Overview of the LEAP: A University MicroSatellite Program at NCKU

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NCKU (National Cheng Kung University) Taiwan is designing a micro-satellite, the LEAP, standing for Low-frequency Earthquake Precursor, for earthquake precursor research. It is aimed to detect the ULF/ELF emission in space to confirm postulations on the correlation between the presence of ULF/ELF signals and earthquake activities so as to pave a way for earthquake detection. Taiwan is in the Earthquake hotspot region and has previously encountered several major earthquakes including the Chi-Chi (M=7.5) earthquake. Hence, research on earthquake precursor is an important issue in Taiwan. Among many earthquake detection/prediction approaches, the observation of ULF/ELF emissions resulting from tectonic activities stands as a novel one. Evidences of ULF/ELF anomalies in magnetic field has been observed before several major earthquakes including Loma Prieta earthquake, Guam earthquake, Biak earthquake, and Chi-Chi earthquake [4-5]. Although the low frequency geomagnetic signals can be detected on ground, as the wave would propagate through space, detecting such anomalies in space may provides further information for the verification of the earthquake research. Similar satellite missions such as DEMETER [6-7] satellite and QUAKESAT [8-9] satellite have also been designed to detect the ULF/ELF signals in space. The main significance of LEAP project lies in the ULF range signal which is lower than DEMETER (VLF) and QUAKESAT (ELF). The other significance for LEAP project is the close-to-the-equator orbit, providing an Earth magnetic filed observation rather than synchronized orbits of QUAKESAT and DEMETER. In addition, some in-situ analysis capability is built in the on-board digital processor of the LEAP to track the variation of ULF/ELF signal frequency. In addition to support Taiwan Earthquake research, the LEAP project intends to serve as a testbed by utilizing several subsystem/payload techniques developed and fabricated in Taiwan. These domestic components include GPS receiver software, MEMS-based digital sun sensor, a high frequency communication experiment payload.

LEAP satellite includes the satellite bus, payloads, and ground station. The satellite bus consists of six subsystems: power (EPS), structure (SMS), telecommunication (TT&C),

onboard computer (C&DH), thermal control (TCS) and attitude control (ADCS). The satellite payload includes a ULF payload for earthquake precursor research, a GPS payload experiment, a DSS (Digital Sun Sensor) payload for attitude control usage and an ECP (Experiment of Communication Payload) for high frequency communication experiment. The LEAP primarily ground station is positioned at NCKU.

The LEAP satellite body is constructed using 7075 Aluminum. The satellite body dimension is 25cm in width, 25cm in length and 30cm in height. Above the top of satellite body, a cross shape tip is positioned. One cross wing is 25cm in length and 8cm in width. The other cross wing is 25cm in length and 6cm in width. The tip is 7 cm in height for both wings. The structure was designed to be a six faces body with deployable solar panels. Before launch, deployable solar panels will be folded and mounted on satellite body. The folded solar panels will be deployed after separation with launch vehicle provided that the rotation rate is within limit. There are two deployed solar panels onboard. The gravity gradient boom is designed to have 16 tubes with total deployed length 2.96 m. The material of the boom is Aluminum. LEAP ADCS control hardware adopted active control hardware and passive control hardware. The active control hardware is a set of three-axis magnetic coils, which are current-controlled to prevent the temperature fluctuation influence to wire coils. The passive control hardware is to adopt a gravity gradient boom. The ADCS determination is achieved by using a digital magnetometer, solar panel current detection, as well as aiding information from GPS and DSS payloads. LEAP ADCS is designed to have four modes: detumbling mode, normal mode, safety mode and flip recovery mode. In the detumbling mode, B-dot control law will be applied to reduce the angular velocities. ADCS will be switched into the normal mode after B-dot control is completed and adopt the passive control method, not performing active activity. It will be switched into the safety mode as the measured magnetic moment differences between two samplings is greater than 0.01Nm and B-dot control law will be applied again in the safety mode. LEAP EPS contains solar cells, batteries and distribution and regulation unit. Solar cells are designed to be positioned on satellite body five faces except that the bottom face is designed to put launch vehicle adaptor. Four faces of deployed solar panels are positioned full with solar cells. LEAP will use one hundred and four pieces of solar cells in total. Four Li-ion batteries are arranged into a battery module. Eight battery modules, thirty two batteries, will be positioned onboard the satellite. A COTS (commercial off-the-shelf) C&DH module is used in LEAP. Figure 8 shows the module with CPU, DIO, ADC, and DAC. The interface function test and coding format design had been completed.

Flight software includes mission/application subroutines, subsystem subroutines and payload subroutines. In the self-maintenance subroutine, it consists of hardware maintenance subroutine and software maintenance subroutine. Each subsystem and payload has its own subroutine in the flight software. LEAP TCS adopts NCKU self fabricated MEMS experiment as temperature sensors. Patch heaters are also used as active control devices. Sensors will be positioned on several components, which show the sensitivity to temperature fluctuations. Once the temperature drops down to a limit, the patch heater will be switched on. LEAP TT&C chose a COTS transceiver module. It operates at an amateur radio band 430MHz with a date rate 1200bps. It is designed to have two modes: contact mode and beacon mode. LEAP will send continuous beacon signals intending to reach the NCKU ASTRC ground station and for amateur radio users. It is going into contact mode when the satellite is in the pass with ground station. Downloaded data type and size are described in C&DH section. The uploaded data includes software remedy commands, synchronized time, two line element data and Almanac data for GPS payload.

The ULF (Ultra-Low Frequency payload) sensor is positioned in the tip of the gravity gradient boom. It is aimed to measure the earth magnetic field in ultra-low frequency range. It consists of a search coil, a calibration coil and an amplifier/filter circuit. The search coil is length 20 cm, diameter 5cm and weight 2kg with sampling rate 10Hz. It is aimed to measure the magnetic field in 0.03 to 3 Hz. The GPS receiver payload includes a processor, a RF board with RF/correlator IC, antenna, interface circuits, and GPS software. The software consists of orbit propagator, Kalman filter, tracking loop control, visibility computing, Ephemeris management, data demodulation and measurement processing. The payload produces position, velocity and time as output to C&DH. The NCKU LEAP team develops the first version of MEMS DSS, a space qualified 2-axis Digital Sun Sensor by using a COTS CMOS APS sensor. The payload includes an image sensor, an AD converter and a separate data processing unit to compute the sun vector, and to communicate with the C&HD. LEAP Satellite is going to implement an onboard 2.4GHz transmitter. It will be operated in the contact pass to download scientific data from other three payloads. The hardware of ECP part includes a transceiver module with four patch antennas. Payload patch antennas are dedicated to position on the bottom body face. It can be operated only when the satellite attitude is not in the flip.

Several innovations and progresses have been made in the LEAP project. The LEAP satellite is expected to have four payloads. The design and fabrication of these payloads are made primarily in Taiwan. To speed up the design of the satellite bus technology has inherited some features from the PACE satellite, another satellite project that has been conducted at National Cheng Kung University [1-3]. There are a significant portion of the satellite bus design that are unique to LEAP including boom deployment, standard circuit board form factor and interface, antenna design, control algorithm, operating sequence, and contingency plan. These features will be described in the paper.

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