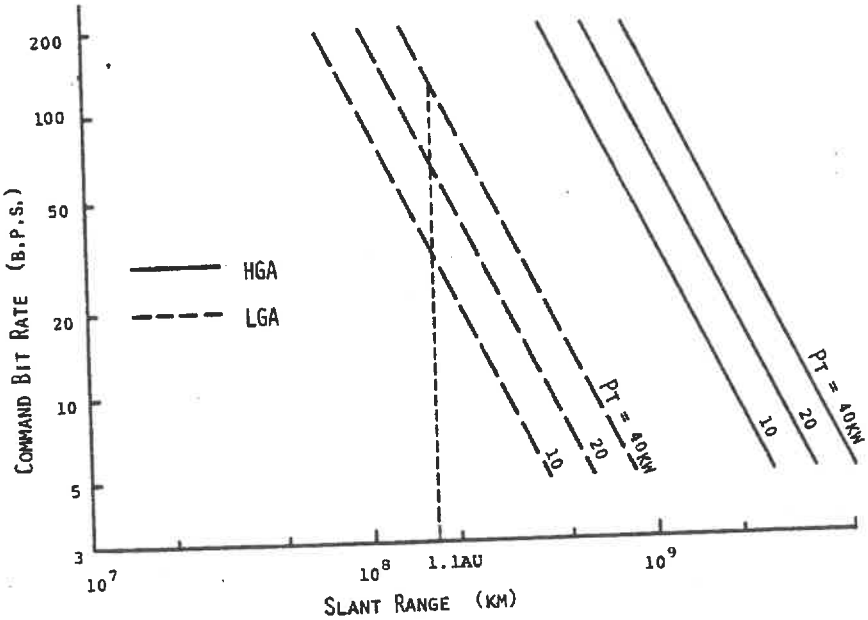

Fig. 5. Uplink command bit rate vs. slant range

MGA consists of five dipole antennas arranged colinearly, and is used as a back-up subsystem of HGA. The gain will be greater than 6 dBi in the plane normal to the spin axis and 3 dBi within ±30 deg from this plane. Its polarization is linear. LGA is mounted on the lower side of spacecraft and when two antennas are required, another one is mounted on the top of MDA. The gain greater than -8 dBi will be obtained almost omnidirectionally. The polarization is circular.

Power Subsystem

The power subsystem consists of: sbout 2,000 solar cells (each solar cell size is 2 × 6 cm and 2 × 2 cm) attached to the cylindrical side of the spacecraft; 2 AH nickel-cadmium batteries; and the various sensing and control units. As shown in Table 2, for the power requirements in the various phases of the mission such as injection phase, cruising phase and observation phase, the power subsystem can provide enough power to each subsystem.

TABLE 2 Power Output and Requirements

Conditions				Power (W)		
Phase	Distance from Sun (AU)	Sun Angle (deg)	Event	Req.	Output	Require. - Output
Injection	1.0	35.	Attitude Control	36.	39.	3.
		90.	Cruising	46.	67.	21.
Perihelion	0.68	90.	Data Transmission	78.	104.	26.
			No Data Transmission	43.	104.	61.
Encounter	0.82	90.	Data Transmission	80.	82.	2.
			Halley Observation	70.	82.	12.

Control Subsystem

The control subsystem provides the attitude sensors, bias momentum wheel, electronics and mono-propellant gas jet engines to accomplish several tasks. Slit field of view sun and star sensors are used to determine and control spacecraft attitude and spin rate, and to provide science roll reference signals. Event sequence after the injection may be divided into five phases as shown in Table 3.

TABLE 3 Event Sequence

Phase	Event	Event Magnitude	Spin Rate after Event (rpm)
1	Spacecraft Injection		120
	Despin	-115rpm	5
2	Orient to Normal-to-Sun	60deg	5
	Orient to Normal-to-Ecliptic	180deg	5
3	Orient for Midcourse Correction	180deg	5
4	Midcourse Correction	30m/s	5
5	Re-orient to Cruise	180deg	5
	Wheel Run-up		0.2-0.5
	Antenna Change (LGA→HGA)		0.2-0.5
	Attitude Maintennance	70deg	0.2-0.5
	Wheel Unloading	10rpm	0.2-0.5

The first includes re-tracking after 4 hrs invisible time following injection, and spin reduction from 120 rpm to 5 rpm for spacecraft operations. In the second phase, spacecraft attitude and spin rate will be evaluated and a star mapping carried out. Also, a precession maneuver may be required to position the spacecraft in a normal-to-the-ecliptic attitude. During the first 3 days of the mission, accurate ranging and orbit determination will be made and then the third phase prepares the attitude for midcourse correction maneuver. Phase four includes jet calibrations, one or more midcourse correction maneuvers. The final phase covers interplanetary cruise up including a bias momentum wheel run-up,spin reduction to 0.2-0.5 rpm, attitude maintenance and wheel unloadings. Spacecraft spin rate, attitude and velocity control is provided by the propulsion subsystem. It consists of six 0.3 kg thrusters; four are mounted radially, and two are mounted axially on the top side of the equipment shelf. Various valves, line heaters, propellant tanks, and filters complete the propulsion subsystems. Hydrazine monopropellant of 5 kg is capable of 30 m/s velocity correction and of attitude control.

Structure and Thermal Subsystem

The spacecraft structure is shown in Fig. 6. The seven basic components are the despun antenna assembly, the bearing and RF joint, their support structure, the equipment shelf, the substrate and solar panel, the thrust tube, and the struts.

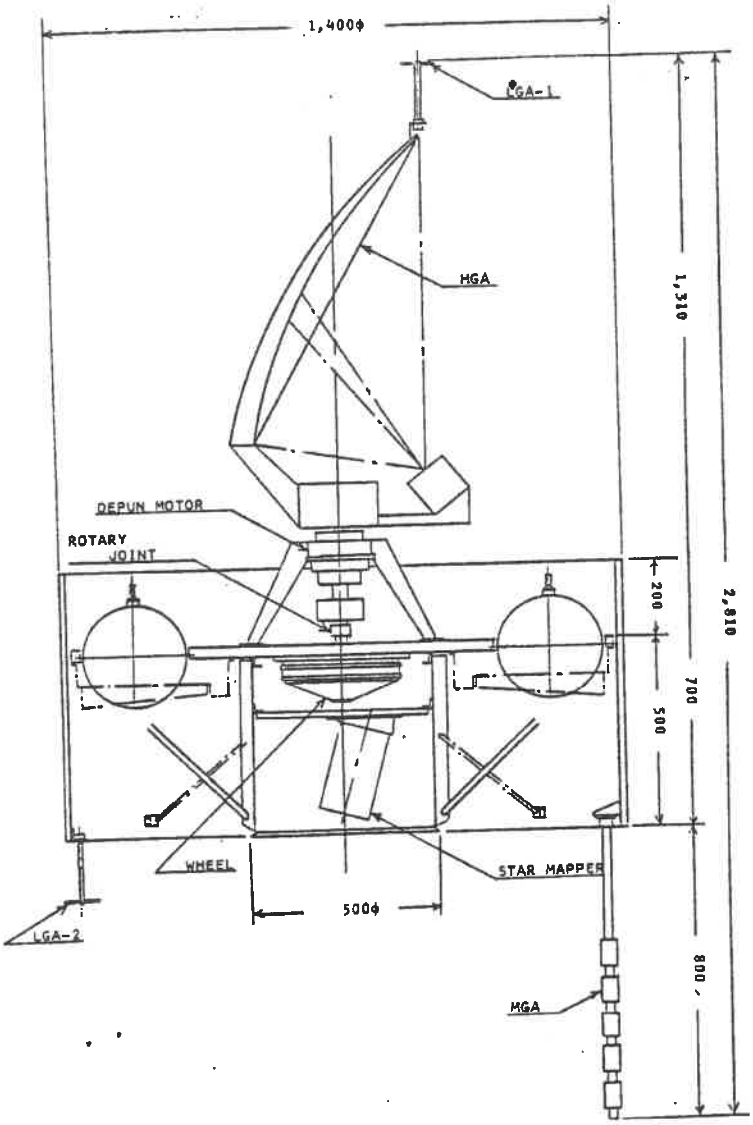

Fig. 6. Structure of the spacecraft

The material mainly used is CFRP in order to save the weight. The basis of the thermal design is that the spacecraft is to be isolated from the external solar heat of which intensity varies from 1 sun to 2.2 suns at perihelion. Although the spin axis is maintained to the direction normal to the ecliptic plane, the passive thermal control such as thermal blankets, thermal finishes, paints and structural materials is not enough to maintain the temperature of the shelf-mounted electronics within adequate upper and lower limits. Then thermostatically controlled louvers mounted to the underside of the equipment shelf provides the active thermal control.

ıs and Weight

ɪs a cutaway illustration of the spacecraft. And Table 4 lists the ɜight breakdown. Basically the spacecraft has a cylindrical shape which ı diameter and 700 mm in height. The roll-to-transverse inertia ratio :o exceed 1.3. The weight of spacecraft is now estimated as 125 kg Table 4, and though the weight margin against the payload capability ıicle is not so much, it may be hard to reduce the weight still more. ɜcted that the capability will grow with the progress of the development ket.

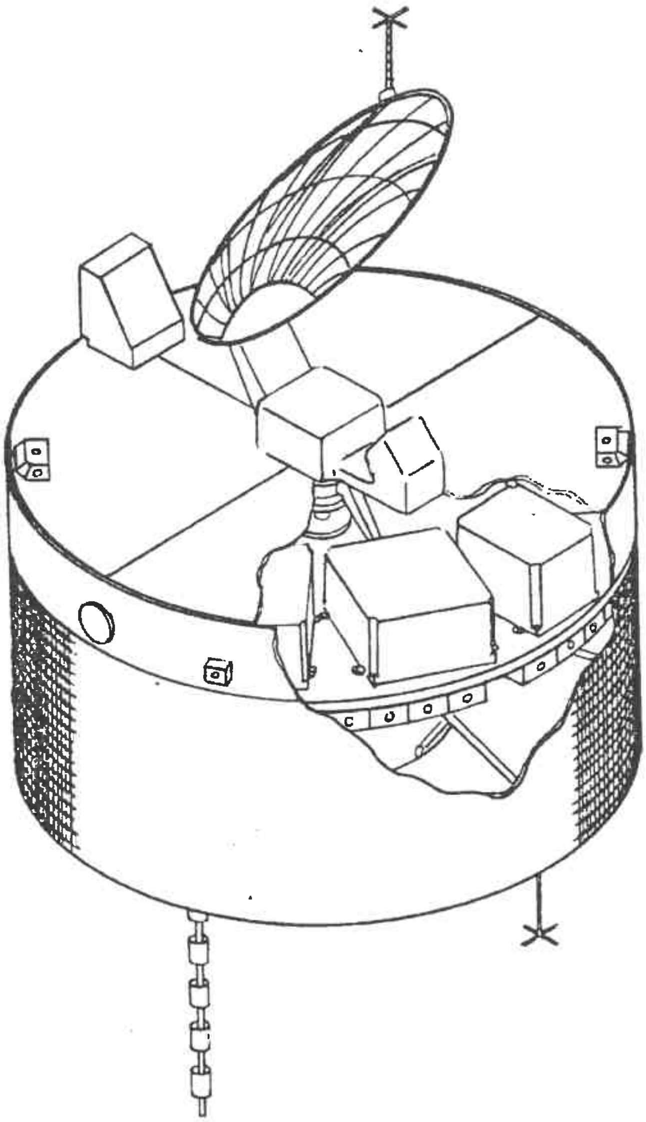

Fig. 7. Cutaway view of the spacecraft

TABLE 4 PLANET-A Weight Breakdown

Power Subsystem	
Solar Cell Panel	10.6
Battery	2.2
Converter	4.3
Power Control Unit	1.2
Circuits	0.8
Sub-total	19.1
Communication & Antennas Subsystem	
Low Gain Antenna x2	1.2
Medium Gain Antenna	1.0
High Gain Antenna	3.3
Transmitter & Receiver	5.0
Rotary Joint	1.9
Antenna Support	1.2
Despun Motor	5.9
Motor Control Unit	1.5
Sub-total	21.0
Telemetry & Command Subsystem	
Data Processing Unit	5.0
Command Decorder	2.0
Data Recorder	3.2
House Keeping	1.0
Sub-total	11.2
Control Subsystem	
Momentum Wheel	8.6
Wheel Driver	1.4
Control Circuits	3.0
Sun Sensors	0.8
Star Mapper	1.4
Nutation Damper	0.6
Propulsion System	15.0
Sub-total	30.8
Structure & Thermal Subsystem	
Structure	17.0
Thermal Louvers	4.5
Blankets etc.	2.5
Sub-total	24.0
Integration	
Bolts etc.	4.0
Circuits	5.0
Sub-total	9.0
Scientific Instruments	10.0
Total Weight	125.1 kg

CONCLUDING REMARKS

PLANET-A project was approved and authorized last year by Space Activities Commission of Japan. This may be the first Halley's Comet exploration program formally approved in the world though the probe may be the smallest. In company with the development of PLANET-A program and the improvement of launch vehicle, the construction program of the earth station is now scheduled.

ACKNOWLEDGEMENT

The authors would like to their gratitude to the members of PLANET-A project team of Nippon Electric Co. LTD. (NEC). They devoted their effort to a one-year preliminary investigation at ISAS. Portions of the data were obtained for this paper from their works.

REFERENCE

Akiba, R., F. R. Liann, H. Matsuo, K. Uesugi, and M. Ichikawa (1979). Orbital design and technological feasibility of Halley mission. Proceeding 30th IAF Congress Munich, GFR. (also to be published in Acta Astronautica)