From Hands-on Project Learning to an International Collaborated Satellite Research/Education Project

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Abstract *— In engineering education, the teaching and learning of hands-on experiences are deemed as essential. This is especially true for space education in which the notion of 3I principle which stands for international, intercultural, and interdisciplinary has been advocated. Ever since 2002, a pico-satellite system engineering has been offered by the National Cheng Kung University (NCKU) with two innovations in mind: one is to conduct the course teaching through the internet and the other is to facilitate the course through pico-satellite design and competition. The course is symbolized with several student projects in which students in group are required to perform concept and preliminary spacecraft system design. An outcome of the student project is the PACE (Platform for Attitude Control Experiment) satellite, which is a three-axis stabilizing pico-satellite. The experiences and confidence gained in the PACE project have served as a basis for an international joint collaboration in the development of the ESEMS (Experimental Scientific-Education Micro-Satellite). The ESEMS is a cooperated project between Taiwan and Russia in promoting space science research and education through the development, launch, and operation of a micro-satellite. The joint activity fulfills international, intercultural, and interdisciplinary principles. The project is international as universities in Taiwan including NCKU and National Central University and Moscow State University in Russia take part in this joint project. During the development process, teams from different countries are required to exchange engineering knowledge and to overcome cultural gap. The ESEMS (aka, Tatyana-2) has been successfully launched in 2009. In the paper, some space education and research activities at NCKU will be briefly reviewed. The collaboration of the Taiwanese team and Russian counterpart in the development of ESEMS will then be described. Some design and operation results of the ESEMS will also be discussed. This is followed by a section on the lesson learned on this joint activity.*

Index Terms *— Project based learning, space education, satellite, international collaboration.*

INTRODUCTION

The PACELAB in National Cheng Kung University (NCKU) of Taiwan has been established since 2003, in order to pursue the development of satellite components and systems. The team members are from the Department of Electrical Engineering, the Department of Astronautical and Aeronautical Engineering and international internship students. The laboratory was formed in order to provide the students with hands-on training for the design and development of space systems, and thus to enhance the education of the students to capable space system engineers. Up to present, several satellite projects have been carried out, including PACE, LEAP, CKUTEX and ESEMS. The team also received support from National Space Organization (NSPO) of Taiwan. The first satellite project, PACE, started in 2003. It is a two unit CubeSat. The main mission is to demonstrate the 3-axies attitude determination and control capability on such scale satellite. Two micro satellite projects supported by NSPO, LEAP and CKUTEX, are developed to establish the space engineering capability in university. In the end of 2005, NCKU, National Central University (NCU) in Taiwan and Moscow State University (MSU) in Russia initiated the collaboration on ESEMS satellite development. NCKU developed the payload, BCK, to demonstrate the capability on satellite on-board computer. ESEMS has been launched on Sep. 2009. The NCKU team also analyzed the telemetry data to understand the performance of ESEMS.

PACE, LEAP AND CKUTEX SATELLITE PROJECTS

PACE, stands for Platform for Attitude Control Experiment, is a 3-axis stable satellite. The dimensions of the satellite are 100x100x227 mm3 at a weight of less than 2 kilograms. It is designed to operate in orbit for a period of six

months. The orbit is a sun-synchronous with altitude at 600~800 km. PACE serves as a test-bed for the precise attitude control of nanosatellites as well as space system developed with COTS (commercial off-the-shelf) components. The attitude determination is within 1º accuracy and the three-axis attitude control is within 10º accuracy. In addition to the technical objectives, the PACE project is expected to provide valuable output in terms of satellite engineering knowledge, with the aim to establish a national center of excellence in NCKU for the development of small satellites. It is planned to launch in 2011.

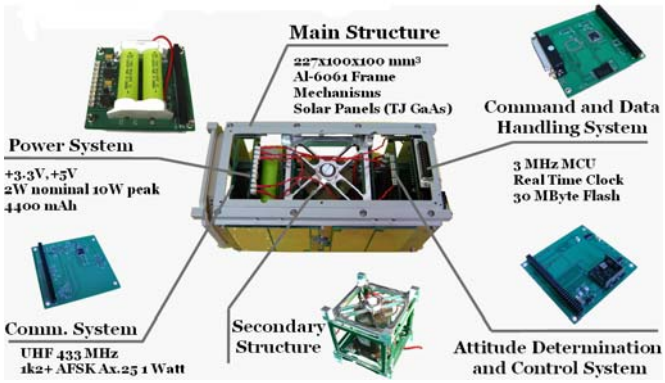

FIGURE 1
OVERVIEW OF PACE SATELLITE

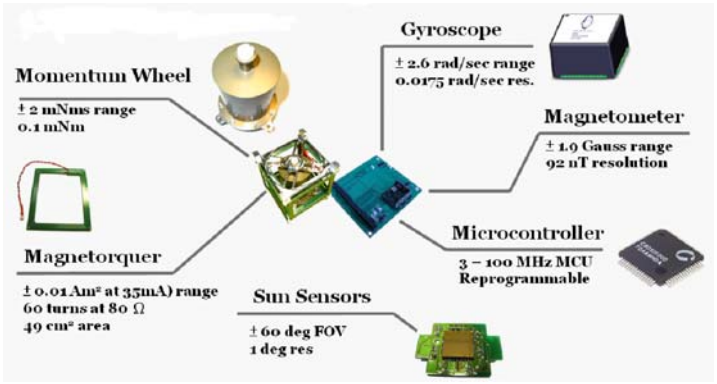

FIGURE 2
ADCS COMPONENTS OF PACE SATELLITE

The LEAP, standing for Low frequency EArthquake Precursor, satellite is developed for earthquake precursor research. It is aimed to detect the ULF emission in space to confirm postulations on the correlation between the presence of ELF/ULF signals and earthquake activities so as to pave a way for earthquake detection. Taiwan is in the earthquake hotspot region. Hence, research on earthquake precursor is an important issue in Taiwan. The main significance of LEAP project lies in the ULF range signal. The other significance for LEAP project is the close-to-the-equator orbit, providing an earth magnetic filed observation rather than sun-synchronous orbits. In addition, some capability is built in the on-board digital processor of the LEAP to track the variation of ELF/ULF 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. The LEAP project is conducted in the university with assistance from local industry and research institutions. The research fellows and students in the project have many opportunities to interact with engineers from national laboratory, domestic industry, and international companies. Several international internship students also join in the development. It provides the domestic students to cooperate with foreign students.

FIGURE 3
LEAP TEAM MEMBERS

The CKUTEX, stands for Cheng-Kung University Technology EXperimental Satellite, satellite is a micro satellite with 30 kg, and dimension 350×260×400 mm^3. It is the current project in PACELab. The main goal is to demonstrate university capability in micro-satellite development and establish a development platform for microsatellites in university. The technical objective is design and fabrication of an experimental satellite, integration and functional test of the experimental satellite and to obtain the satellite deployment and early orbit data using a microsatellite. CKUTEX has two payloads, GPSR and DSS. GPSR is a self-developed space-borne GPS receiver. The position accuracy is 50 m 2dRMS, and its velocity accuracy is 0.5 m/sec. DSS is a MEMS based digital sun sensor.

FIGURE 1
OVERVIEW OF PACE SATELLITE

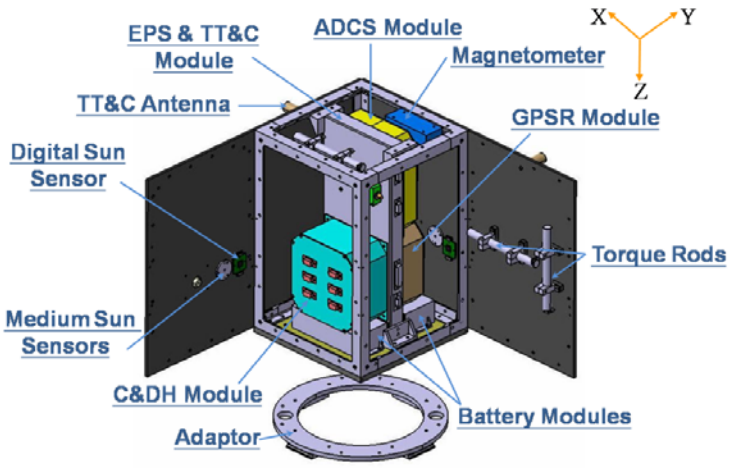

FIGURE 4
CKUTEX CONFIGURATION

ESEMS PROJECT

ESEMS (Experimental Scientific-Education Micro-Satellite) is a collaboration project by NCKU, NCU in Taiwan and MSU in Russia. It started in the end of 2005 and launched in Sep. 17th, 2009. It is supported by the National Science Council and National Space Organization. ESEMS is around 100kg and with 500*500*700 mm^3. NCKU is responsible of the contact window of Taiwan side, the hardware/software of on-board computer payload, CKB, and the secondary ground station. On-board computer is the core of a satellite. NCKU team developed CKB based on a PC-104 computer.

In order to cooperate with the Russian side, two identical development platforms are established at NCKU and Russian side. The CKB passed functional tests in the end of 2008 and environmental test in the early 2009. The test sequence of CKB and protocol become a valuable heritage of the NCKU team.

FIGURE 5
ESEMS IN FACTORY. THE YELLOW CIRCLE INDICATES THE LOCATION OF CKB

FIGURE 6
ESEMS SECONDARY GROUND STATION IN NCKU

After the launch, NCKU establishes the data base to distribute satellite data to related organizations. The flight data, including temperature, voltage, magnetic data and so on, are analyzed. The data from magnetometers are analyzed to reconstruct the track of ESEMS. The result is also compared with the official orbit parameter.

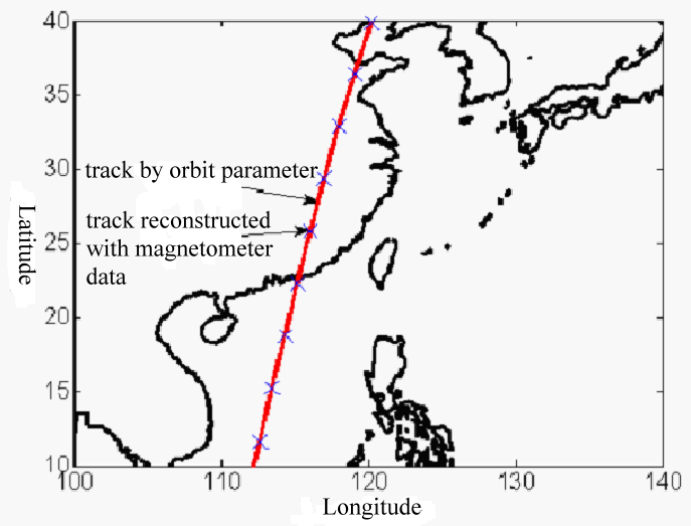

FIGURE 7
ESEMS TRAJECTORY RECONSTRUCTION

CONCLUSIONS

Through several satellite projects and international cooperation, the PACELab provides an opportunity for engineering students to take part in gaining teamwork spirits and hands on experiences. In the development, members from different technical background exchange engineering knowledge and overcome cultural gap. The international students in PACELab also bring different concept during the interaction. The joint activity fulfills international, intercultural, and interdisciplinary principles in engineering education.

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