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Innovative deployable biological experiment for a compact automatized measurement of organisms' development under cosmic radiations onboard a CubeSat in lunar orbit

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Abstract

OBELICS (deplOyable Biological Experiment in Lunar orbit to study Cosmic rayS) is a biological experiment for CubeSats that has been developed by the Space Center (CS³) of CentraleSupélec, France. It allows to study the impact of cosmic rays on the development of organisms subjected to the space environment. In our case, the payload will be embarked into lunar orbit (fig. 1). Up to now, no organism has been studied in the lunar environment for more than a week. This is due to a need for an assessment of the number and the state of life of the organisms, and this is often achieved through manual analysis of the samples. This cannot be envisaged in the case of a CubeSat which is not meant to be retrieved at the end of the mission. Therefore, an onboard automatic technique has been developed, through turbidimetry and nephelometry, that is the analysis of the light absorbed and scattered by the organisms. It is both a light and an efficient approach which will bring meaningful results for the manned lunar missions to come.

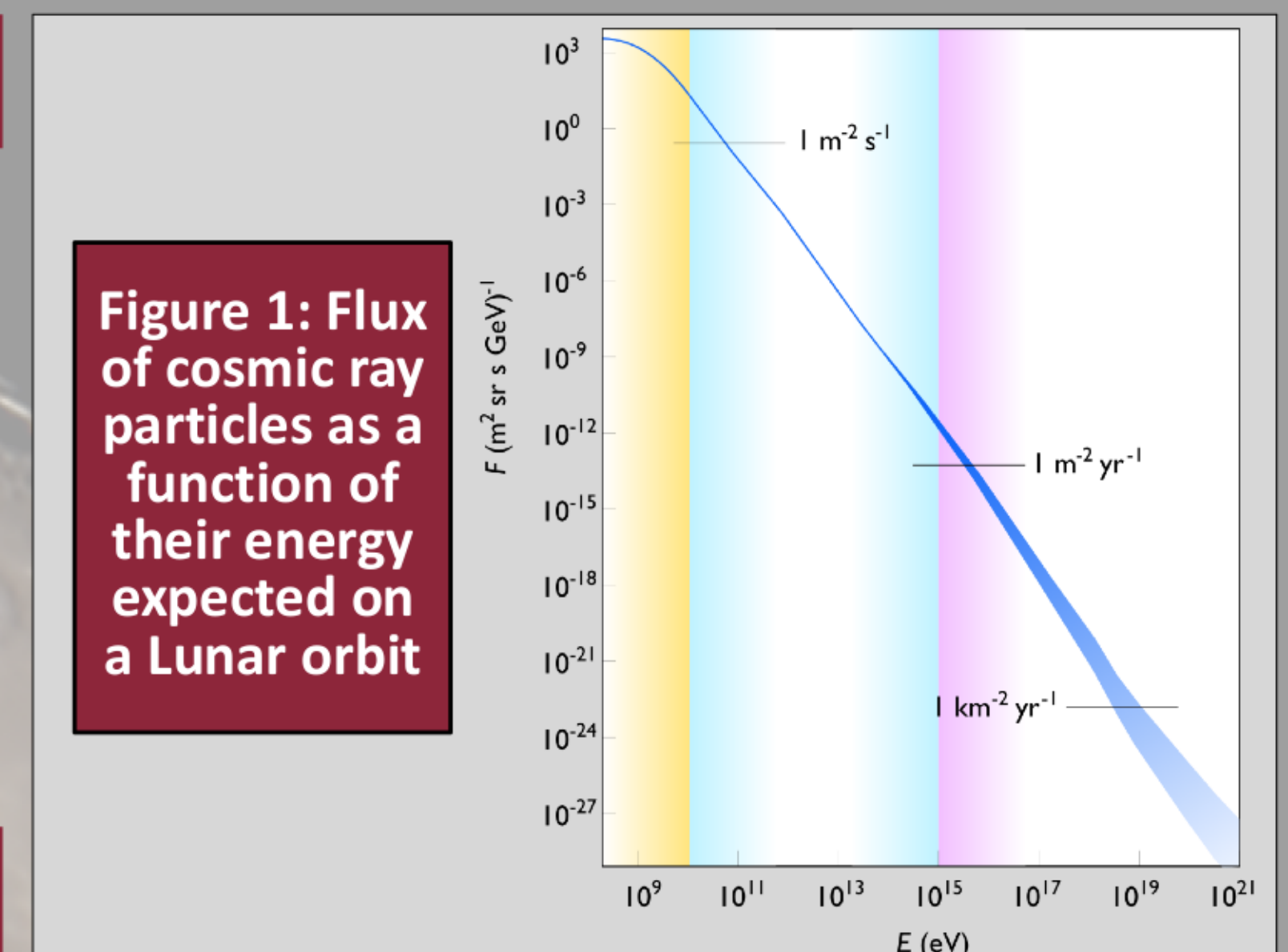


Figure 1: Flux of cosmic ray particles as a function of their energy expected on a Lunar orbit

Turbidimetry and nephelometry

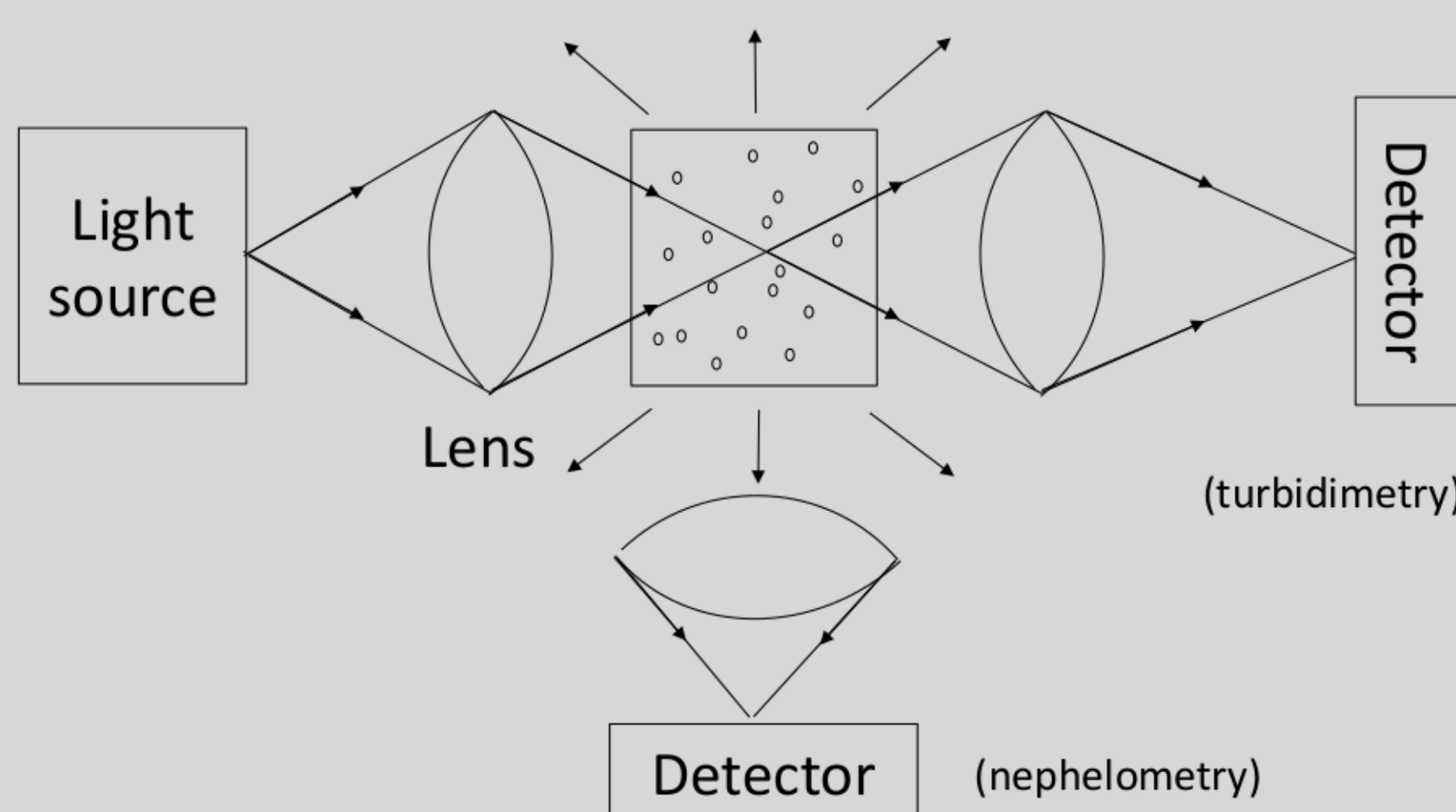


Figure 2: Principle of turbidimetry and nephelometry

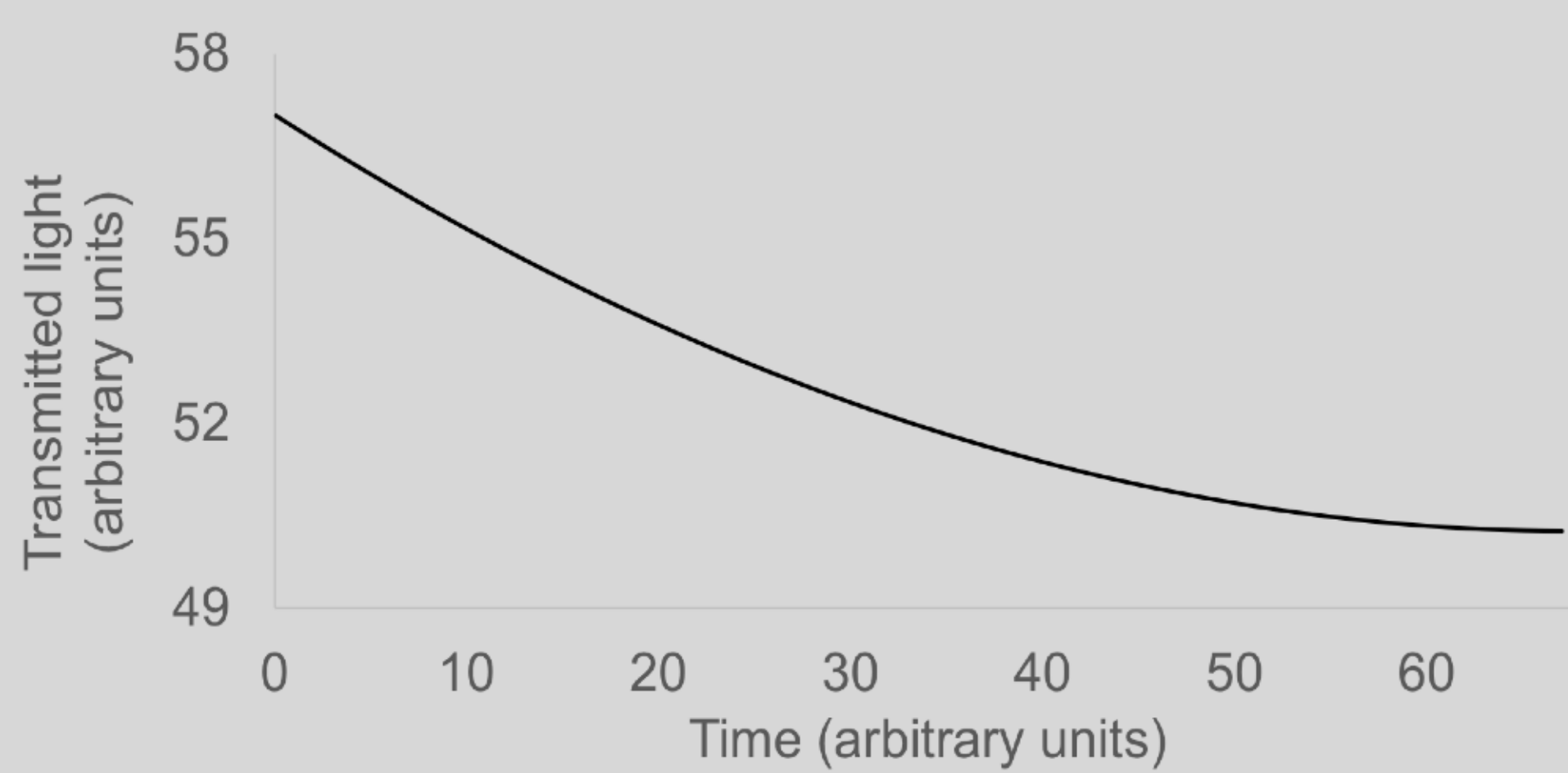


Figure 3: Expected evolution of the transmitted light over time (typical graph expected as the result of OBELICS, here for *bacillus subtilis*)

The payload will be centered around wells that will accommodate organisms (bacteria, spores, yeasts, plants...). To evaluate the number of organisms inside one well, several methods can be envisaged, but turbidimetry/nephelometry has the advantage of providing good average results for the whole well as well as being rather light and straightforward to integrate into the payload.

It consists in the lighting of the well through a source (which we have chosen to be a LED emitting at 600nm, a wavelength known for bringing meaningful results) (fig. 2). This LED lights the wells, where it is partly absorbed, transmitted and scattered [1]. Detectors then measure the quantity of light which was transmitted and scattered. These absolute values, coupled with the ratio of the lights scattered at various angles can bring at the same time relevant information on the number of organisms inside the well, but also on their state (alive or dead). This is due to the fact that the light scattered is a function of the size of the particles in suspension [2].

The information is retrieved thanks to photodiodes. The frequency of the measurement depends on several factors. The main one being the nature of the organisms. The typical bacterial mitosis cycle approximately lasts 30 minutes, but for plants it can take much longer.

It can afterwards be sent directly to Earth, as it

represents a small quantity of data, unlike methods which necessitate pictures. Moreover, it does not need any posttreatment between the measurement and the radio downlink. Another substantial advantage of this technic is that as long as the well is not too wide, there is no need for any dilution or sampling, which would be hazardous on board a CubeSat.

Depending on the format of the whole system, a lens combination is not absolutely necessary, but gives more accurate results. In our board, the light's path will be small enough to make insignificant the losses due to its absence.

Moreover, the electrical consumption of such a system does not exceed 1 W, which correspond to the lighting of the LED. In addition, it does not have to take place throughout the mission, the lighting can take place only for the measurement, and only for a fraction of a second. This is useful because the device is not designed for a single well, but for an accumulation of several dozens of them. This can enable a measurement rotation.

The results that we expect (fig. 3), obtained with the prototype from figure 4, are graphs of transmitted light over time. On their own, they may depend partially on calibration. They will have to be compared to reference tables or to control samples in order to give quantitative results of the concentration of organisms.

Format and integration

OBELICS will consist in a board with a few dozens of wells. These wells are the basic units of OBELICS, in which the organisms will grow. Their size will vary depending on the nature of the organisms, though they will all be 1 cm deep. For bacteria, the diameter will be around 3mm. The board split into such wells has numerous upsides: enables the study of organisms of different natures; makes it possible to postpone the onset of the development of the organisms of certain wells, for instance to avoid, or on the contrary to wait for specific space weather events (and also to wait to be in lunar orbit and protect from the influence of the Van Allen radiation belt). Besides, it will be possible to place different shielding types for each well (varying material or thickness).

This modular layout allows to obtain meaningful results and provides with a direct analysis of suitable radiation shielding materials to protect astronauts located in future Moon bases or cislunar stations without the traditional heavy aluminum shields. The different wells could also have variations in the organisms' living conditions, namely in their growth medium, to also study the impact it can have on their development.

Each well will be equipped with its own turbidimetric and nephelometric apparatus (fig. 5), to have accurate values for each of them. Temperature sensors and thermal regulators will also be present to help stabilize its value as much as possible in order to provide a stable environment for the organisms. A system to renew the growth media will also be integrated, as the organisms will very probably develop too fast to last for the few months expected for this experiment, and will therefore end up dying of lack of nutrients without this implementation. Besides, there will be dosimeters on different sides of the payload, to have a good knowledge of the ongoing space weather, and to correlate the development of the organisms with it. The board will be 9 x 7.5 x 3cm³, for a weight of less than 500g. It will be put on a side of the CubeSat, to be deployed once in lunar orbit (fig. 6). The deployability is a requirement in order to expose the wells to radiations only in the desired lunar orbit. The deployment will expose

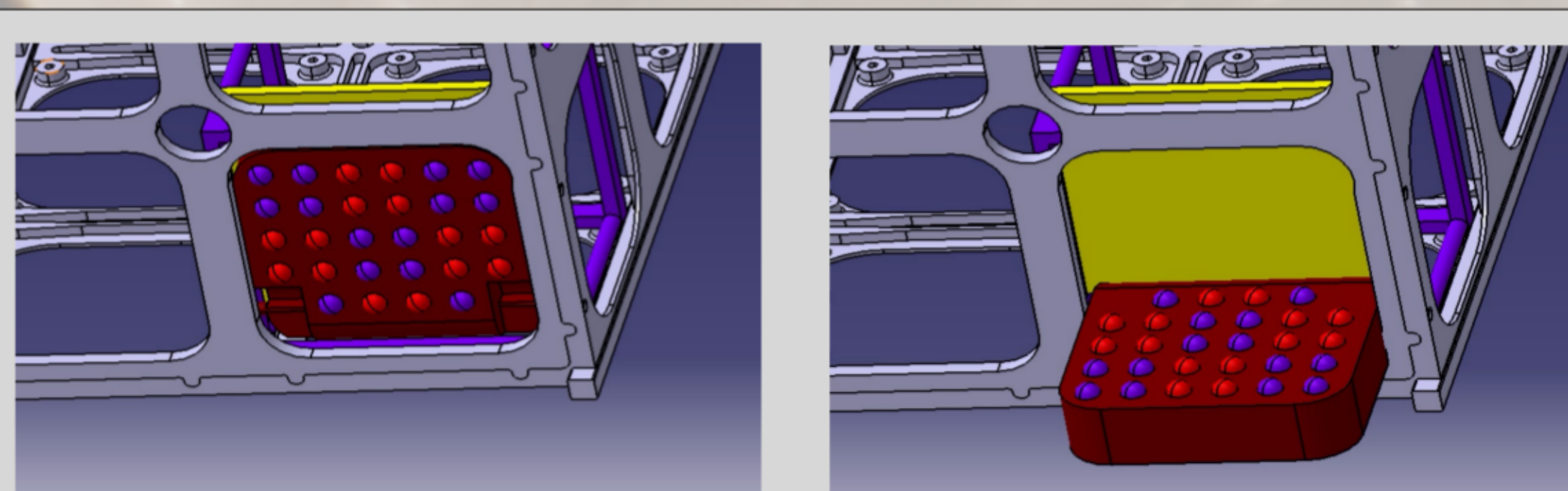


Figure 6: Deployment of OBELICS (the different well colours account for the different shielding materials)

OBELICS to radiation with minimal shielding from the host spacecraft and the boundary conditions will then be well known and expected to be uniform for each well. A system of springs and hot knife will be used to deploy the payload for minimal platform impact.

Figure 4: Prototype of a turbidimeter enabling a measurement of the evolution of bacterial concentration in petri dishes

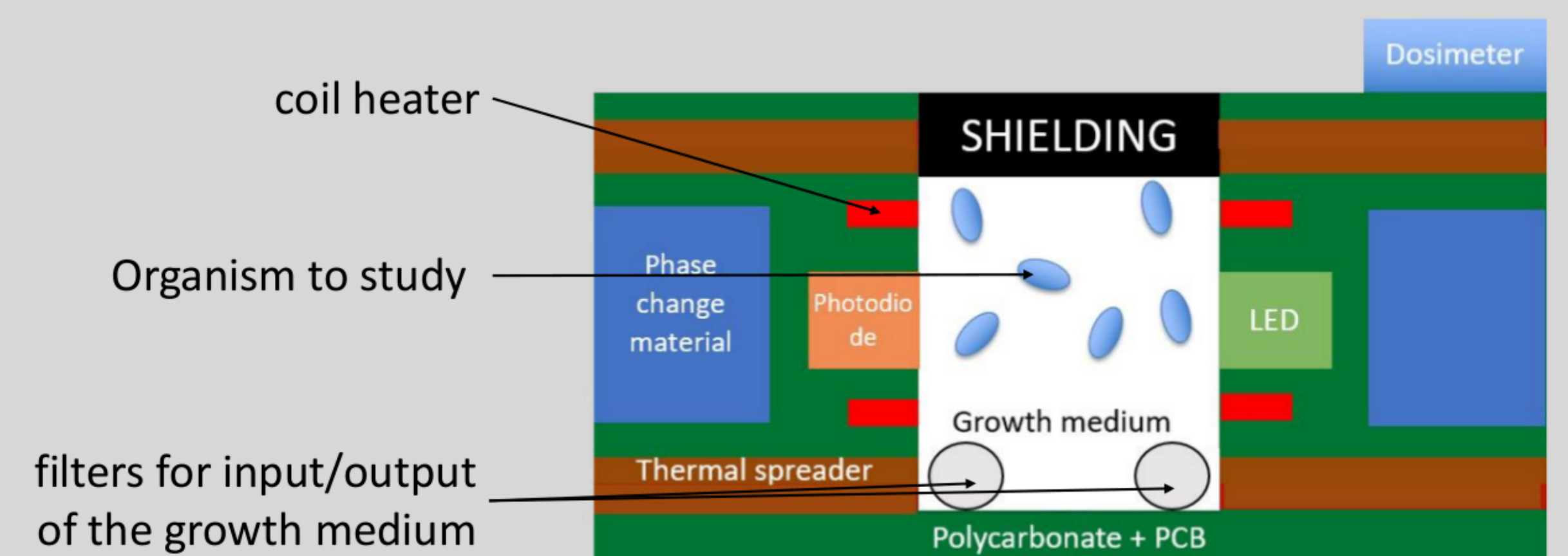


Figure 5: Diagram of the cross-section of one well (the photodiodes outside the plane remain unrepresented)

Conclusion

OBELICS is a pioneering biological payload for CubeSats. It will enable a low-cost, light and easy monitoring and analysis of the development of organisms in space. It takes advantage of turbidimetry and nephelometry, two techniques that bring meaningful results, while being energy-efficient. It offers a large spectrum of organisms able to be studied within it. Not only will it be a major support to study the impact of cosmic rays on organisms in lunar orbit but it will also be reusable for other missions targeting different operational orbits. OBELICS as such could be a precursor to any human missions into the solar system.

References

- [1] C. D. Kelley et al. (2014), "An Affordable Open-Source Turbidimeter" in *Sensors*, 14(4), 7142-7155
- [2] A. F. Bin Omar et al. (2009), *Turbidimeter Design and Analysis: A Review on Optical Fiber Sensors for the Measurement of Water Turbidity*

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