A UNIVERSITY PICO-SATELLITE PROGRAM: PACESAT

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ABSTRACT

PACEsat, the name abbreviated from Platform for Attitude Control Experiment, is featured with a three-axis stabilizing capability, developed at the National Cheng Kung University.[1] It is a 20x10x10 cm^3 double cube satellite, less than 2 kg in mass. A miniature momentum wheel is employed to achieve stability in the pitch (orbit normal) axis. Magnetic coils are employed to generate control torques to stabilize roll and yaw axes. When performing the three-axis stability control, these orthogonal coils will dump momentum to balance the miniature momentum wheel. The attitude sensors employed in the design include a three-axis magnetometer, a three-axis gyro, and coarse sun sensors. In addition, MEMS temperature sensors were employed as the secondary payloads for monitoring the thermal environment inside the satellite.

1. INTRODUCTION

The satellite was designed for a near-circular orbit 600km at inclination 98^o, with a life time 2 months. Figure 1 shows the hierarchy of the PACE project. A mission analysis suggested that the satellite be operated in three modes, namely, the stand-by mode, the 3-axis mode, and the safe mode. The mode transitions critically depend on the power and attitude of the satellite.

Figure 2 illustrates the relations between the three modes. In the standby mode, the magnetometer, coarse sun sensors, and magnetic coils are worked together, according to the B-dot control law to reduce the angular rate of the satellite and reach the Earth-pointing attitude roughly. Satellite can be set in this mode if the spacecraft angular rate is too high. The main purpose of this mode is to reduce the spacecraft angular rate to an acceptable level.

The 3-axis mode implies that the satellite is performing the attitude control experiment, which is enabled with a momentum wheel with rotation in the Y axis. The pitch momentum bias provides coupling for the roll-yaw (X-Z) systems. The estimated pitch control accuracy is up to ±2^o.

In the safe mode, minimum power consumption is ensured, such that the satellite can gain net energy and recover to the standby mode. Meanwhile, most of the subsystems will be shutdown for power saving. The on-board computer will keep monitoring the power status, while the on-board communication subsystem will transmit the state of health (SOH) data periodically to ground station. After the power level having reached a pre-set threshold value, the on-board computer will start up the system automatically and switch to standby mode. On the other hand, the satellite can be switched in this mode if the power level is low.

In addition to the momentum wheel as the main payload of the satellite, self-made MEMS temperature sensors and coarse sun sensors are employed as the secondary pay-loads. The characteristics of these sensors will be described in the full-length paper later.

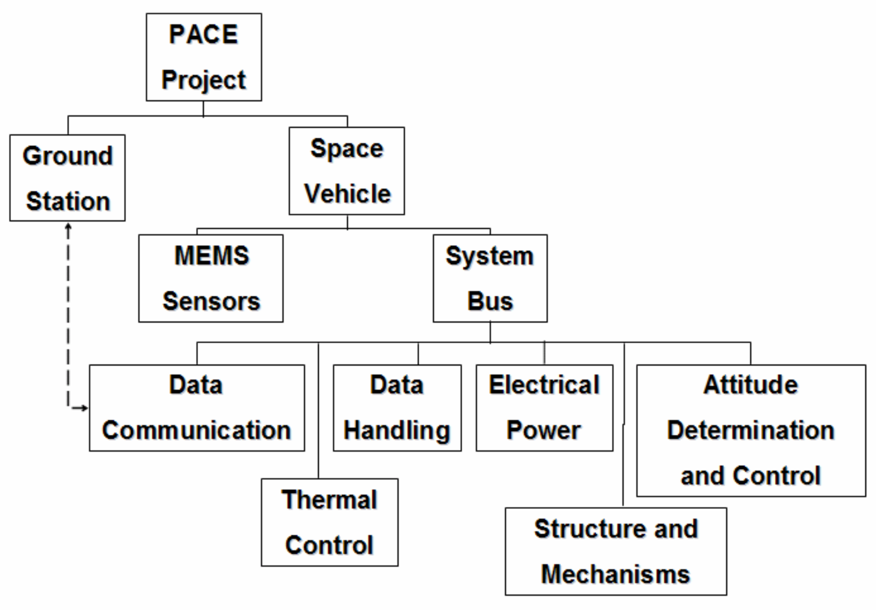

Fig.1 The hierarchy of the PACEsat project

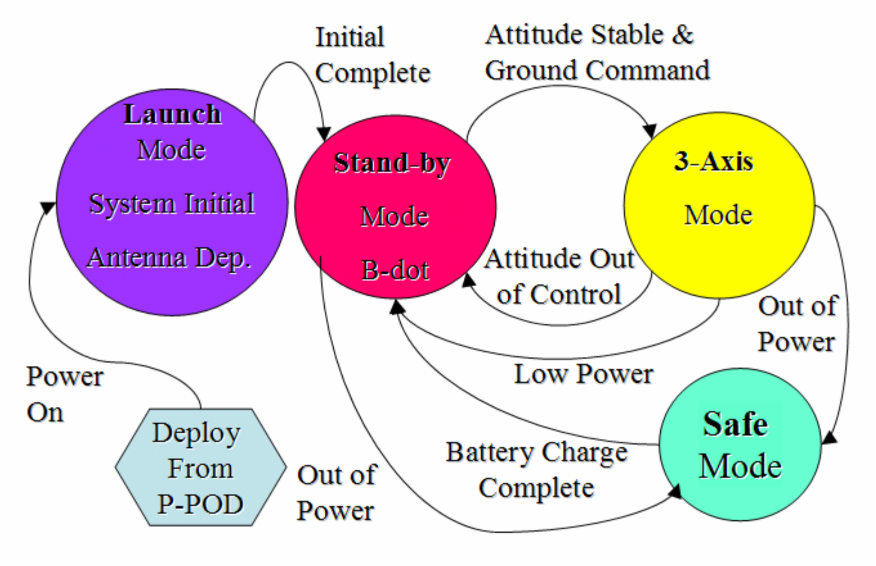

Fig.2 PACEsat operation modes

2. PACESAT OVERVIEW

An overview of the PACEsat subsystems is given below, with reference to Fig. 3 depicting the system design concept of the satellite.

2.1 C&DH Subsystem

In PACEsat, the command and data handling subsystem (C&DH) is functioned to perform data processing, computation, and satellite bus maintenance. It is featured with an enhanced 8051-class microprocessor, C8051F020, up to 25 MIPS. An external 64KB SRAM is provided for storing the SOH, MEMS sensors, and gyro data processed by the microprocessor.

2.2 TT&C Subsystem

The communication links between the satellite and a ground station rely on the telemetry, tracking and command (TT&C) subsystem, which was designed to transmit the data at a rate of 1200 bps. The format of telemetry data follows the AX.25 protocol. Besides, the subsystem provides a function of continuous wave (CW) transmission, which broadcasts the SOH data in the format of Moses code at constant time interval. This CW transmission is particularly useful when the spacecraft is in the safe mode.

2.3 TCS and SMS Subsystem

Due to the power and mass constraints, the thermal control subsystem (TCS) and structure mechanism subsystem (SMS) of the satellite were designed as simple as possible. To minimize power consumption, a passive thermal control by means of thermal insulation is adopted. On the other hand, a simple antenna deployment mechanism was designed by using a set of nickel-chromium resistor and a nylon wire. The structure and thermal control subsystems were analyzed and confirmed to meet the design requirements.

2.4 EPS Subsystem

The electrical power subsystem (EPS) is responsible for power generation, storage, regulation, and distribution. The power is acquired from 20 pieces of high efficient triple junction gallium arsenide (GaAs) solar cell mounted on the surface panels. The power then is converted to 5V first, in order to charge the Lithium-Ion batteries. A battery charger and a protector are used to prevent from overcharge of the battery. The power bus provides 5V and 12 V regulated source for component onboard. The power generation, consumption, and battery status are continuously monitored by the on-board computer. The information is important to power management and for the decision of mode switching.

2.5 ADCS Subsystem

The attitude determination and control subsystem (ADCS) is to ensure attitude acquisition, momentum dumping, stabilizing and pointing control. The subsystem receives the data from the on-board attitude sensors and, in turn, provides control commands to drive actuation devices. The ADCS subsystem includes a three-axis magnetometer, coarse sun sensors, three orthogonal magnetic coils, and a micro momentum wheel. The ADCS employs a momentum-biased attitude stabilization scheme, which has been widely used in the design of small satellites. As the rotation axis of the micro wheel is perpendicular to the orbit plane, the pitch axis stability can be achieved by controlling the wheel speed. The momentum bias provides couplings for the roll-yaw (X-Z) systems. Through magnetic coil control along the pitch (Y) axis, the precession and nutation along the roll-yaw system due to environmental torques can then be stabilized. Further, magnetic coils along the roll and yaw axes, respectively, are used to facilitate momentum dumping.

2.6 MEMS Payload

Although MEMS applications have been seen in the areas of photoelectric, biology and medicine to date, applications to the space technology are yet comparatively less. Since PACE employs a passive thermal control scheme, the thermal control design will be verified with the self-developed MEMS temperature sensors while the satellite is in flight. The sensors are placed at several locations in the satellite to monitor the temperature variations. Subsequently, safety measures could be taken if necessary. In addition, MEMS fabrication technology was employed to produce the coarse sun sensors, which are capable of providing the information necessary for attitude determination. There sensors are placed on the outside panels of PACE to obtain the information regarding the sun direction, based on the signals measured.

2.7 Ground Station

A ground station has been established at NCKU, which is capable of transceiving UHF, VHF, and HF signals. For PACEsat, the frequency145 MHz is selected for up and downlink communication.

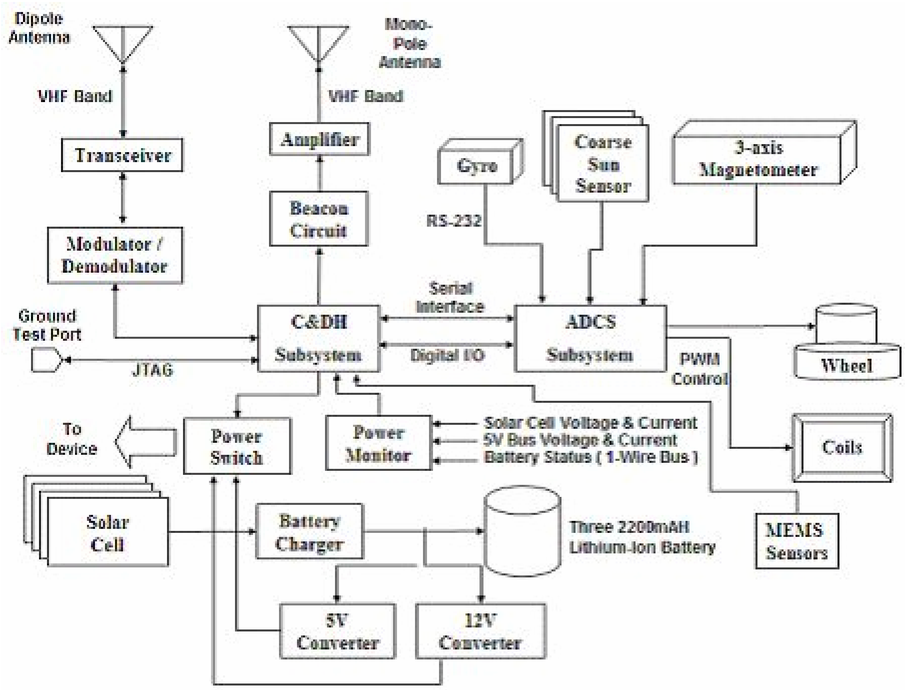

Fig. 3 System design concept of PACEsat

3. REFERENCES

[1] PACEsat, National Cheng Kung University, Tainan, Taiwan, Website: http://www.iaalab.ncku.edu.tw/pace/.