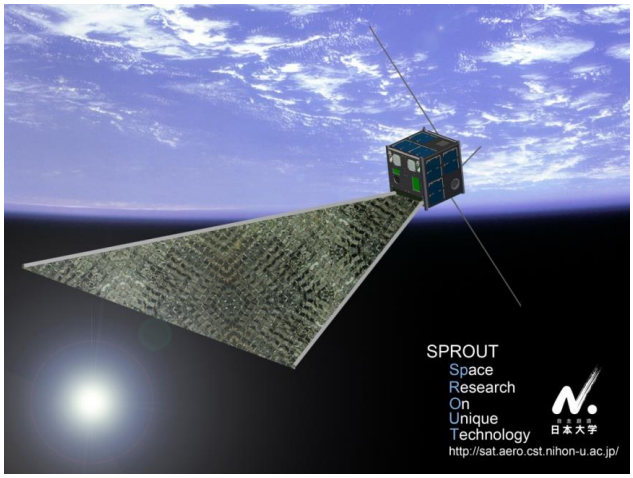
FM Telemetry Data Format

For "SPROUT" CDH1

Revision B	Date : 2014/6/3



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	2014/4/25	2014/5/23	2014/6/3				

Revision

Revision	Date	Revised point	Authored by
	2014/4/25		Yusuke Yamaguchi
A	2014/5/23	Revised telemetry format	Kento Ohinata
B	2014/6/3	Revised telemetry format	Kento Ohinata

Chapter List

1. Communication Protocol

This is the protocol of FM communication of SPROUT. And, you need to see our HP to know which mode SPROUT is in now.

SPROUT FM Downlink	
Band rate and type	437.525MHz 1200bps FM/AFSK 9600bps FM/GMSK 437.600MHz 1200bps FM/AFSK

2. FM Telemetry Format

These is seven mode of SPROUT FM Telemetry.

(1) Test FM

Send real time sensor data by FM packet

(2)CDH1 Sensing Data

Send CDH1 sensor data which saved at FEPROM by FM packet.

(3)INF Sensing Data(Pressure, Temperature)

Send INF sensor data (Pressure Sensor, Temperature Sensor) which saved at FEPROM by FM packet.

(4)INF Sensing Data(Piezo)

Send INF sensor data(Piezo Sensor) which saved at FEPROM by FM packet.

(5)CAM Row Data

Send camera data(row data) which saved at FEPROM by FM packet.

(6)CAM Thumbnail Data

Send camera data(Compressed data) which saved at FEPROM by FM packet.

(7)ADC Data

Send ADC sensor data which saved at FEPROM by FM packet.

This paper provide FM packet formant only "Test FM" and "CDH1 sensing data"

2.1. FM downlink data structure

These are data structure for FM downlink except "Test FM".

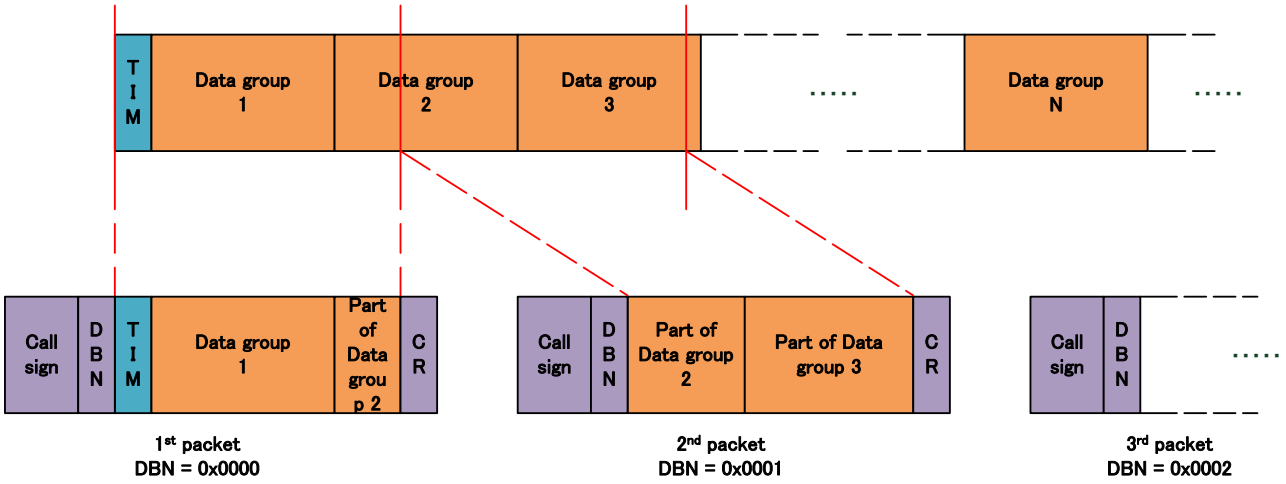
Type of FM packet telemetry	
Call sign	“SPROUT>JQ1ZJQ:”
DBN	Data Block Number
TIM	Time Data Group.
Data group	Data group number for one sensing.
CR	Carriage Return "0X0D"

Put sensing time is N(times). The data saved in FEPROM is below. And, satellite time is header of data structure.

The data group saved in FEPROM

This saved data group will send downlink by FM packet.

The data quantity of data group and single packet is different. So, FM packet downlink such as this figure below.



The maximum data of single packet is 224[byte]. We use DBN (Data Block Number) method. The number of data group and single packet is not same quantity. So the data break into couple blocks. We call this bock is "Data Block".

A DBN shows downlink packet number (This number is serial number which saved in FEPROM). Also, A satellite time shows time which is inside satellite. Each number formed hexadecimal number.

DBN	TIM
$0_3 0_2$ $0_1 0_0$	$1_7 1_6$ $1_5 1_4$ $1_3 1_2$ $1_1 1_0$

This calculation is below.

FM downlink calculation				
Group	**data**	**Word(s)**	**Mean**	**Calculation**
DBN	$0_3 0_2 0_1 0_0$	4	Data block number	$0_3\times16^3+0_2\times16^2+0_1\times16^1+0_0\times16^0$ [blocks]
TIM	$1_7 1_6 1_5 1_4 1_3 1_2 1_1 1_0$	8	Satellite time	$(1_7\times16^7+1_6\times16^6+1_5\times16^5+1_4\times16^4+1_3\times16^3+1_2\times16^2+1_1\times16^1+1_0\times16^0)/10$ [s]

The satellite time gives only start of sensing. And, An interval time between sensing is only able to see at telemetry format (Chaper 3 testFM ,4 CDH1 sensing). However, this cycle can change by us. So you have to see our web site to know this information.

Usually, single packet is contain 224[byte] (448 worlds)for SPROUT. However , we can change packet number. You can see our website to know this information.

2.2. Notification

There is 4 things have to be checked our Operation site to use FM telemetry.

（1） Communication mode

This shows FM communication mode.

（2） Sensing start time

Sensing start time is only give top of DBN.　You can see our website to know FM sensing start time.

（3） Sampling cycle

The time between sensing(sampling cycle)is written on(chapter 3,4).　But, this cycle is able to change.

（4） Number of single packet

This is the number(s) of byte contain single packet.　Normally, this number is 224[byte](448 worlds).　But it is able to change.

(Operation site: http://sat.aero.cst.nihon-u.ac.jp/wordpress/)

3. Test FM

JQ1ZJQ>SPROUT: Data 0x0D

Callsign　Satellite name　Carriage return

Test FM data group	
HKD	Housekeeping Data Group
STA	Status Data Group
TIM	Time Data Group
RES	Reset Count Data Group

If FM downlink is Test FM. It is need to transform row data to binary data after header call sign.

Data group(362 worlds)
0_30_2 0_10_0 1_31_2 1_11_0 2_32_2 2_12_0 3_33_2 3_13_0 4_34_2 4_14_0 5_35_2 5_15_0 6_36_2 6_16_0 7_37_2 7_17_0 8_38_2 8_18_0 9_39_2 9_19_0 a_3a_2 a_1a_0 b_3b_2 b_1b_0 c_3c_2 c_1c_0 d_3d_2 d_1d_0 e_3e_2 e_1e_0 f_3f_2 f_1f_0 g_3g_2 g_1g_0 h_3h_2 h_1h_0 i_3i_2 i_1i_0 j_3j_2 j_1j_0 k_3k_2 k_1k_0 l_3l_2 l_1l_0 m_3m_2 m_1m_0 n_3n_2 n_1n_0 o_3o_2 o_1o_0 p_3p_2 p_1p_0 q_3q_2 q_1q_0 r_3r_2 r_1r_0 s_3s_2 s_1s_0 t_3t_2 t_1t_0 u_3u_2 u_1u_0 v_3v_2 v_1v_0 w_3w_2 w_1w_0 x_3x_2 x_1x_0 y_3y_2 y_1y_0 z_3z_2 z_1z_0 A_3A_2 A_1A_0 B_3B_2 B_1B_0 C_3C_2 C_1C_0 D_3D_2 D_1D_0 E_3E_2 E_1E_0 F_3F_2 F_1F_0 G_3G_2 G_1G_0 H_3H_2 H_1H_0 I_3I_2 I_1I_0 J_3J_2 J_1J_0 K_3K_2 K_1K_0 L_3L_2 L_1L_0 M_3M_2 M_1M_0 N_3N_2 N_1N_0 O_3O_2 O_1O_0 P_3P_2 P_1P_0 Q_3Q_2 Q_1Q_0 R_3R_2 R_1R_0 S_3S_2 S_1S_0 T_3T_2 T_1T_0 U_3U_2 U_1U_0 V_3V_2 V_1V_0 W_3W_2 W_1W_0 X_3X_2 X_1X_0 Y_3Y_2 Y_1Y_0 Z_3Z_2 Z_1Z_0 $\alpha_3\alpha_2$ $\alpha_1\alpha_0$ $\beta_3\beta_2$ $\beta_1\beta_0$ $\gamma_3\gamma_2$ $\gamma_1\gamma_0$ $\delta_3\delta_2$ $\delta_1\delta_0$ $\varepsilon_3\varepsilon_2$ $\varepsilon_1\varepsilon_0$ $\zeta_3\zeta_2$ $\zeta_1\zeta_0$ $\eta_3\eta_2$ $\eta_1\eta_0$ $\theta_3\theta_2$ $\theta_1\theta_0$ $\iota_3\iota_2$ $\iota_1\iota_0$ $\kappa_3\kappa_2$ $\kappa_1\kappa_0$ $\lambda_3\lambda_2$ $\lambda_1\lambda_0$ $\mu_3\mu_2$ $\mu_1\mu_0$ $\nu_3\nu_2$ $\nu_1\nu_0$ $\xi_3\xi_2$ $\xi_1\xi_0$ o_3o_2 o_1o_0 $\pi_3\pi_2$ $\pi_1\pi_0$ $\rho_3\rho_2$ $\rho_1\rho_0$ $\sigma_3\sigma_2$ $\sigma_1\sigma_0$ $\tau_1\tau_0$ $\upsilon_1\upsilon_0$ $\varphi_1\varphi_0$ $\chi_1\chi_0$ $\psi_1\psi_0$ $\omega_7\omega_6$ $\omega_5\omega_4$ $\omega_3\omega_2$ $\omega_1\omega_0$ $A_{23}A_{22}$ $A_{21}A_{20}$ $A_{19}A_{18}$ $A_{17}A_{16}$ $A_{15}A_{14}$ $A_{13}A_{12}$ $A_{11}A_{10}$ A_9A_8 A_7A_6 A_5A_4 A_3A_2 A_1A_0

Give the "0X0D" code at end of downlink data.
All data formed hex except "HKD" data.　This data (on the figure below) is decimal number.

Test FM packet structure（total362 words）				
Group	data	Word(s)	Mean	Calculation
HKD	$0_30_20_10_0$	4	+X Solar cell 1 generation	(5 × x)/(4096×9) [A]
	$1_31_21_11_0$	4	−X Solar cell 1 generation	(5 × x)/(4096×9) [A]
	$2_32_22_12_0$	4	−X Solar cell 2 generation	(5 × x)/(4096×9) [A]
	$3_33_23_13_0$	4	−Y Solar cell 1 generation	(5 × x)/(4096×9) [A]
	$4_34_24_14_0$	4	−Y Solar cell 2 generation	(5 × x)/(4096×9) [A]
	$5_35_25_15_0$	4	−Y Solar cell 3 generation	(5 × x)/(4096×9) [A]
	$6_36_26_16_0$	4	+Y Solar cell 1 generation	(5 × x)/(4096×9) [A]
	$7_37_27_17_0$	4	+Y Solar cell 2 generation	(5 × x)/(4096×9) [A]
	$8_38_28_18_0$	4	+Y Solar cell 3 generation	(5 × x)/(4096×9) [A]
	$9_39_29_19_0$	4	+Z Solar cell 1 generation	(5 × x)/(4096×9) [A]
	$a_3a_2a_1a_0$	4	+Z Solar cell 2 generation	(5 × x)/(4096×9) [A]
	$b_3b_2b_1b_0$	4	+Z Solar cell 3 generation	(5 × x)/(4096×9) [A]
	$c_3c_2c_1c_0$	4	−Z Solar cell 1 generation	(5 × x)/(4096×9) [A]

Group	data	Word(s)	Mean	Calculation
HKD	$d_3d_2d_1d_0$	4	−Z Solar cell 2 generation	$(5 \times x)/(4096\times9)$ [A]
	$e_3e_2e_1e_0$	4	−Z Solar cell 3 generation	$(5 \times x)/(4096\times9)$ [A]
	$f_3f_2f_1f_0$	4	Bus current	$(5 \times x)/(4096\times0.5)$ [A]
	$g_3g_2g_1g_0$	4	Bus voltage	$(5 \times x)/4096$ [V]
	$h_3h_2h_1h_0$	4	Temperature（Satellite surface＋X)	$0.282\times((5 \times x)/4096)^2 - 38.98\times(5 \times x)/4096 + 101.68$[deg. C]
	$i_3i_2i_1i_0$	4	Temperature（Satellite surface＋Y)	$0.5777\times((5 \times x)/4096)^2 - 40.453\times(5 \times x)/4096 + 99.226$[deg. C]
	$j_3j_2j_1j_0$	4	Temperature（Satellite surface＋Z)	$0.6493\times((5 \times x)/4096)^2 - 39.896\times(5 \times x)/4096 + 98.469$[deg. C]
	$k_3k_2k_1k_0$	4	Temperature（Satellite surface−X)	$0.4105\times((5 \times x)/4096)^2 - 39.074\times(5 \times x)/4096 + 97.993$[deg. C]
	$l_3l_2l_1l_0$	4	Temperature（Satellite surface−Y)	$0.4383\times((5 \times x)/4096)^2 - 40.076\times(5 \times x)/4096 + 98.771$[deg. C]
	$m_3m_2m_1m_0$	4	Temperature（Satellite surface−Z)	$0.2982\times((5 \times x)/4096)^2 - 38.98\times(5 \times x)/4096 + 99.769$[deg. C]
	$n_3n_2n_1n_0$	4	Temperature(Battery 2)	$0.4342\times((5 \times x)/4096)^2 - 41.236\times(5 \times x)/4096 + 103.46$[deg. C]
	$o_3o_2o_1o_0$	4	Temperature(Battery 1)	$0.3995\times((5 \times x)/4096)^2 - 40.088\times(5 \times x)/4096 + 100.84$[deg. C]
	$p_3p_2p_1p_0$	4	Temperature（Reciver2)	$0.3285\times((5 \times x)/4096)^2 - 39.376\times(5 \times x)/4096 + 98.91$[deg. C]
	$q_3q_2q_1q_0$	4	Temperature (Trensmitter2)	$0.2311\times((5 \times x)/4096)^2 - 38.955\times(5 \times x)/4096 + 100.19$[deg. C]
	$r_3r_2r_1r_0$	4	Temperature (Reciver 1)	$0.3281\times((5 \times x)/4096)^2 - 39.035\times(5 \times x)/4096 + 97.608$[deg. C]
	$s_3s_2s_1s_0$	4	Temperature (Transmitter 1)	$0.2946\times((5 \times x)/4096)^2 - 39.537\times(5 \times x)/4096 + 99.7$[deg. C]
	$t_3t_2t_1t_0$	4	Temperature (Gyro sensor Y axis)	$2.1507\times((5 \times x)/4096)^2 - 46.004\times(5 \times x)/4096 + 106.55$[deg. C]
	$u_3u_2u_1u_0$	4	Temperature (Gyro sensor X axis)	$0.7854\times((5 \times x)/4096)^2 - 41.015\times(5 \times x)/4096 + 100.05$[deg. C]
	$v_3v_2v_1v_0$	4	Temperature (Gyro sensor Z axis)	$0.9648\times((5 \times x)/4096)^2 - 39.886\times(5 \times x)/4096 + 108.37$[deg. C]
	$w_3w_2w_1w_0$	4	Temperature (Magnetic field sensor)	$0.0728\times((5 \times x)/4096)^2 - 36.191\times(5 \times x)/4096 + 95.367$[deg. C]
	$x_3x_2x_1x_0$	4	Temperature（Magnetic valve 1)	$0.1777\times((5 \times x)/4096)^2 - 38.862\times(5 \times x)/4096 + 98.819$[deg. C]
	$y_3y_2y_1y_0$	4	Temperature (storage box top)	$0.7649\times((5 \times x)/4096)^2 - 41.38\times(5 \times x)/4096 + 101.98$[deg. C]
	$z_3z_2z_1z_0$	4	Temperature (ADC board)	$0.2936\times((5 \times x)/4096)^2 - 39.207\times(5 \times x)/4096 + 99.713$[deg. C]
	$A_3A_2A_1A_0$	4	Temperature (EPS board)	$0.3051\times((5 \times x)/4096)^2 - 39.009\times(5 \times x)/4096 + 99.257$[deg. C]
	$B_3B_2B_1B_0$	4	Temperature (CDH1 board)	$0.3241\times((5 \times x)/4096)^2 - 39.444\times(5 \times x)/4096 + 100.56$[deg. C]
	$C_3C_2C_1C_0$	4	Temperature (CAM3 board)	$0.3862\times((5 \times x)/4096)^2 - 39.157\times(5 \times x)/4096 + 100.05$[deg. C]
	$D_3D_2D_1D_0$	4	Temperature (FMR1 board)	$0.3366\times((5 \times x)/4096)^2 - 39.025\times(5 \times x)/4096 + 98.665$[deg. C]
	$E_3E_2E_1E_0$	4	Temperature (bottom of membrane)	$0.0832\times((5 \times x)/4096)^2 - 38.109\times(5 \times x)/4096 + 96.654$[deg. C]
	$F_3F_2F_1F_0$	4	Temperature (InflatableTube 1)	$0.1625\times((5 \times x)/4096)^2 - 38.356\times(5 \times x)/4096 + 98.533$[deg. C]
	$G_3G_2G_1G_0$	4	Temperature (InflatableTube2)	$0.0357\times((5 \times x)/4096)^2 - 37.908\times(5 \times x)/4096 + 98.005$[deg. C]

Group	data	Word(s)	Mean	Calculation
HKD	$H_3H_2H_1H_0$	4	Temperature (Inside pipe)	$0.3021\times((5\times x)/4096)^2 - 39.42\times(5\times x)/4096 + 98.922$[deg. C]
	$I_3I_2I_1I_0$	4	Temperature (Inside storage box)	$-0.0318\times((5\times x)/4096)^2 - 37.221\times(5\times x)/4096 + 98.686$[deg. C]
	$J_3J_2J_1J_0$	4	Pressure sensor Primary pressure	$(20689.66\times x)/4096$ [kPa]
	$K_3K_2K_1K_0$	4	Pressure sensor Secondly pressure	$(206.90\times x)/4096$ [kPa]
	$L_3L_2L_1L_0$	4	No-Data	-
	$M_3M_2M_1M_0$	4	Magnetic field sensor Ref value	$V_{ref} = (5\times x)/4096$ Ref (V_{ref})value uses for calculate parameter of magnetic field sensor
	$N_3N_2N_1N_0$	4	Magnetic field sensor Y axis	$(5\times x)/4096 - V_{ref}$ [gauss]
	$O_3O_2O_1O_0$	4	Magnetic field sensor X axis	$(5\times x)/4096 - V_{ref}$ [gauss]
	$P_3P_2P_1P_0$	4	Magnetic field sensor Z axis	$(5\times x)/4096 - V_{ref}$ [gauss]
	$Q_3Q_2Q_1Q_0$	4	Gyro sensor Y axis	$((5\times x)/4096 - 2.4824)/1.1288$ [rad/s]
	$R_3R_2R_1R_0$	4	Gyro sensor X axis	$-((5\times x)/4096 - 2.4913)/1.1309$ [rad/s]
	$S_3S_2S_1S_0$	4	Gyro sensor Z axis	$((5\times x)/4096 - 2.4752)/1.1199$ [rad/s]
	$T_3T_2T_1T_0$	4	No-Data	-
	$U_3U_2U_1U_0$	4	Sun sensor 1 +X	$(5\times x)/4096$ [V]
	$V_3V_2V_1V_0$	4	Sun sensor 1 −X	$(5\times x)/4096$ [V]
	$W_3W_2W_1W_0$	4	Sun sensor 1 +Y	$(5\times x)/4096$ [V]
	$X_3X_2X_1X_0$	4	Sun sensor 1 −Y	$(5\times x)/4096$ [V]
	$Y_3Y_2Y_1Y_0$	4	Sun sensor 2 +X	$(5\times x)/4096$ [V]
	$Z_3Z_2Z_1Z_0$	4	Sun sensor 2 −X	$(5\times x)/4096$ [V]
	$\alpha_3\alpha_2\alpha_1\alpha_0$	4	Sun sensor 2 +Y	$(5\times x)/4096$ [V]
	$\beta_3\beta_2\beta_1\beta_0$	4	Sun sensor 2 −Y	$(5\times x)/4096$ [V]
	$\gamma_3\gamma_2\gamma_1\gamma_0$	4	Sun sensor 4 −Y	$(5\times x)/4096$ [V]
	$\delta_3\delta_2\delta_1\delta_0$	4	Sun sensor 4 +Y	$(5\times x)/4096$ [V]
	$\varepsilon_3\varepsilon_2\varepsilon_1\varepsilon_0$	4	Sun sensor 4 −X	$(5\times x)/4096$ [V]
	$\zeta_3\zeta_2\zeta_1\zeta_0$	4	Sun sensor 4 +X	$(5\times x)/4096$ [V]
	$\eta_3\eta_2\eta_1\eta_0$	4	Sun sensor 3 −Y	$(5\times x)/4096$ [V]
	$\theta_3\theta_2\theta_1\theta_0$	4	Sun sensor 3 +Y	$(5\times x)/4096$ [V]
	$\iota_3\iota_2\iota_1\iota_0$	4	Sun sensor 3 −X	$(5\times x)/4096$ [V]
	$\kappa_3\kappa_2\kappa_1\kappa_0$	4	Sun sensor 3 +X	$(5\times x)/4096$ [V]
	$\lambda_3\lambda_2\lambda_1\lambda_0$	4	Sun sensor 6 −Y	$(5\times x)/4096$ [V]
	$\mu_3\mu_2\mu_1\mu_0$	4	Sun sensor 6 +Y	$(5\times x)/4096$ [V]
	$\nu_3\nu_2\nu_1\nu_0$	4	Sun sensor 6 −X	$(5\times x)/4096$ [V]
	$\xi_3\xi_2\xi_1\xi_0$	4	Sun sensor 6 +X	$(5\times x)/4096$ [V]
	$o_3o_2o_1o_0$	4	Sun sensor 5 −Y	$(5\times x)/4096$ [V]
	$\pi_3\pi_2\pi_1\pi_0$	4	Sun sensor 5 +Y	$(5\times x)/4096$ [V]
	$\rho_3\rho_2\rho_1\rho_0$	4	Sun sensor 5 −X	$(5\times x)/4096$ [V]
	$\sigma_3\sigma_2\sigma_1\sigma_0$	4	Sun sensor 5 +X	$(5\times x)/4096$ [V]
STA	$\tau_1\tau_0$	2	Shunt 1 ON/OFF	Use T_0 Number τ_0 = 0x0 : shunt 1 OFF τ_0 = 0x1 : shunt 1 ON
	$\upsilon_1\upsilon_0$	2	Shunt 2 ON/OFF	Use U_0 number υ_0 = 0x0 : shunt 2 OFF υ_0 = 0x1 : shunt 2 ON
	$\varphi_1\varphi_0$	2	ADC Activation	Use Φ_0 number φ_0 = 0x0 : ADC Stop φ_0 = 0x1 : ADCacitivate

Group	data	Word(s)	Mean	Calculation
STA	$\chi_1\chi_0$	2	CAM1,2 Activation	Use χ_1 number χ_0 = 0x0 : CAM1,2Stop χ_0 = 0x1 : CAM1,2acitivate
	$\psi_1\psi_0$	2	CAM3 Activation	Use Ψ_0 number. ψ_0 = 0x0 : CAM3Stop ψ_0 = 0x1 : CAM3acitivate
TIM	$\omega_7\omega_6\omega_5\omega_4\omega_3\omega_2\omega_1\omega_0$	8	Satellite time	$(\omega_7\times16^7+\omega_6\times16^6+\omega_5\times16^5$ $+\omega_4\times16^4+\omega_3\times16^3+\omega_2\times16^2$ $+\omega_1\times16^1+\omega_0\times16^0)/10$ [s]
RES	$A_{23}A_{22}A_{21}A_{20}A_{19}A_{18}$ $A_{17}A_{16}A_{15}A_{14}A_{13}A_{12}$ $A_{11}A_{10}A_9A_8A_7A_6A_5A_4$ $A_3A_2A_1A_0$	2 4	Rest time	$A_{23}\times16^1+A_{22}\times16^0$= RTC time(s) $A_{21}\times16^1+A_{20}\times16^0$= FMR1 time(s) $A_{19}\times16^1+A_{18}\times16^0$= FMR2 time(s) $A_{17}\times16^1+A_{16}\times16^0$= EPS time(s) $A_{15}\times16^1+A_{14}\times16^0$= CW time(s) $A_{13}\times16^1+A_{12}\times16^0$= CDH1 time(s) $A_{11}\times16^1+A_{10}\times16^0$= CDH2 time(s) $A_9\times16^1+A_8\times16^0$ = INF time(s) $A_7\times16^1+A_6\times16^0$ = ADC time(s) $A_5\times16^1+A_4\times16^0$ = CAM1 time(s) $A_3\times16^1+A_2\times16^0$ = CAM2 time(s) $A_1\times16^1+A_0\times16^0$ = CAM3 time(s)

4. CDH1 Sensing Data

JQ1ZJQ>SPROUT: DBN Data 0x0D

Callsign / Satellite name / Data Block Number / Carriage return

CDH1 sensing data group	
DBN	Data Block Number
HKD	Housekeeping Data Group

The calculation process of DBN(Data Block Number) shows to chapter 2.1. This data formed hex number.

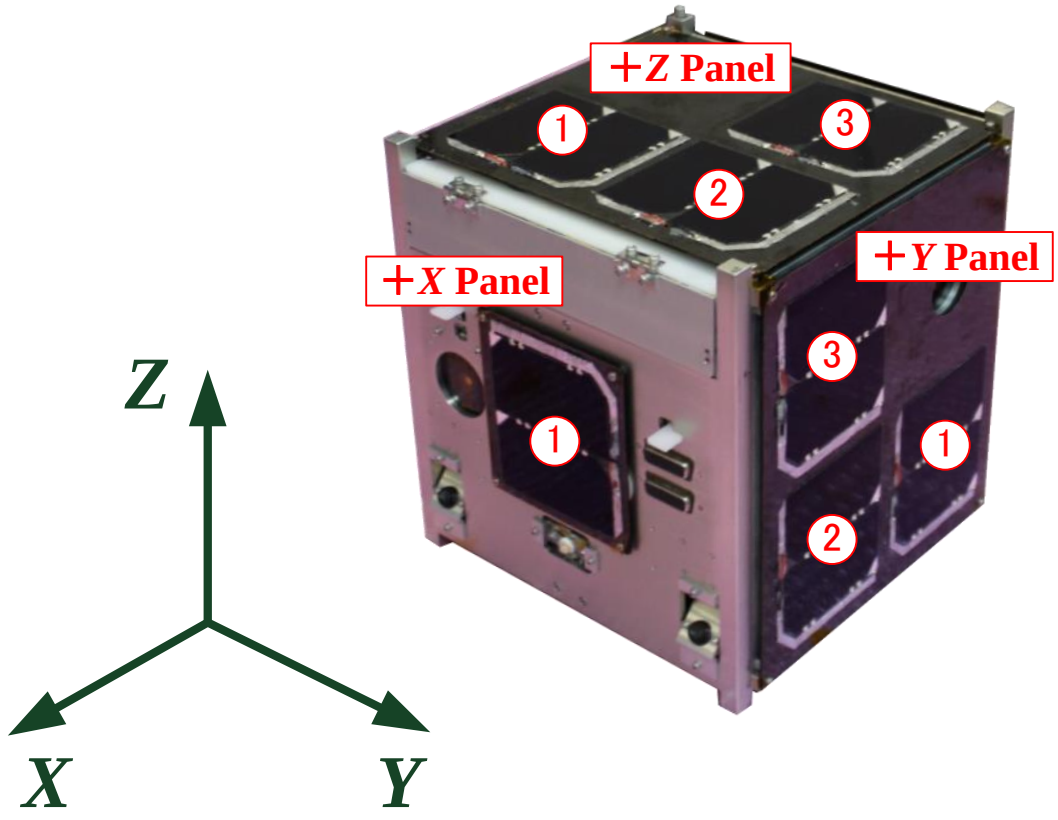
Data group (320 words)
$0_3 0_2$ $0_1 0_0$ $1_3 1_2$ $1_1 1_0$ $2_3 2_2$ $2_1 2_0$ $3_3 3_2$ $3_1 3_0$ $4_3 4_2$ $4_1 4_0$ $5_3 5_2$ $5_1 5_0$ $6_3 6_2$ $6_1 6_0$ $7_3 7_2$ $7_1 7_0$ $8_3 8_2$ $8_1 8_0$ $9_3 9_2$ $9_1 9_0$ $a_3 a_2$ $a_1 a_0$ $b_3 b_2$ $b_1 b_0$ $c_3 c_2$ $c_1 c_0$ $d_3 d_2$ $d_1 d_0$ $e_3 e_2$ $e_1 e_0$ $f_3 f_2$ $f_1 f_0$ $g_3 g_2$ $g_1 g_0$ $h_3 h_2$ $h_1 h_0$ $i_3 i_2$ $i_1 i_0$ $j_3 j_2$ $j_1 j_0$ $k_3 k_2$ $k_1 k_0$ $l_3 l_2$ $l_1 l_0$ $m_3 m_2$ $m_1 m_0$ $n_3 n_2$ $n_1 n_0$ $o_3 o_2$ $o_1 o_0$ $p_3 p_2$ $p_1 p_0$ $q_3 q_2$ $q_1 q_0$ $r_3 r_2$ $r_1 r_0$ $s_3 s_2$ $s_1 s_0$ $t_3 t_2$ $t_1 t_0$ $u_3 u_2$ $u_1 u_0$ $v_3 v_2$ $v_1 v_0$ $w_3 w_2$ $w_1 w_0$ $x_3 x_2$ $x_1 x_0$ $y_3 y_2$ $y_1 y_0$ $z_3 z_2$ $z_1 z_0$ $A_3 A_2$ $A_1 A_0$ $B_3 B_2$ $B_1 B_0$ $C_3 C_2$ $C_1 C_0$ $D_3 D_2$ $D_1 D_0$ $E_3 E_2$ $E_1 E_0$ $F_3 F_2$ $F_1 F_0$ $G_3 G_2$ $G_1 G_0$ $H_3 H_2$ $H_1 H_0$ $I_3 I_2$ $I_1 I_0$ $J_3 J_2$ $J_1 J_0$ $K_3 K_2$ $K_1 K_0$ $L_3 L_2$ $L_1 L_0$ $M_3 M_2$ $M_1 M_0$ $N_3 N_2$ $N_1 N_0$ $O_3 O_2$ $O_1 O_0$ $P_3 P_2$ $P_1 P_0$ $Q_3 Q_2$ $Q_1 Q_0$ $R_3 R_2$ $R_1 R_0$ $S_3 S_2$ $S_1 S_0$ $T_3 T_2$ $T_1 T_0$ $U_3 U_2$ $U_1 U_0$ $V_3 V_2$ $V_1 V_0$ $W_3 W_2$ $W_1 W_0$ $X_3 X_2$ $X_1 X_0$ $Y_3 Y_2$ $Y_1 Y_0$ $Z_3 Z_2$ $Z_1 Z_0$ $\alpha_3 \alpha_2$ $\alpha_1 \alpha_0$ $\beta_3 \beta_2$ $\beta_1 \beta_0$ $\gamma_3 \gamma_2$ $\gamma_1 \gamma_0$ $\delta_3 \delta_2$ $\delta_1 \delta_0$ $\varepsilon_3 \varepsilon_2$ $\varepsilon_1 \varepsilon_0$ $\zeta_3 \zeta_2$ $\zeta_1 \zeta_0$ $\eta_3 \eta_2$ $\eta_1 \eta_0$ $\theta_3 \theta_2 \theta_1 \theta_0$ $\iota_3 \iota_2$ $\iota_1 \iota_0$ $\kappa_3 \kappa_2$ $\kappa_1 \kappa_0$ $\lambda_3 \lambda_2$ $\lambda_1 \lambda_0$ $\mu_3 \mu_2$ $\mu_1 \mu_0$ $\nu_3 \nu_2$ $\nu_1 \nu_0$ $\xi_3 \xi_2$ $\xi_1 \xi_0$ $o_3 o_2$ $o_1 o_0$ $\pi_3 \pi_2$ $\pi_1 \pi_0$ $\rho_3 \rho_2$ $\rho_1 \rho_0$ $\sigma_3 \sigma_2$ $\sigma_1 \sigma_0$

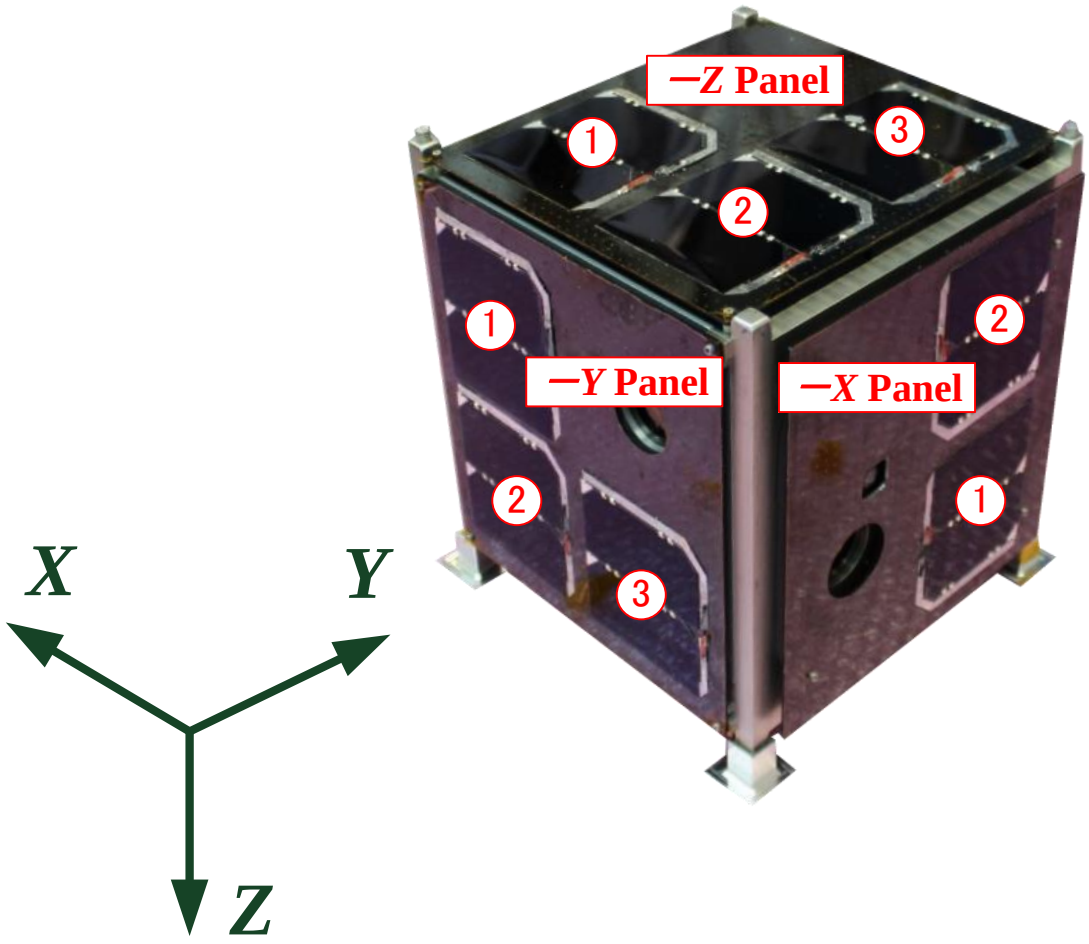
CDH1 Sensing FM packet structure (total 320 words)				
Group	**data**	**Word(s)**	**Mean**	**Calculation**
HKD	$0_3 0_2 0_1 0_0$	4	+X Solar Cell 1 generation	$(5 \times x)/(4096\times9)$ [A]
	$1_3 1_2 1_1 1_0$	4	−X Solar Cell 1 generation	$(5 \times x)/(4096\times9)$ [A]
	$2_3 2_2 2_1 2_0$	4	−X Solar Cell 2 generation	$(5 \times x)/(4096\times9)$ [A]
	$3_3 3_2 3_1 3_0$	4	−Y Solar Cell 1 generation	$(5 \times x)/(4096\times9)$ [A]
	$4_3 4_2 4_1 4_0$	4	−Y Solar Cell 2 generation	$(5 \times x)/(4096\times9)$ [A]
	$5_3 5_2 5_1 5_0$	4	−Y Solar Cell 3 generation	$(5 \times x)/(4096\times9)$ [A]
	$6_3 6_2 6_1 6_0$	4	+Y Solar Cell 1 generation	$(5 \times x)/(4096\times9)$ [A]
	$7_3 7_2 7_1 7_0$	4	+Y Solar Cell 2 generation	$(5 \times x)/(4096\times9)$ [A]
	$8_3 8_2 8_1 8_0$	4	+Y Solar Cell 3 generation	$(5 \times x)/(4096\times9)$ [A]
	$9_3 9_2 9_1 9_0$	4	+Z Solar Cell 1 generation	$(5 \times x)/(4096\times9)$ [A]
	$a_3 a_2 a_1 a_0$	4	+Z Solar Cell 2 generation	$(5 \times x)/(4096\times9)$ [A]
	$b_3 b_2 b_1 b_0$	4	+Z Solar Cell 3 generation	$(5 \times x)/(4096\times9)$ [A]
	$c_3 c_2 c_1 c_0$	4	−Z Solar Cell 1 generation	$(5 \times x)/(4096\times9)$ [A]
	$d_3 d_2 d_1 d_0$	4	−Z Solar Cell 2 generation	$(5 \times x)/(4096\times9)$ [A]
	$e_3 e_2 e_1 e_0$	4	−Z Solar Cell 3 generation	$(5 \times x)/(4096\times9)$ [A]
	$f_3 f_2 f_1 f_0$	4	Bus current	$(5 \times x)/(4096\times0.5)$ [A]

Group	data	Word(s)	Mean	Calculation
HKD	$g_3g_2g_1g_0$	4	Bus voltage	$(5 \times x)/4096$ [V]
	$h_3h_2h_1h_0$	4	Temperature（Satellite surface +X Panel)	$0.282\times((5 \times x)/4096)^2 - 38.98\times(5 \times x)/4096 + 101.68$[deg. C]
	$i_3i_2i_1i_0$	4	Temperature（Satellite surface +Y Panel)	$0.5777\times((5 \times x)/4096)^2 - 40.453\times(5 \times x)/4096 + 99.226$[deg. C]
	$j_3j_2j_1j_0$	4	Temperature（Satellite surface +Z Panel)	$0.6493\times((5 \times x)/4096)^2 - 39.896\times(5 \times x)/4096 + 98.469$[deg. C]
	$k_3k_2k_1k_0$	4	Temperature（Satellite surface −X Panel)	$0.4105\times((5 \times x)/4096)^2 - 39.074\times(5 \times x)/4096 + 97.993$[deg. C]
	$l_3l_2l_1l_0$	4	Temperature（Satellite surface −Y Panel)	$0.4383\times((5 \times x)/4096)^2 - 40.076\times(5 \times x)/4096 + 98.771$[deg. C]
	$m_3m_2m_1m_0$	4	Temperature（Satellite surface −Z Panel)	$0.2982\times((5 \times x)/4096)^2 - 38.98\times(5 \times x)/4096 + 99.769$[deg. C]
	$n_3n_2n_1n_0$	4	Temperature (Battery 2)	$0.4342\times((5 \times x)/4096)^2 - 41.236\times(5 \times x)/4096 + 103.46$[deg. C]
	$o_3o_2o_1o_0$	4	Temperature (Battery 1)	$0.3995\times((5 \times x)/4096)^2 - 40.088\times(5 \times x)/4096 + 100.84$[deg. C]
	$p_3p_2p_1p_0$	4	Temperature (Reciver2)	$0.3285\times((5 \times x)/4096)^2 - 39.376\times(5 \times x)/4096 + 98.91$[deg. C]
	$q_3q_2q_1q_0$	4	Temperature (Trensmitter2)	$0.2311\times((5 \times x)/4096)^2 - 38.955\times(5 \times x)/4096 + 100.19$[deg. C]
	$r_3r_2r_1r_0$	4	Temperature (Reciver 1)	$0.3281\times((5 \times x)/4096)^2 - 39.035\times(5 \times x)/4096 + 97.608$[deg. C]
	$s_3s_2s_1s_0$	4	Temperature (Transmitter 1)	$0.2946\times((5 \times x)/4096)^2 - 39.537\times(5 \times x)/4096 + 99.7$[deg. C]
	$t_3t_2t_1t_0$	4	Temperature (Gyro sensor Y axis)	$2.1507\times((5 \times x)/4096)^2 - 46.004\times(5 \times x)/4096 + 106.55$[deg. C]
	$u_3u_2u_1u_0$	4	Temperature (Gyro sensor X axis)	$0.7854\times((5 \times x)/4096)^2 - 41.015\times(5 \times x)/4096 + 100.05$[deg. C]
	$v_3v_2v_1v_0$	4	Temperature (Gyro sensor Z axis)	$0.9648\times((5 \times x)/4096)^2 - 39.886\times(5 \times x)/4096 + 108.37$[deg. C]
	$w_3w_2w_1w_0$	4	Temperature（Magnetic field sensor)	$0.0728\times((5 \times x)/4096)^2 - 36.191\times(5 \times x)/4096 + 95.367$[deg. C]
	$x_3x_2x_1x_0$	4	Temperature（Magnetic valve 1)	$0.1777\times((5 \times x)/4096)^2 - 38.862\times(5 \times x)/4096 + 98.819$[deg. C]
	$y_3y_2y_1y_0$	4	Temperature (storage box top)	$0.7649\times((5 \times x)/4096)^2 - 41.38\times(5 \times x)/4096 + 101.98$[deg. C]
	$z_3z_2z_1z_0$	4	Temperature (ADC board)	$0.2936\times((5 \times x)/4096)^2 - 39.207\times(5 \times x)/4096 + 99.713$[deg. C]
	$A_3A_2A_1A_0$	4	Temperature (EPS board)	$0.3051\times((5 \times x)/4096)^2 - 39.009\times(5 \times x)/4096 + 99.257$[deg. C]
	$B_3B_2B_1B_0$	4	Temperature (CDH1 board)	$0.3241\times((5 \times x)/4096)^2 - 39.444\times(5 \times x)/4096 + 100.56$[deg. C]
	$C_3C_2C_1C_0$	4	Temperature (CAM3 board)	$0.3862\times((5 \times x)/4096)^2 - 39.157\times(5 \times x)/4096 + 100.05$[deg. C]
	$D_3D_2D_1D_0$	4	Temperature (FMR1 board)	$0.3366\times((5 \times x)/4096)^2 - 39.025\times(5 \times x)/4096 + 98.665$[deg. C]
	$E_3E_2E_1E_0$	4	Temperature（bottom of membrane)	$0.0832\times((5 \times x)/4096)^2 - 38.109\times(5 \times x)/4096 + 96.654$[deg. C]
	$F_3F_2F_1F_0$	4	Temperature (InflatableTube 1)	$0.1625\times((5 \times x)/4096)^2 - 38.356\times(5 \times x)/4096 + 98.533$[deg. C]
	$G_3G_2G_1G_0$	4	Temperature (InflatableTube2)	$0.0357\times((5 \times x)/4096)^2 - 37.908\times(5 \times x)/4096 + 98.005$[deg. C]
	$H_3H_2H_1H_0$	4	Temperatue (Inside pipe)	$0.3021\times((5 \times x)/4096)^2 - 39.42\times(5 \times x)/4096 + 98.922$[deg. C]

Group	data	Word(s)	Mean	Calculation
HKD	$I_3I_2I_1I_0$	4	Temperature (Inside storage box)	$-0.0318\times((5 \times x)/4096)^2$ $-37.221\times(5 \times x)/4096+98.686$[deg. C]
	$J_3J_2J_1J_0$	4	Pressure sensor Primary pressure	$(20689.66 \times x)/4096$ [kPa]
	$K_3K_2K_1K_0$	4	Pressure sensor Secondly pressure	$(206.90 \times x)/4096$ [kPa]
	$L_3L_2L_1L_0$	4	No-Data	–
	$M_3M_2M_1M_0$	4	Magnetic field sensor Ref value	$V_{ref} = (5 \times x)/4096$ Ref (V_{ref})value uses for calculate parameter of magnetic field sensor
	$N_3N_2N_1N_0$	4	Magnetic field sensor Y axis	$(5 \times x)/4096 - V_{ref}$ [gauss]
	$O_3O_2O_1O_0$	4	Magnetic field sensor X axis	$(5 \times x)/4096 - V_{ref}$ [gauss]
	$P_3P_2P_1P_0$	4	Magnetic field sensor Z axis	$(5 \times x)/4096 - V_{ref}$ [gauss]
	$Q_3Q_2Q_1Q_0$	4	Gyro sensor Y axis	$((5 \times x)/4096 - 2.4824)/1.1288$ [rad/s]
	$R_3R_2R_1R_0$	4	Gyro sensor X axis	$-((5 \times x)/4096 - 2.4913)/1.1309$ [rad/s]
	$S_3S_2S_1S_0$	4	Gyro sensor Z axis	$((5 \times x)/4096 - 2.4752)/1.1199$ [rad/s]
	$T_3T_2T_1T_0$	4	Non-Data	–
	$U_3U_2U_1U_0$	4	Sun sensor 1 +X	$(5 \times x)/4096$ [V]
	$V_3V_2V_1V_0$	4	Sun sensor 1 −X	$(5 \times x)/4096$ [V]
	$W_3W_2W_1W_0$	4	Sun sensor 1 +Y	$(5 \times x)/4096$ [V]
	$X_3X_2X_1X_0$	4	Sun sensor 1 −Y	$(5 \times x)/4096$ [V]
	$Y_3Y_2Y_1Y_0$	4	Sun sensor 2 +X	$(5 \times x)/4096$ [V]
	$Z_3Z_2Z_1Z_0$	4	Sun sensor 2 −X	$(5 \times x)/4096$ [V]
	$\alpha_3\alpha_2\alpha_1\alpha_0$	4	Sun sensor 2 +Y	$(5 \times x)/4096$ [V]
	$\beta_3\beta_2\beta_1\beta_0$	4	Sun sensor 2 −Y	$(5 \times x)/4096$ [V]
	$\gamma_3\gamma_2\gamma_1\gamma_0$	4	Sun sensor 4 −Y	$(5 \times x)/4096$ [V]
	$\delta_3\delta_2\delta_1\delta_0$	4	Sun sensor 4 +Y	$(5 \times x)/4096$ [V]
	$\varepsilon_3\varepsilon_2\varepsilon_1\varepsilon_0$	4	Sun sensor 4 −X	$(5 \times x)/4096$ [V]
	$\zeta_3\zeta_2\zeta_1\zeta_0$	4	Sun sensor 4 +X	$(5 \times x)/4096$ [V]
	$\eta_3\eta_2\eta_1\eta_0$	4	Sun sensor 3 −Y	$(5 \times x)/4096$ [V]
	$\theta_3\theta_2\theta_1\theta_0$	4	Sun sensor 3 +Y	$(5 \times x)/4096$ [V]
	$\imath_3\imath_2\imath_1\imath_0$	4	Sun sensor 3 −X	$(5 \times x)/4096$ [V]
	$\kappa_3\kappa_2\kappa_1\kappa_0$	4	Sun sensor 3 +X	$(5 \times x)/4096$ [V]
	$\lambda_3\lambda_2\lambda_1\lambda_0$	4	Sun sensor 6 −Y	$(5 \times x)/4096$ [V]
	$\mu_3\mu_2\mu_1\mu_0$	4	Sun sensor 6 +Y	$(5 \times x)/4096$ [V]
	$\nu_3\nu_2\nu_1\nu_0$	4	Sun sensor 6 −X	$(5 \times x)/4096$ [V]
	$\xi_3\xi_2\xi_1\xi_0$	4	Sun sensor 6 +X	$(5 \times x)/4096$ [V]
	$o_3o_2o_1o_0$	4	Sun sensor 5 −Y	$(5 \times x)/4096$ [V]
	$\pi_3\pi_2\pi_1\pi_0$	4	Sun sensor 5 +Y	$(5 \times x)/4096$ [V]
	$\rho_3\rho_2\rho_1\rho_0$	4	Sun sensor 5 −X	$(5 \times x)/4096$ [V]
	$\sigma_3\sigma_2\sigma_1\sigma_0$	4	Sun sensor 5 +X	$(5 \times x)/4096$ [V]

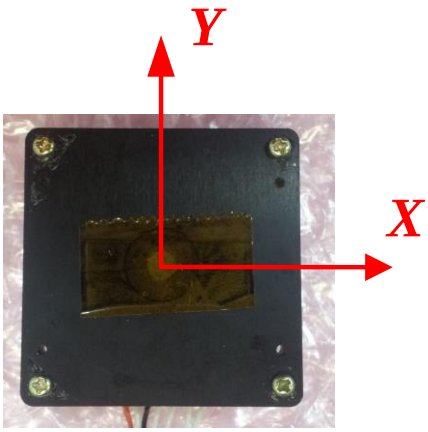
5. The Coordinate System of SPROUT and Solar Cell Number



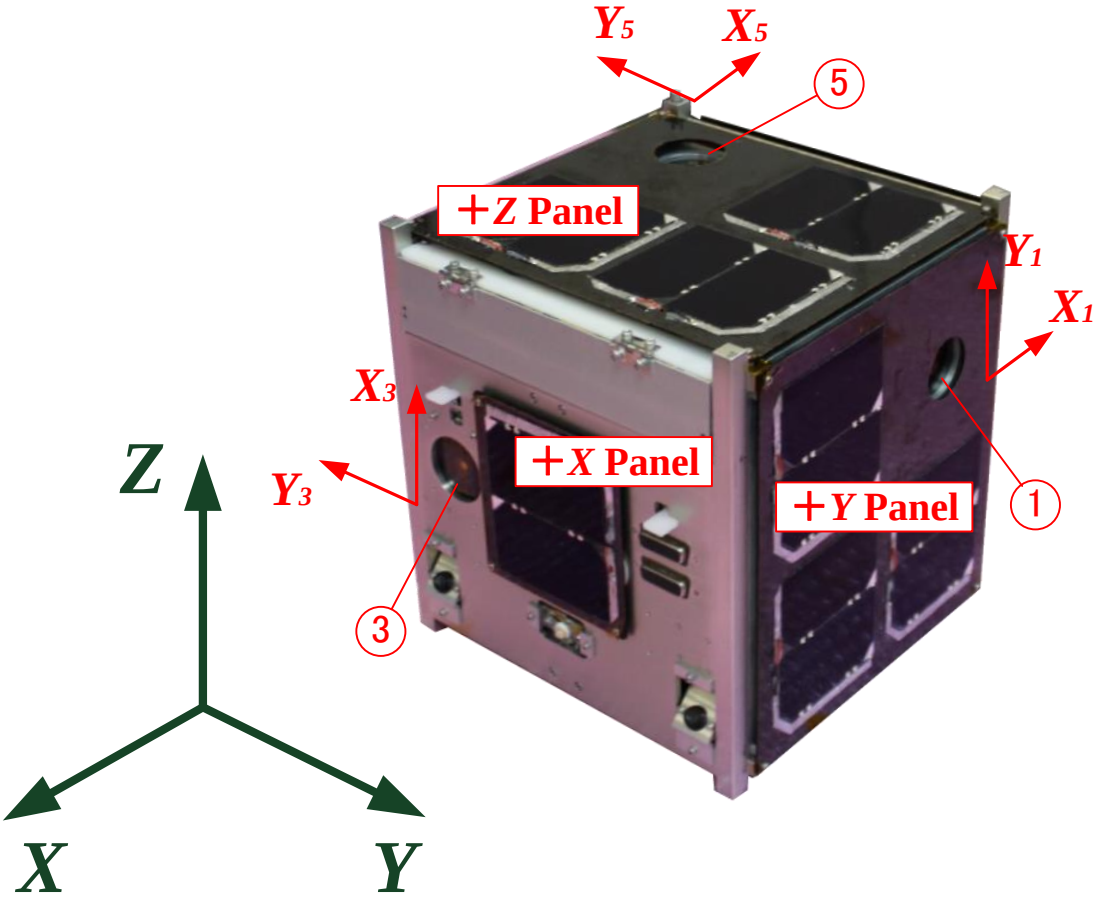


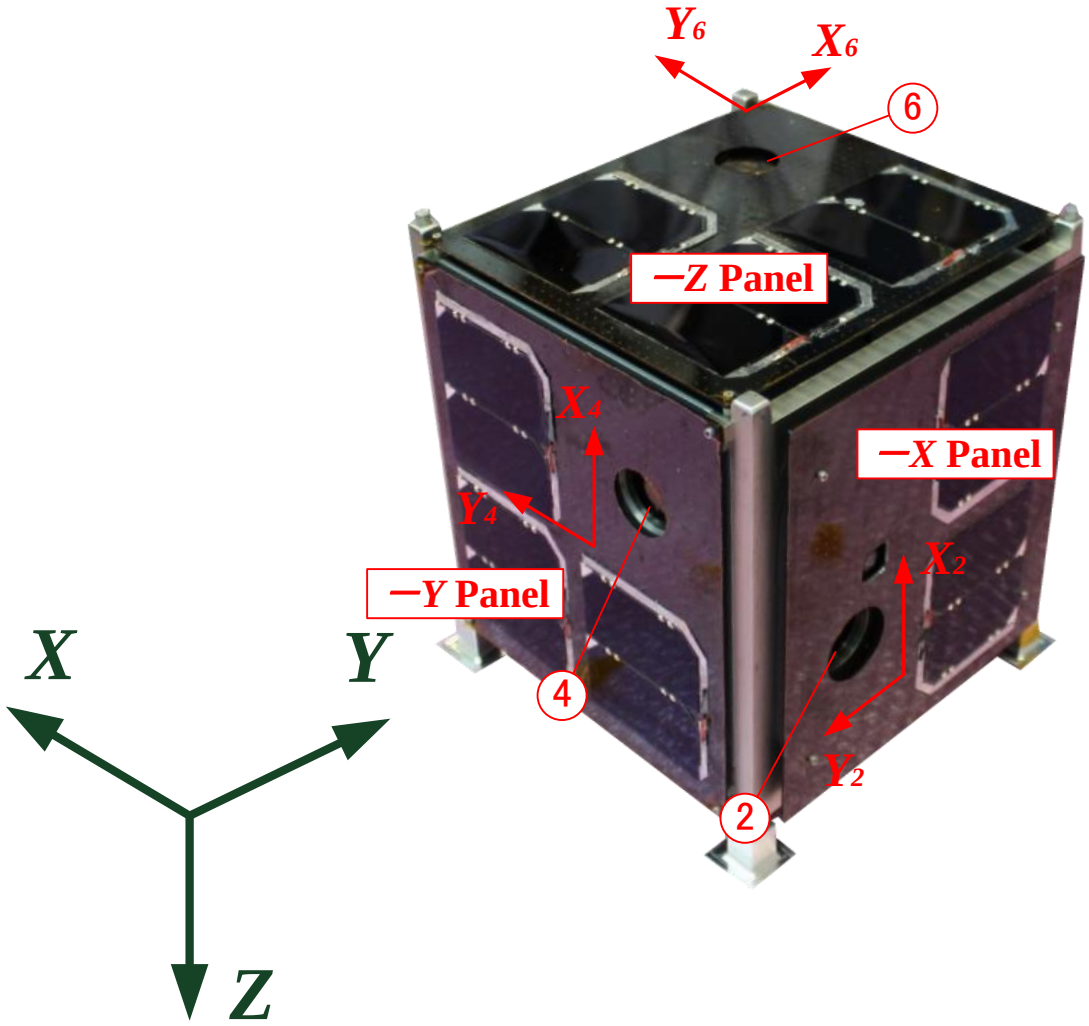
6. The Relationship between Coordinate System and Sun Sensor

The SPROUT has six sun sensors. And, each sensor keep coordinate system(shows below).



So it needs to know where the sun sensors are. This is the relationship between coordinate system and sun sensor.




Y6
X6
6
−Z Panel
X4
Y4
−X Panel
X2
−Y Panel
4
Y2
2
X
Y
Z

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