

Miniaturized payload for biological research in low Earth orbit utilizing CubeSat standard nanosatellites

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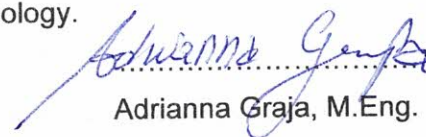
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This doctoral dissertation focuses on the development of a sub-miniature biomedical laboratory in the form of a nanosatellite payload, enabling the conduct of scientific experiments in low Earth orbit (LEO). The subject undertaken is of paramount importance from the perspective of acquiring tools for faster and cheaper space exploration. Thanks to small satellites (nanosatellites) equipped with laboratory payloads, it is possible to design autonomous experiments and conduct them in a diverse cosmic environment without human intervention. The results from such missions can support the understanding of processes occurring in living matter exposed to space conditions.

This work is the ninth in the world and the third in Europe to address the construction of a nanosatellite autonomous biological laboratory for space operations. However, it is the first to tackle the construction of a payload that enables the automated study of various biological objects and the transmission of results from orbit to Earth in near real-time.

The payload concept employs lab-on-chip technology, placing lab-chips in a hardware setup that allows control of all variables critical for conducting experiments in microgravity - as assumed in this work - biological, utilizing fungi and plant seeds. Adequate measurement systems for environmental variables and an experiment control and service system compatible with the nanosatellite bus were proposed. After sealing the laboratory in an airtight housing, a payload measuring nearly 2U (20 cm x 10 cm x 10 cm) and weighing 1.45 kg was obtained. A series of tests were conducted to check the operation of individual components and the entire payload under terrestrial conditions and space flight qualification tests. Subsequently, the laboratory was integrated with a CubeSat standard nanosatellite and placed in orbit.

A several-day orbital test at an altitude of approximately 530 km above Earth demonstrated the correct operation of the laboratory, as well as confirmed proper cooperation with the electronic and information systems of a CubeSat standard nanosatellite. Data from orbit verified that temperature, humidity, atmospheric pressure, and radiation levels were within the appropriate range for conducting experiments with living matter in LEO under microgravity conditions. The final outcome of this work is a sub-miniature, autonomous laboratory capable of simultaneously conducting several different experiments in LEO. It is assessed to be the most complex and versatile solution in the discussed field of technology, paving the way for the development, including in Poland, of so-called microgravity medicine and biology.


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