NEAR SPACE SATELLITE

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ABSTRACT

Our project had 2 parts: biological and engineering. The main part of the engineering subset consisted in assembling, programming, and launching the device into the stratosphere, as well as developing, programming a ground-based receiving rotary station, and creating a web application for visualization and analysis of the received data. The biological part consisted of conducting a biological experiment to study the possibility of regeneration of Dugesia Tigrina planaria and the development of Danio Rerio larvaes after exposure to radiation, ultraviolet radiation, temperature changes and mechanical effects during stratospheric flight.

Key Words : *Biology, Engineering, Stratosphere, Dugesia Tigrina Planaria*

1. Introduction

The stratosphere is a layer of the atmosphere located at an altitude of 11 to 50 kilometers. Rockets fly through it in a matter of minutes, planes very rarely get there, and the people who were there can be counted on the fingers. The stratosphere is very dangerous due to its harsh conditions, such as low pressure and temperature, as well as increased solar radiation, which is why it is often called near space. But this is what attracts researchers - in the stratosphere, you can conduct many experiments with conditions close to real space. Therefore, our goal was to develop a stratospheric satellite as a platform for scientific experiments and directly conduct them.

The zebrafish or Danio Rerio is an aquarium fish which belongs to the minnow family of the order Cypriniformes. A distinctive feature of this species of fish is rapid development, which makes it extremely interesting for scientific research. Researchers who studied zebrafish development concluded that «The interaction between UV-B and temperature impaired the development of zebrafish embryos and disrupted their metabolism» [Aksakal, Ciltas 2018]

Planarias Dugesia Tigrine are free-living aquatic flatworms that can regenerate cells. Scientists who studied planaria's regeneration and development at different temperatures and at certain doses of ultraviolet radiation UV-B concluded that «Doubt is therefore cast on the hypothesis of an adaptive value of regeneration in view of the fact that several planarian species actually live and reproduce at temperatures well below those necessary for regeneration». [Brøndsted, Brøndsted 1961]

Planarias Dugesia Tigrina and Danio Rerio larvaes became our first passengers.

The purpose of our biological research is to study planarias' Dugesia Tigrine regeneration and Danio Rerio larvaes' development after the influence of irradiation, ultraviolet radiation, low temperatures, and mechanical damage after the stratospheric flight. To successfully conduct the experiment, it was necessary to create a satellite platform and equip a receiving station, as well as create a means of processing the received data.

In addition, we assumed that Danio Rerio larvaes can fall into state of suspended animation at low temperatures and radiation and ultraviolet exposure adversely affect the regeneration of Dugesia Tigrina planarian cells and we checked it during our flight.

These studies will be useful in the future as they help to find the optimal conditions for transporting living objects from Earth to space station or other planets as the conditions in the stratosphere are quite similar to space.

2. Materials and Methods

To conduct the experiment, a satellite platform was developed with a set of necessary sensors and tools necessary for recording environmental parameters: 4 temperature sensors in the main compartments of the satellite and outside (battery, electronics, interior space and one sensor outside the satellite), a GPS sensor (for tracking the satellite and pointing the receiving station at it during flight, and to facilitate the search after landing), barometers and gas analyzers (for dynamic analysis of the composition and pressure of the surrounding atmosphere), as well as an ultraviolet sensor and a Geiger-Muller counter.

The engineers faced several tasks, for example, placing test tubes with living organisms inside and outside the device (additive technologies were used for this purpose) or placing all sensors. For each module, it was necessary to develop a firmware and ensure that they work together through the main board. Specialized libraries were used to work with additional modules, a lot of work was done with microcontrollers.

Also, to monitor the launches of the platform, a rotary receiving station was assembled (metal structures and additive technologies were also used during assembly) and programmed, whose orientation method is described above. Such a mechanism of the station helped to significantly improve the signal quality and dramatically increase the data transmission distance. During the creation of the receiving station, new machine parts for us and methods of complex mathematical modeling were used.

To successfully conduct the experiment, all factors affecting living objects during the flight were studied. The oxygen consumption of each of the creatures was calculated to avoid a fatal outcome because of its shortage. According to the plan, oxygen in the test tubes should have been enough for larvaes for 5 hours and for planarians for 7 hours (more than doubled flight duration). Special transport capsules were found that met all the requirements to ensure a comfortable flight (ability to transmit ultraviolet and radiation, tightness, Impact resistance 5 N). To increase the amount of scientific data obtained and confirm their liquidity, we divided the samples under study into two groups: the first was placed in more greenhouse conditions inside the satellite, and the second had to endure more severe conditions outside the satellite, including temperature differences.

Subsequently, a web application was developed using the Python and JavaScript programming languages, with the help of which the data received from the satellite is visualized. The application can work both with pre-recorded data and with values received directly during the flight.

One of the recent achievements of our programmers was the transition to the Grafana service to improve the quality of visualization, as well as the successful implementation of relational databases in our hardware and software complex.

3. Experiment

On June 12, 2022, the first launch of our satellite platform into the stratosphere was carried out near Pereslavl-Zalessky. Our satellite was fixed on the suspension of a helium balloon. At a certain point in time, due to the increased pressure difference between the pressure inside the ball and outside, a planned rupture occurred. During the entire flight, the satellite regularly transmitted up-to-date data about the environment and its location. The duration of the flight exceeded 3 hours, during which time the device covered over 35 km and reached an altitude of over 25.5 kilometers. 4 transport capsules (2 test tubes inside the satellite and 2 outside) with living objects (1 larvae and 2 planarians outside the satellite, 2 larvaes and 3 planarians inside the satellite) were launched and successfully returned to the satellite (Figs. 1 and 2).

Larvaes and planarians were exposed to:

1) Irradiation (Maximum index – 731.1 mcR/h
The usual indicator on Earth is 15-20 mcR/ h)
2) Temperature differences (-14°C - 50°C inside the satellite, -45.7°C - 27.6°C outside)
3) Ultraviolet radiation
4) Mechanical damage

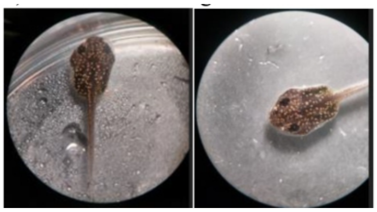

Fig. 1: Test organism №1. Danio Rerio larvae. Henry

Fig. 2: Test organisms №2, №3. Planarias. Sam and Bob

Not all the living objects survived the stratospheric flight. The planarias died from cell destruction, due to mechanical damage by reason of strong impacts on the test tubes.

Not all biological objects survived the stratospheric flight. Subjects 2 and 3 (Dugesia Tigrina planaria) stopped functioning due to cell destruction caused by strong mechanical impacts on the walls of test tubes. According to the camera recordings, the larvae, located outside the satellite, finally stopped its motor activity at an altitude of 15 km and a temperature of -20 °C. The probable cause is the influence of extremely low temperatures. 11 days after the launch, the process of decomposition of the larvaes's body began. Usually, this process begins 2-3 days after death. The larvae showed no motor activity and did not decompose for 11 days. Based on this, we can say that the larvae has fallen into a state of suspended animation, which probably can confirm the above hypothesis.

Scientists have found out that «The physiological adaptations required by these animals and plants to survive extreme conditions at no detectable metabolic rate are generally complex and specialized» [Withers, Cooper 2008]. On this basis, we can put forward a hypothesis that Danio Rerio larvaes probably have «complex and specialized physiological adaptations» to survive such low temperature.

One of the larvaes inside the satellite died at an altitude of 20 km and at a temperature of -10°C. The decomposition process began 2 days after launch. The second larvae, located inside the satellite, successfully survived most of the flight, which can be seen from the cameras, but during landing, due to a hard impact, it stopped its vital activity.

All larvaes lost the black pigment in melanocytes, acquired a gray-brown translucent color (the alleged reason is exposure to a large dose of radiation and ultraviolet radiation).

The satellite, the receiving station and the application performed well at the first launch. All systems worked correctly and without critical interruptions. In the course of the work, a software and hardware complex of the receiving station was created that performs dynamic reception and processing of data from a satellite platform, the satellite platform itself was implemented, providing the necessary conditions for various scientific experiments, a successful test launch was made with Dugesia Tigrina planarians and Danio Rerio larvaes. During the test flight, it was possible to reach an altitude of 25 kilometers 700 meters and get all the necessary data.

4. Results and Discussion

1) For realization of biological experiments in the stratosphere with a lower percentage of deaths, the development of a special capsule protecting against mechanical damage is required.

2) Danio Rerio larvaes can survive sub-zero and extremely high temperatures (-14°C - -50°C), ultraviolet and radiation exposure (maximum index – 731.1 mcR/h) with a smooth change and in small timespan.

3) The hypothesis that Danio rerio larvaes can fall into state of suspended animation at low temperatures (-20°C) is confirmed.

5. Conclusion

In the course of work, it was possible to create a fully working receiving station for the satellite and the satellite itself, reach a height of 25 kilometers 700 meters, get all the necessary data, develop a web application with full telemetry of the device and conduct a biological experiment in the stratosphere using the developed hardware and software complex.

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