PW-Sat3 - third iteration of CubeSats developed at Warsaw University of Technology. Mission definition and feasibility study process description.

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***Abstract*—This paper consists of the description of Students' Space Association activities, knowledge transfer process in PW-Sat, mission definition workshops and methods applied during feasibility study of PW-Sat3.**

Keywords—concurrent engineering, ECSS, mission definition, system description.

I. STUDENTS' SPACE ASSOCIATION INITIATIVE

Students' Space Association is placed at the Faculty of Power and Aeronautical Engineering, Warsaw University of Technology. It is the largest student organization at WUT, with approximately 110 active members. Education is its main goal. Organization consists of four main divisions: Rockets, Robotics, Balloons and PW-Sat. Students' Space Association members are also participating in different space projects, e.g. organized by ESA REXUS/BEXUS programme or IGLUNA programme organized by Swiss Space Center.

A. Satellite programme

PW-Sat is the most complex programme among all the Association activities. The first project started in 2005. After 7 years of development, with great help of Polish Space Research Centre, the satellite was launched to orbit onboard Vega rocket on its maiden flight on February 2012. PW-Sat was a 1U CubeSat - the first Polish satellite ever. Its main mission was to test a drag tail, made of flexible solar panels. Due to poor power budget at the early phase of the mission and problems with communication PW-Sat tail eventually was not deployed.

PW-Sat2 project started in January 2013. The team decided to continue with the deorbitation technology development. The final project experiments consisted of 4m2 deorbit sail , in-home built sun sensor, solar panels deployment system and two cameras to capture the sail deployment and confirm its proper functioning. PW-Sat2 was launched on SpaceX's Falcon 9 rocket on 3rd of December 2018. From the beginning the mission was going well. Main experiment - solar sail was deployed on 29th December 2018. After that time the team was expecting to observe lower power production and eventually even for satellite lost. However, it did not happen. After the sail deployment it was discovered, that the sail structure was torn. Currently, PW-Sat2 is still in orbit and communication is constantly sustained. The satellite is gradually lowering its orbit. More information about PW-Sat2 project can be found at https://pw-sat.pl/en/home-page/. In October 2018 the team started to develop PW-Sat3 satellite, which is widely described in next chapter of this paper.

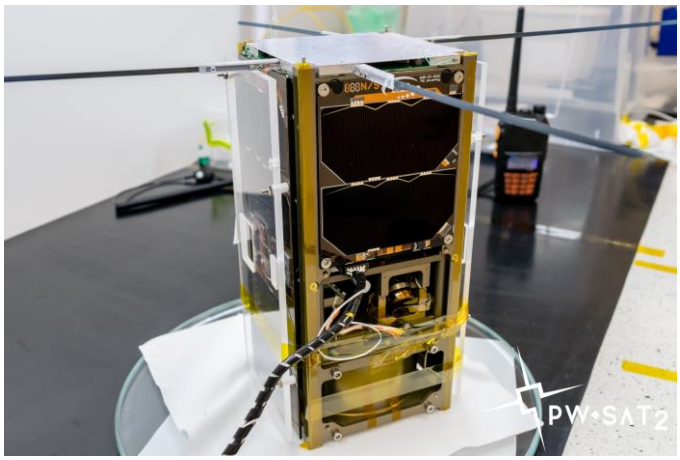

Fig. 1. PW-Sat2 during the final assembly.

B. Transfer of knowledge

In all Students' Space Association activities internal transfer of knowledge plays a major role for organization development and allow its divisions to build more and more complex projects.

Every year approximately 50 students who successfully finished their recruitment projects join the Association. Usually their first duty is to attend lectures conducted by experienced members and learn as much as possible about current and previous projects conducted by the division they want to join. When PW-Sat3 project was starting for first two months main activity of its members was attending workshops conducted by PW-Sat2 team leaders. These workshops included topics such as mechanical design, thermal control system, electronics, software, design and testing requirements.

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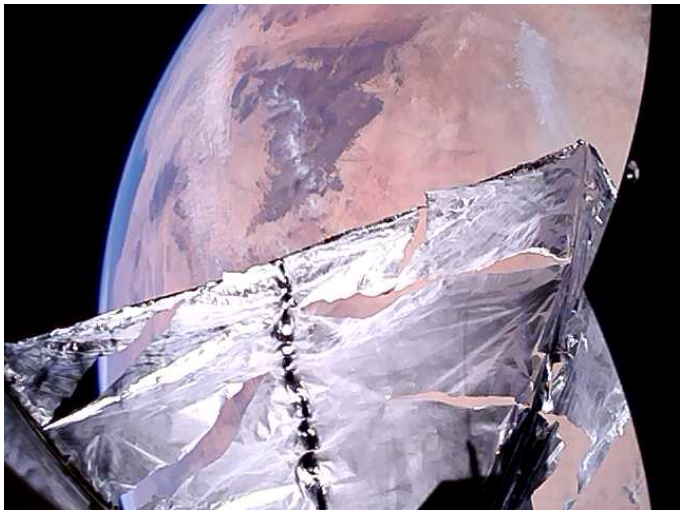

Fig. 2. PW-Sat2 onboard camera photo with torn structure of deorbit sail.

This wide range training allowed PW-Sat3 team to smoothly start the project and avoid unnecessary early stage problems.

C. *Organization activities outcome*

All activities performed by members of the Association have great influence on what happens in Polish space sector and raises social awareness about space exploration.
Students, who leave the Association usually join companies from space industry or set up their own business in this sector. Among them one can find the most important space related companies such as Airbus, Thales Alenia, SENER, GMV, but also fast-growing Polish companies e.g. Astronika, CreoTech or science and research institutions such as Polish Institute of Aviation or Space Research Centre.
Social aspect of Association actions is also significant. The organisation members participate in many events, where students inform attendees about developed projects and sparks curiosity about space, especially among youngsters.

II. PW-SAT3

A. *Mission definition*

The primary mission experiment is a propulsion system for controlled orbit traverse. A cold gas thruster is being designed to achieve the demanded circular orbit. It was decided to apply one nozzle for impulse generation in desired direction. For this operation, and to stabilize the satellite during and after the orbital maneuvers ADCS (altitude determination and control system) with reaction wheels will be in use. The propulsion system is a *cold gas* thruster with butane as a propellant and industrial valves, with no space heritage, are considered to be applied.
The mission plan includes preheating the butane and use of heating coil inside which the propellant will be transferred to the nozzle.

B. *Feasibility study process description*

PW-Sat3 phase A lasts from March 2019. During this time, technical budgets, components trade-offs, requirements and significant decision about the mission simplification were made. The approach for this phase of development was based on knowledge and methods gathered during CubeSat Concurrent Engineering Design Workshop 2019. Use of Open Concurrent Design Tool for budgets, simulations and preliminary components list definition inspired PW-Sat3 system engineer to create similar tool for these tasks. Shared Google Sheets used during team workshops organized weekly let to first budgets and CubeSat design sketch in one month. Mechanical and power consumption data were gathered in one document with links to datasheets with more accurate information. To ensure that components will fit to mass, volume and power constraints, margins were set according to the policy introduced to members of CubeSat Concurrent Engineering Workshop 2019. The requirements design based on ECSS (European Commision for Space Standarization) Applicability Requirements Matrix with strong simplifications let to define crucial payload parameters needed to be tested as well as shortages in specialist knowledge. Ways to tackle with the problems were defined. The requirements were considered by the subteam and then discussed by whole team and accepted by the system engineer. To make sure that members are familiar with project status, current tasks lists for the subteams and manager are available for all team members. Kanban methodology is applied for tasks management.

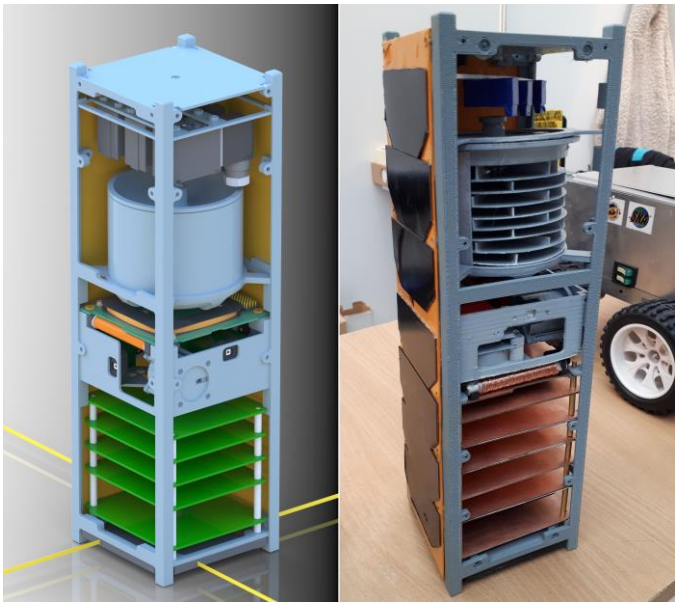

Fig. 3. Up-to-date PW-Sat3 design, together with first, 3D printed satellite model.

The next stage of the feasibility study is the propulsion system testing and facility development. Tests output data is necessary for detailed ADCS requirements definition. The facility was also the first opportunity to get familiar with designed mechanical components being part of PW-Sat3 main

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payload and give the students a motivation for further progress.
To check if the volume budget and components placement is designed properly, 3D printed model was created and integrated to check if the assembling process is possible and find the best way of going through it.

C. Development plans

One of the most important technical problems in PW-Sat3 is to ensure negligible propulsion slosh impact on ADCS design. This is why the tank containing the propellant will consist of the anti-slosh system which is in the development phase now. To control internal tank pressure and reduce liquid butane escape from the system, heating subsystem is being developed. As a part of considerations from phase 0, the reaction wheel is being designed as potential payload. Other PW-Sat3 components are being developed in varied tempo according to the needs of the whole project and current workforce which is monitored by shared sheets. By the end of 2019 the preliminary test campaign for the propulsion system will be done together with finishing the trade-offs for COTS (components of the shelf) and development options for any designed subsystem.

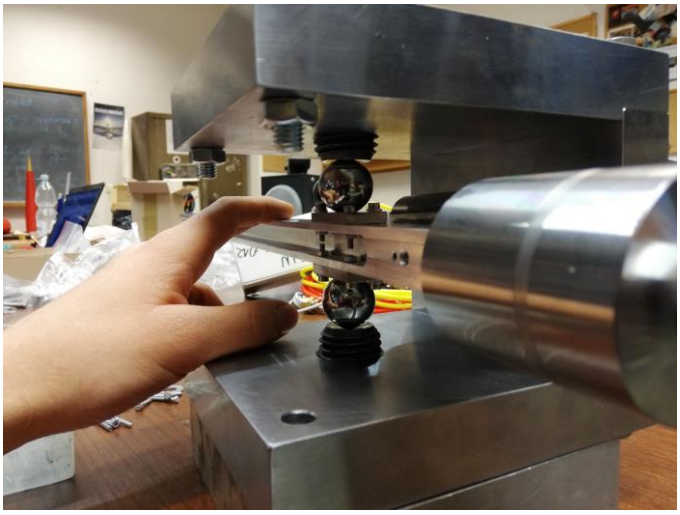

Fig. 4. Torosional pendulum based thrust stand developed for propulsion system test campaign, during its itegration.

The phase of preliminary design of PW-Sat3 will begin. PW-Sat3 launch is planned for the last months of 2022.

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