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Star of AOXiang: An innovative 12U CubeSat to demonstrate polarized light navigation and microgravity measurement

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ABSTRACT

Most of the CubeSats have a volume range from 1U to 3U, which limits their applications due to the difficulty of miniaturizing payloads. To facilitate the needs on a larger but low-cost satellite platform, the AOXiang (AOX) project has been developed by Northwestern Polytechnical University (NPU). The primary objectives of AOX project are four-folds: 1) To demonstrate the world first 12U CubeSat Star of AOXiang and 12U orbit deployer which uses an innovative electromagnetic unlocking technology. 2) To investigate the feasibility of using polarized sunlight for spacecraft attitude determination and navigation, and perform microgravity research using a miniaturized gravimeter. 3) To test a fault tolerant on-board computer using the System On the Programmable Chip (SOPC) technology, and 4) To gain the experience from developing the CubeSat and the subsystems. The CubeSat was launched in June 2016. Now, the mission has achieved all the goals. This paper provides the detail information of the AOX project, with a focus on the introduction of the subsystems of the 12U CubeSat, the orbit deployer and the payloads. The recent in-orbit results of the first NPU are also presented. In addition to the educational objective that has been reached with more than 50 young scholars and students participated in the project.

1. Introduction

Since initiated in 1999 by Professor Jordi Puig-Suari of California Polytechnic State University and Professor Bob Twiggs of Stanford University, there has been more than 500 CubeSats launched by the end of 2016. The CubeSat missions include Earth observation, astronomy, communication, space environment study, basic research, technology demonstration, etc. The standard size of CubeSat is 100 mm × 100 mm × 100 mm (1U), having a mass of no more than 1.33 kg and typically using Commercial Off-The-Shelf (COTS) components for its electronics. Most of the CubeSats launched are 1U~3U (300 mm × 100 mm × 100 mm) [1]. In 2016 California Polytechnic State University released the 6U CubeSat Design Specification [2].

With the requirement of larger CubeSat platform, the 12U CubeSat steps into the people's horizon. The AOXiang (AOX, the meaning of AOXiang is soaring in Chinese) project is developed by the students and young scholars in Shaanxi Engineering Laboratory (SELM), Northwestern Polytechnical University (NPU). The AOX project developed a 12U CubeSat Star of AOXiang (SAOX), and a CubeSat ElectroMagnetic Unlocking POD (EMUPOD). The SAOX and EMUPOD are shown in Fig. 1. All the subsystems of AOX project are built in-house by SELM except for the communication system, solar panels, and attitude sensors. The key goals of AOX project are:

1. To design, build and test the world first 12U CubeSat platform and an electromagnetic unlocking orbit deployer.
2. To investigate the feasibility of using polarized sunlight for spacecraft attitude determination and do the microgravity research by using a miniaturized gravimeter.
3. To test a fault tolerant On-Board Computer (OBC) used System on the Programmable Chip (SOPC) technology.
4. To develop the most subsystems of the CubeSat in-house and get the experience.

SAOX carries three payloads. One payload is a Polarized Light Sensor (PLS) developed by SELM. Polarized sunlight has useful information for spacecraft attitude determination and navigation. PLS is used to collect the polarized sunlight data in lower earth orbit. SELM has done the research of PLS for years. The in orbit science data would accelerate the possible future application of polarization navigation [3]. Another payload is a gravimeter which comes from an open call for payload. It is built by another research team in NPU. The purpose is to

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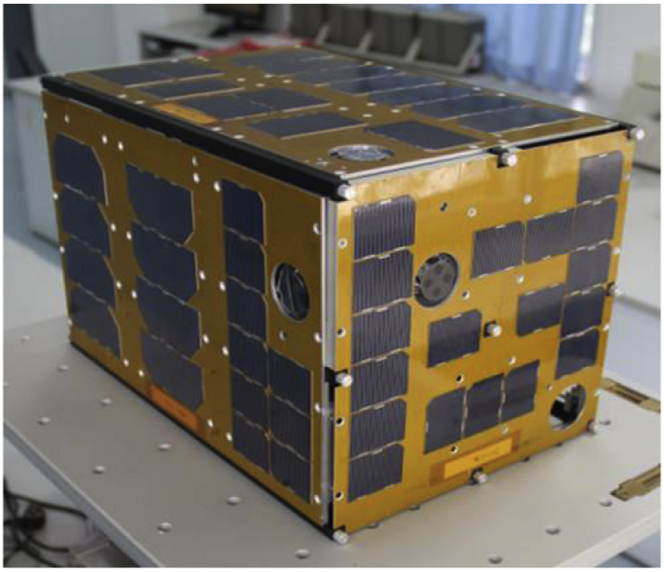

Fig. 1. SAOX 12U CubeSat and 12U EMUPOD.

measure the gravity field that contributes to seismic survey and forecast, oil and gas exploration, etc [4]. The other payload is a fault tolerant OBC built by SELM, which uses two kinds of Field Programmable Gate Arrays (FPGA) with embedded soft core processors.

2. The main timeline of AOX project

The project began in December 2013 and was launched in June 2016. The main timeline of the project is shown in Fig. 2.

- In December 2013, the proposal of AOX was selected by China Manned Space Engineering Office as as one of the payloads of LongMarch-7 (LM-7) maiden flight.
- In March 2014, an open call for the third payload of SAOX is released by SELM and the gravimeter is selected finally.
- In May 2014, SAOX passed the Preliminary Design Review (PDR).
- In February 2015, SAOX passed the Critical Design Review (CDR).
- In July 2015, SAOX passed the Assembly, Integration, and Test Readiness Review (AITRR).
- In February 2016, SAOX passed the Flight Readiness Review (FRR).
- On June 25th, 2016, SAOX was successfully sent to the orbit by LM-7 from Hainan Wenchang Space Launch Centre. This launch is the maiden flight of the LM-7 and also the first use of the new launch center.

3. 12U CubeSat design overview

SELM has developed the AOX CubeSat family. The first CubeSat project is AoXiang-1 (AX-1), which is accepted as one of the 50 CubeSats of European QB50 program in 2011 [5–8]. The main mission of AX-1 is the lower thermosphere research and will be launched in 2017 [5,9]. SAOX is the second CubeSat project, however, for the change of AX-1 launch time, SAOX become the first CubeSat of NPU. Fig. 3 shows the five main parts of SAOX. They are the structure and thermal system, the power system, the payloads, the OBC and the Attitude Determination and Control System (ADCS), and the Communication system. Table 1 lists all the subsystems of SAOX [10].

3.1. 12U CubeSat structure

CubeSat structure is used to mount the subsystems and the payloads. For there is no existing standard of 12U structure, the researchers in SELM built a 12U structure based on the CubeSat design specification (1~3U) by California Polytechnic State University [1]. The 12U structure is shown in Fig. 4. Table 2 gives the specifications of the structure.

The detail dimension of the structure is shown in Fig. 5. The material of the primary structure, rails and side panels is Aluminum 7075. There is a deployment switch on the standoff of a rail. The switch could cut off the power system before the separation of the CubeSat. After the CubeSat separated from the EMUPOD, the power system would be connected to other subsystems, and the OBC begin to operate. The 12U structure passed all the qualification and acceptance tests and showed good performance in orbit.

3.2. Thermal system

During the design of the CubeSat, many methods are used to minimize the power requirement of the subsystems. However, this brought another problem of the thermal control. The initial simulation showed that the CubeSat would suffer from lower temperature especially at the end of the eclipse.

The SAOX is not the first separation payload of LM7 launcher, the EMUPOD had to stay in the space for a long time. The POD would also possibly undertake the hot and cold situation. To control the temperature change, passive and active methods are introduced in the design of the thermal system. The passive method of thermal control: the Multi-Layered Insulation (MLI) is used for passive thermal control and made by Shanghai Institute of Ceramics (SIC). MLI is a kind of composite mostly used as thermal insulation of the spacecraft and propellant tank. SAOX and EMUPOD used a new kind of ten layers MLI which has low thermal conductivity (<0.001 W/m·K in the atmosphere) and low surface density. In a vacuum environment, its thermal insulation ability is much better than other material several orders of magnitude. Fig. 6 shows the MLI which is very easy to use scissors cut into various shapes. Fig. 7 simulates the temperature of EMUPOD after using

Fig. 2. The main timeline of SAOX.