BUTCube – small satellite technology demonstrator development

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Project motivation

BUTCube is the very **first student´s** CubeSat development project at **Brno University of Technology** (BUT, Czech Republic). Project´s main goal is to demonstrate the technology adaptation in our academic conditions, to develop a **1U CubeSat prototype** and to integrate the customized hardware and scientific mission on-board. All the systems are being developed as an in-house solution applying an ESA´s Fly Your Satellite! Design specification. This allows the know-how consolidation for the future CubeSat activities within the university. Currently, the 1U BUTCube CubeSat is in development to achieve the project goals as well as the **mission demonstration**.

BUTCube team

BUTCube project launched on February 1st, 2021 as one of the supported Ph.D. grant proposals. The team is composed of 5 inter-faculty BUT students and mentor. Team members background is in design, electron microscopy, additive manufacturing, orbital mechanics, thermo-vacuum testing, HW & SW development, image processing, detection systems and scanning.

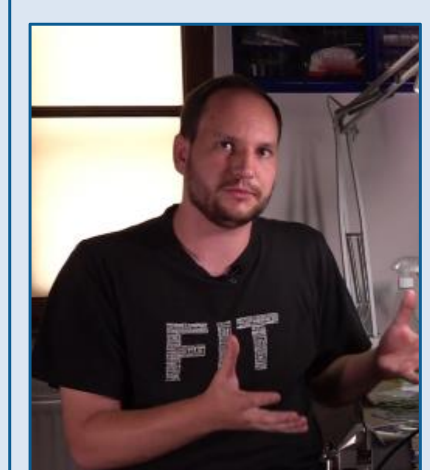
Vaclav Lazar

- **Team leader**
- Institute of Aerospace Engineering
- Faculty of Mechanical Engineering

Tomas Laznicka

- **Structure design**
- Institute of Physical Engineering
- Faculty of Mechanical Engineering

Stepan Rydlo



- **Hardware**
- Department of Intelligent Systems
- Faculty of Information Technology

Petr Malanik

- **Hardware**
- Department of Intelligent Systems
- Faculty of Information Technology

Jaroslav Bartonek

- **Mission**
- Institute of Aerospace Engineering
- Faculty of Mechanical Engineering

BUTCube mission

1U BUTCube demonstrator is currently being developed. The demonstrator will simulate the flight mission objectives during on ground testing.

An in-orbit **Solar Eclipse Observation in a visible wavelength** was proposed as a scientific mission for the future flight BUTCube. Unlike space-based coronagraphs [1], the satellite could provide images of Solar corona at heliocentric distances close to solar limb, utilizing the **Moon occuler** as depicted in Figure 1.

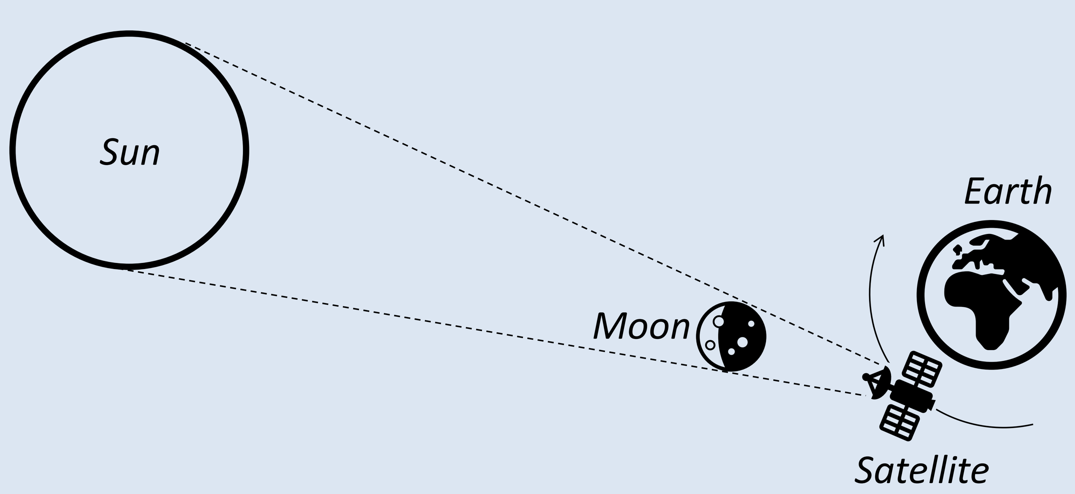


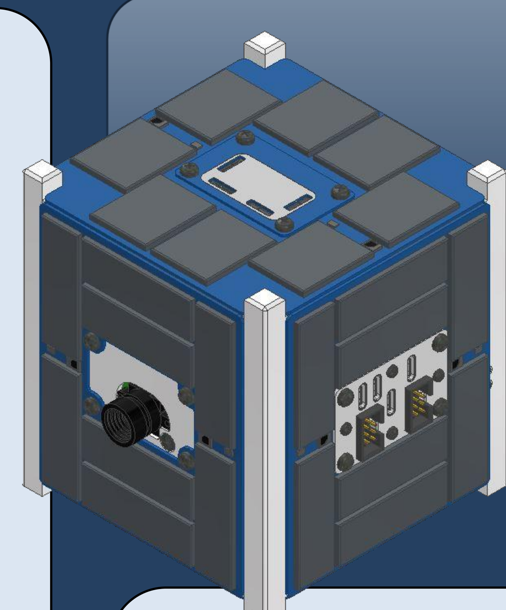
Fig. 1: BUTCube flight mission conceptual proposal

An orbit search algorithm was developed to find two types of unique LEO orbits with such observation conditions. Orbit results are briefly presented in Table 1. The first type orbits (eg. ID 5) provides a unique eclipse observation opportunity without ground-based observation option. Second type orbits (eg. ID 9) provides observation option during concurrent ground-based counterpart.

Tab. 1: observation orbits rearch results

Ground – based	Space – based	Orbit	Observation
X	29.3.2025	ID 5	Unique
12.8.2026	12.8. 2026	ID 9	Concurrent

Proposed flight mission for Space-based white light corona observation benefits from the atmosphere-less ambient and Cubesat platform. A 6U platform is currently assumed. **Current 1U demonstrator** will be equiped with 2 MPx camera testing the image processing onboard. ZWO ASI 1600 MM Pro Mono camera with 17.7 mm x 13.4 mm CMOS sensor will be used for the flight mission. BUTCube demonstrator should also enable the flight camera communication protocol testing once obtained.



1. First BUT´s CubeSat project - student team
- Scientific mission – eclipse observation
- Additive manufacturing – FDM PEEK
- Custom HW – ESA FYS! Design Spec.

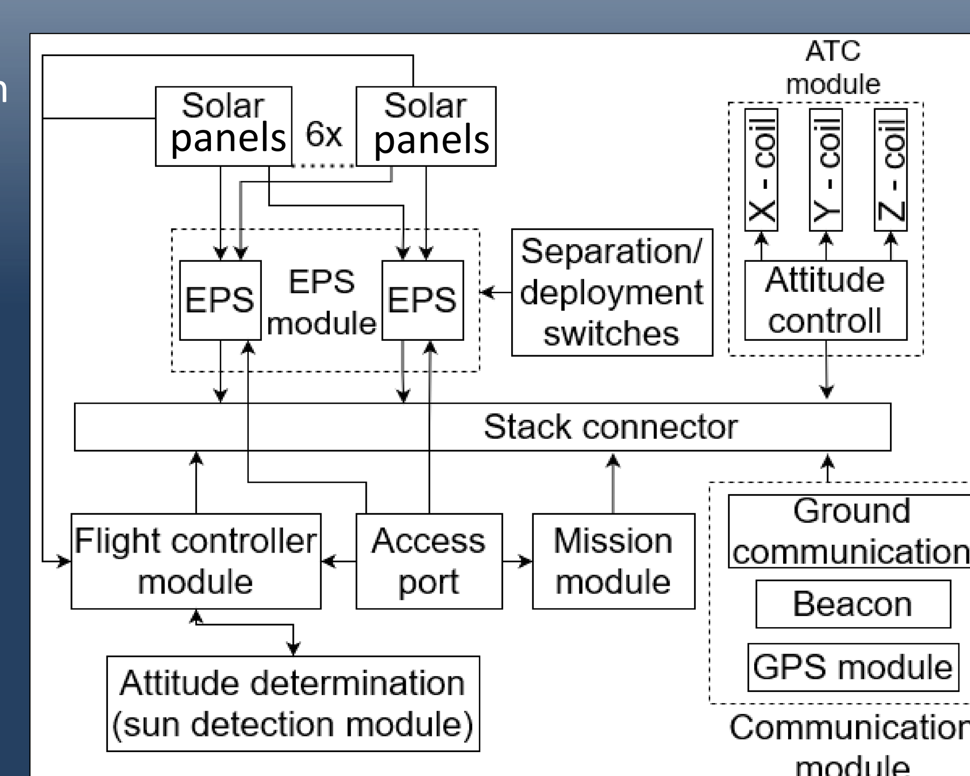


Fig. 3: Schematic interconnection of individual modules in BUTCube

Structure design

Utilizing fast prototyping 3D FDM printing from PLA material, we prepare for the final structure to be additive-manufactured from PEEK. As the frame is subject to high strength and flexibility requirements, very robust mechanical properties in terms of strength, stability, wear and temperature resistance - so strong in fact that PEEK parts can actually do comparable jobs to some metal parts. The use of 3D printing opens a new path to various frame designs, new shapes adapted to extreme conditions in space [2].

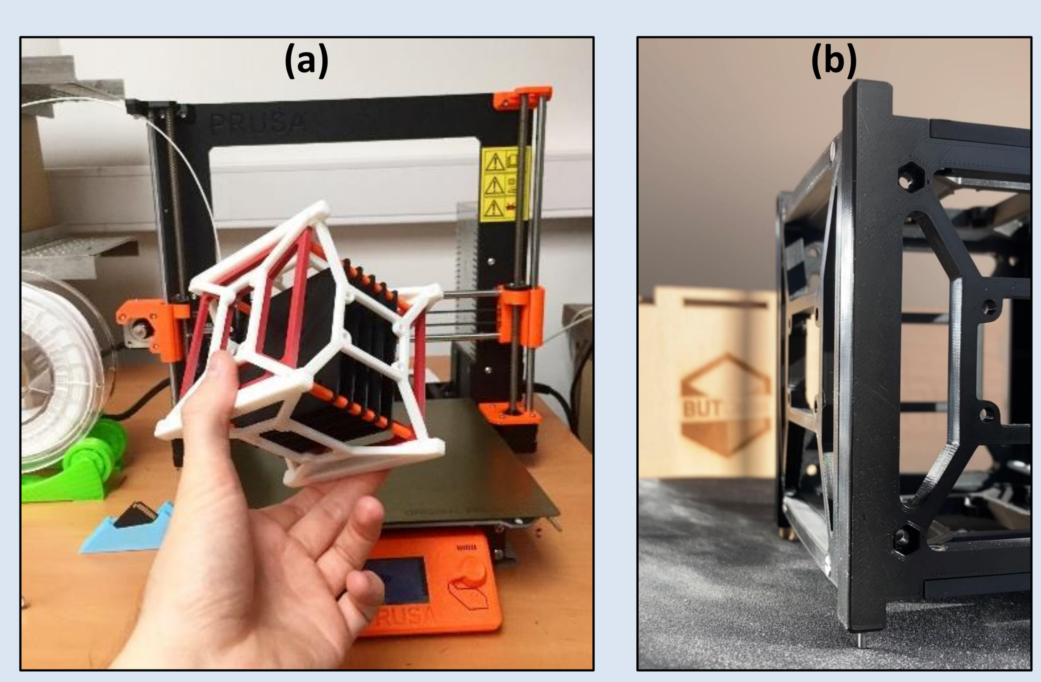


Fig. 2: (a) Cage concept frame structure, (b) current construction

Initial cage concept (Fig 2a) was designed with the idea of part reduction. The frame was printed from 2 separated pieces, but the integration of the inner PCB stack was difficult. Print orientation was also limiting this concept. Sides of the frame, which were not perpendicular to the printer pad, had reduced yield strength; it was changed to a disassembled structure.

Current frame (Fig. 2b) is divided into six individual parts printed in the ideal *+z* orientation, mounted with screws and nuts embedded in the frame. Distributed solution also enhances the integration operations.

Hardware

Hardware of 1U BUTCube demonstrator is divided into 5 modules: Electrical Power System (EPS), Attitude Control (ATC), Flight Control (FC), Mission and Communication (schema in Figure 3). Modules are interconnected via stack connector utilizing CAN, RS 485 and QSPI communication and modules power distribution. The systems are developed at Brno University of Technology premises with respect to ESA Fly Your Satellite! v.3 Design Specification and demonstration mission requirements.

Solar panels are designed from 8 solar cells on each panel, providing 0.98 W output per panel. Design of both +/- *X* and *Y* sides is same, the *Z* side panel´s was modified keeping the same power output.

The EPS is divided into two separated sub-modules, providing total of three independent power lines. Each of the EPS sub-modules has own dedicated MCU, enabling the batteries status monitoring and reporting (temperature, charging etc.).

Communication consists of Open LST on (437 MHz) for beacon telemetry, nRF (2.4 GHz) for science and GPS lines. Mission computer is integrated within communication MCU. Data transmission is possible directly from payload or via QSPI.

Acknowledgment

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[1] Druckmüller et. al., The Astrophysical Journal 785(1);14 (2014)

[2] 3D printing CubeSat bodies for cheaper, faster missions, 2017 [online]. www.esa.it

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