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Lab-payload for biological CubeSat satellite

Abstract: The increasing of space exploration is causing an increase in the demand for nanosatellites and biomedical methodologies. The latest trend is to replace experiments conducted on the International Space Station (ISS) with research performed using autonomous satellites in the CubeSat standard carrying a biomedical payload. This article describes the lab-payload for the first European bio-nanosatellite. The platform enables long-term cultivation of 3 biological experiments simultaneously. This platform is equipped with dedicated lab-on-chips, containers with medium, medium dosing system, optical detection system, lighting, heating system and sensors for reading temperature, humidity, pressure and radiation.

Keywords: payload; lab-chip; astrobiology; CubeSat

Introduction

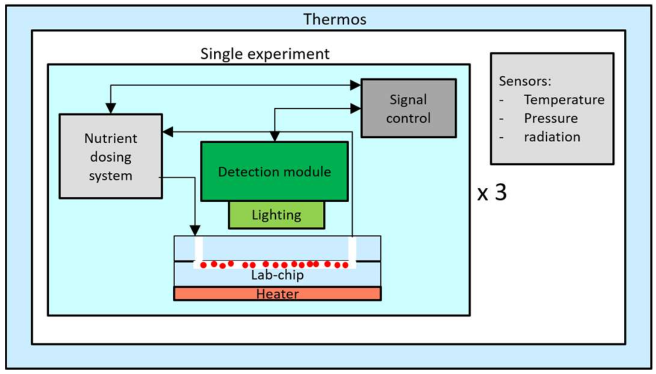
Space exploration is currently one of the main directions of development undertaken by scientists, state institutions and the private sector. It is known that the conditions in space can have different effects on living organisms, so any attempt to trace this effect is very important for the further development of space research. Most of this research at its initial stage is carried out with the use of microgravity simulation devices (RPM, RWV) on Earth [1]. However, it is not possible to create and simulate the space environment in ground laboratories. Therefore, many key studies are carried out in space, where the effects of microgravity, reduced pressure and variable ionizing radiation can be observed simultaneously.

The International Space Station – ISS plays a significant role in space research. Around 2,500 different scientific studies have been conducted on board, including several hundred concerning biology, medicine and biotechnology. However, providing a wide range of services generates high costs for a single experiment. There are also problems with very complex requirements for mission planning and long experiment implementation times due to the high demand for these studies. Intellectual property of the obtained research results is also a problem. Therefore, we can see the development and adaptation of other solutions to conduct bio-medical research in space.

An important place here is played by small satellites in the CubeSat standard, the basic unit of which is a cube with a side of 10 cm (1U unit). This standard has become very widespread and has been used, among others, in telecommunications or Earth observation [2]. The development of these satellites has resulted in the concept of a nanosatellite used to conduct biological research, known as a bio-nanosatellite. So far, 11 biological missions have been carried out with the participation of this type of satellites (including the one presented in the following article). One of the main structural elements of this type of satellites is the payload in which planned biomedical experiments are placed. It must provide appropriate conditions for conducting a biomedical experiment, and thus control of temperature, pressure, radiation, appropriate factors enabling growth such as a medium, gas atmosphere, lighting, signal detection with data acquisition and sending them to Earth. This article will present a lab-payload for the first European space mission enabling the cultivation of biological objects such as fungi and seed.

Lab-payload - conception

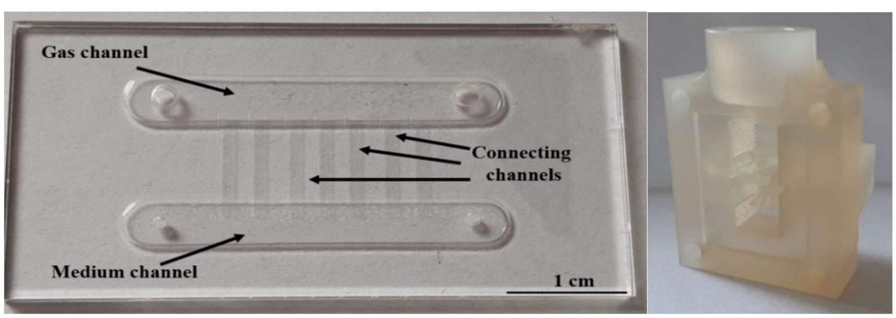
The entire bio-nanosatellite was size 3U, of which the payload took space 2U. The operation of three biological experiments at the same time was planned. Each of them had to be provided with a dedicated lab-chip for cells / seeds, appropriate temperature for the cultivation, proper dosing of the medium, lighting and signal detection in the form of recorded photos. Selected experiments were closed in a thermos (2U) ensuring atmospheric pressure, appropriate sensoring and communication with the computer managing the cultivation process (Fig. **1**).



1. Conception of lab-payload

Lab-payload - construction elements

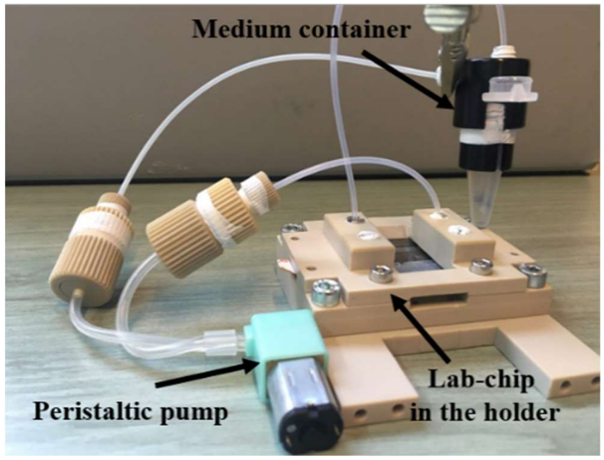
Dedicated lab-on-chips enabling the culture of various biological objects were designed and made (Fig. **2**). Borosilicate glass (Borofloat33, Schott) was chosen as the material for the construction of lab-chips. The layout topology was chosen to ensure optimal development of each of the cultures. The structuring of glass substrates was carried out using the process of wet etching, mechanical drilling and high or low temperature bonding (depending on the structure). A micropot was also made with the use of 3D printing, enabling the growth of a single grain.



2. Lab-chips for fungi)left) and seed (right) culture

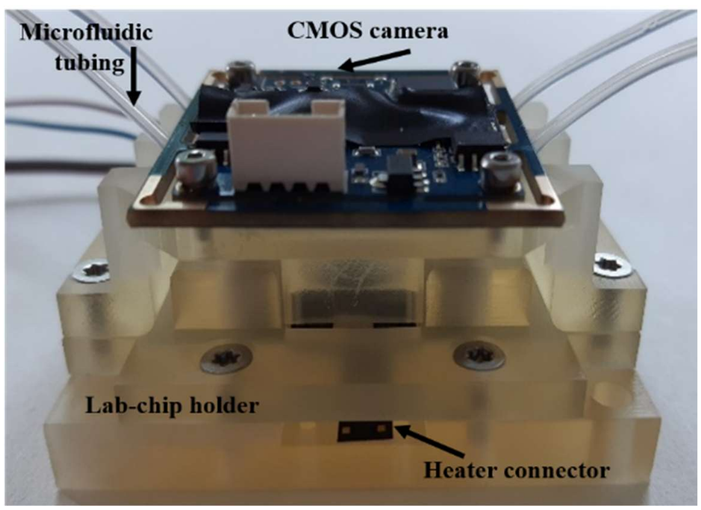
Preliminary cultures were conducted in simulated microgravity using RWV and RPM. It could be observed that fungal spores grew better in simulated microgravity [3]. However, cress seeds showed problems with proper growth [4].

An important element of the system was the dosing of the nutrient solution, was carried out in a closed system. It was used a peristaltic pump (Takasago, Japan) and medium container (Eppendorf). The medium flow rate was adjusted for each of the cultivations carried out, and so for the fungi it was a pulse operation and amounted to 200 µl / min every 10 h, while for the grain it was 500 µl / min every 12 hours (Fig. **3**).



3. Dosing system

In order to parametrically evaluate the conducted cultures, a dedicated optical system was used, which allowed for taking pictures. It was therefore necessary to illuminate each of the experiment. For this purpose, LED diodes were used to enable the observation of the tested samples in the reflection mode. A miniature CMOS camera with a resolution of 8 MP with a USB interface and a specially selected electromagnetically controlled focus was used. It made possible to focus on the tested object. It was important to mount the camera with focus and lighting just above the lab-chip surface so that the system could withstand the 10G overload generated during rocket launch. The assembled detection system allowed the observation of objects with dimensions of 8 µm (Fig. **4**).



4. Detection system

Lab-payload - realization

The individual elements of the set up were placed in a 2U payload. It included 3 experiments. Two of them were dedicated to the culture of fungi from the *Fusarium Culmorum* family, and one to the grow of cress grain. Each of the experiments had the previously described dedicated medium dosing system, optical detection system and thermal control system. The entire structure of the payload was placed in a special thermos to maintain the atmosphere and connect with the satellite's base unit, which ensured control over the experiments. A very important element was the installation of all systems inside the laboratory thermos, so as to ensure a safe launch into the Low Earth Orbit (LEO) – Fig. **5.**

5. Lab-payload for CubeSat satellite

Lab-payload has been integrated with the satellite structure. All necessary tests were carried out before launch, which the satellite successfully passed. In January 2022, the satellite was launched on LEO. The mission's success was obtaining images of the initial stage of grain germination. The correct operation of all lab-payload elements enabling the maintenance of the culture life and the optical system ensuring parametric evaluation of the conducted research were checked and confirmed.

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Source materials

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