ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

ALCYONE e BOREALIS: payload scientifici per l'esecuzione di esperimenti biologici in missioni CubeSat

Mara Mirasoli

Dipartimento di Chimica "Giacomo Ciamician"
Alma Mater Studiorum - Università di Bologna

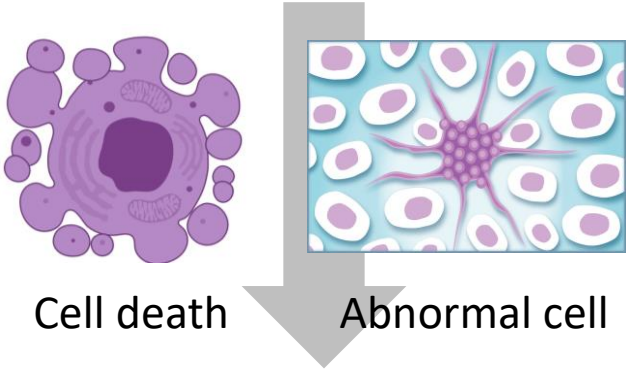
mara.mirasoli@unibo.it

Studying radiation countermeasures on cell cultures

- During deep space missions, humans are exposed to elevated radiation level, which increases possibility of negative outcomes. Microgravity conditions also significantly affect the metabolic processes.

- The combined action of microgravity and radiation exposure may alter cells viability and metabolic activities, including response to pharmacological treatments.

Stresses on cell (microgravity, space radiation)



Physiological changes
Diseases

- No terrestrial experiment currently duplicates the unique space radiation environment.

- *In-situ* studies are fundamental to evaluate the effects of the space environment on living organisms, as well as radiological countermeasures for astronauts.

Nanosatellites: a convenient platform for experiments in space

More experiments at lower cost
CubeSats are miniaturized spacecraft that can be exploited to conveniently deliver small payloads into space.

Biology-focused CubeSats are increasingly proposed for improving our understanding of how living organisms respond to spaceflight.

BioSentinel spacecraft leaves Earth and enters a lunar fly-by trajectory into a heliocentric orbit.
Credits: NASA/Daniel Rutter

Biology payloads for CubeSat experiments must be able to house the biology, maintain temperature, deliver fluids, and monitor the biology throughout the experiment

The project ALCYONE: aims of the investigation

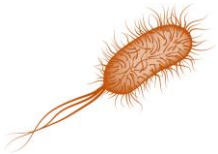
The ***ALCYONE project*** proposes a scientific payload that enables the autonomous execution of experiments on cell cultures matching compact size, automated operation, low-power consumption, and low-data budget specifications required by the target space platforms (aboard microsatellites, planetary probes, orbiters and rovers, exposure facilities on space stations).

This goal is achieved through the combined use of:

- a bio-analytical approach based on bioluminescence cell-based biosensors;
- lab-on-chip technology with integrated thin-film electronic devices;
- an innovative ultra-low power dosimeter system

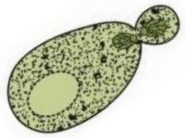
The project ALCYONE: cell-based monitoring

Bacteria (E. coli)

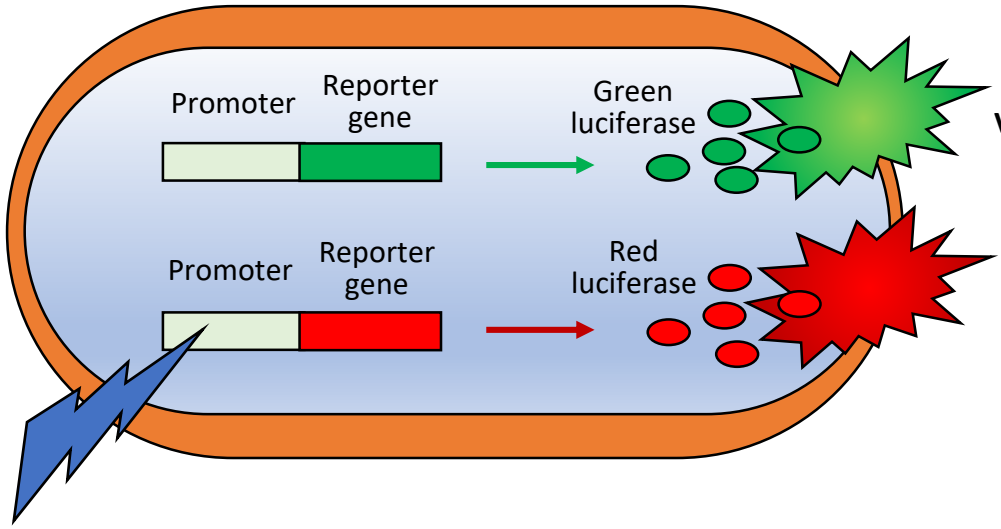


Cyanobacteria (Chroococcidiopsis sp. 029)

Yeast (S. cerevisiae)



Mammalian cell (HEK293)

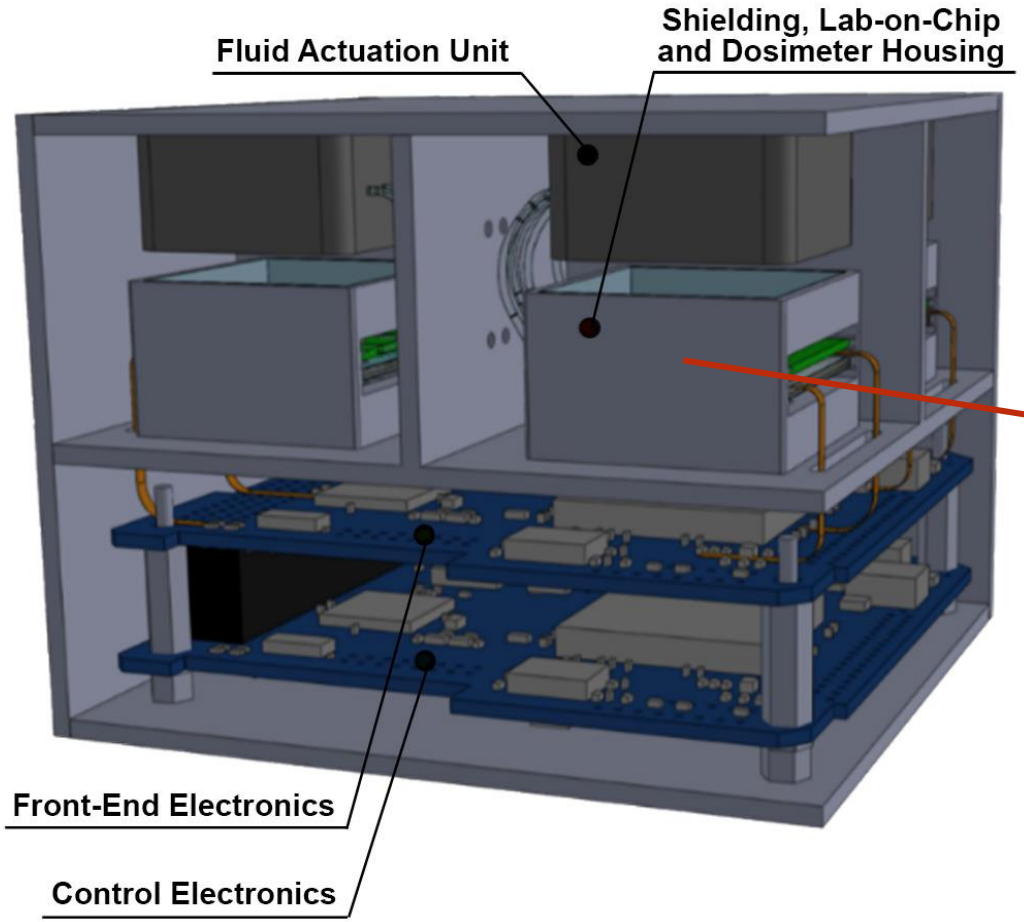


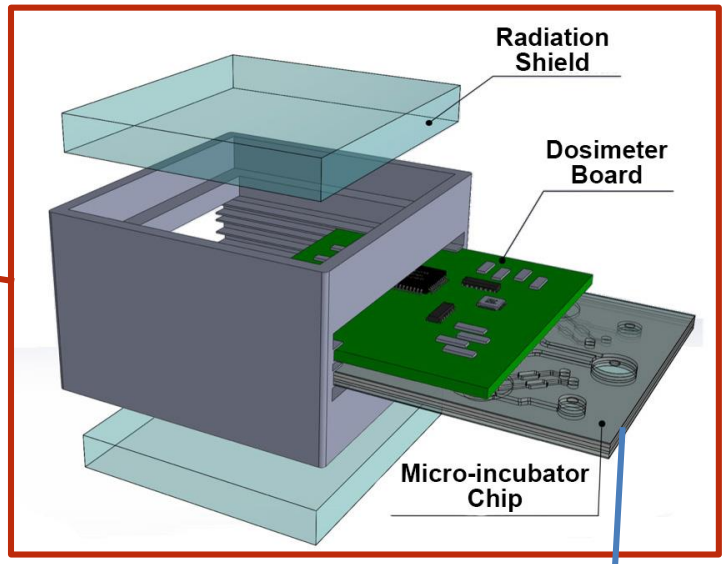
Viability control signal

Specific signal
- **DNA damage**
- **Photosynthesis impairment**
- **Oxidative stress**
- **Apoptosis**

Exposure to space conditions (radiations, microgravity)

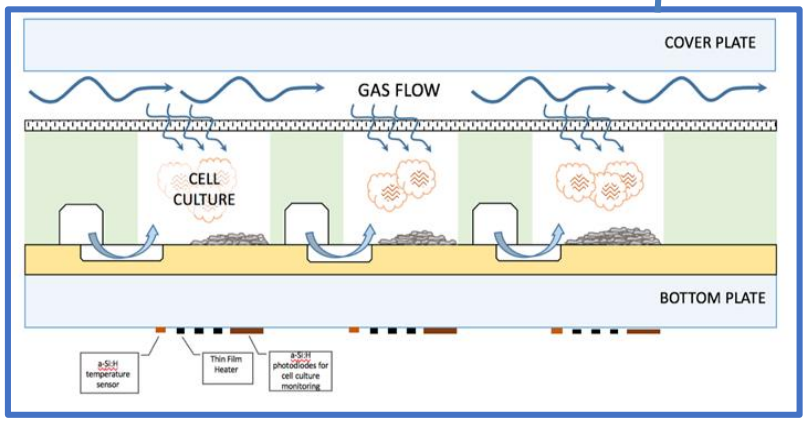
The project ALCYONE: scientific payload





Payload

Micro-incubator Chip



The project BOREALIS: aims of the investigation

Several studies with bacterial and fungal species reported the formation of biofilms on spaceflight surfaces and its water systems, potentially corroding surfaces or becoming detrimental to crew health.

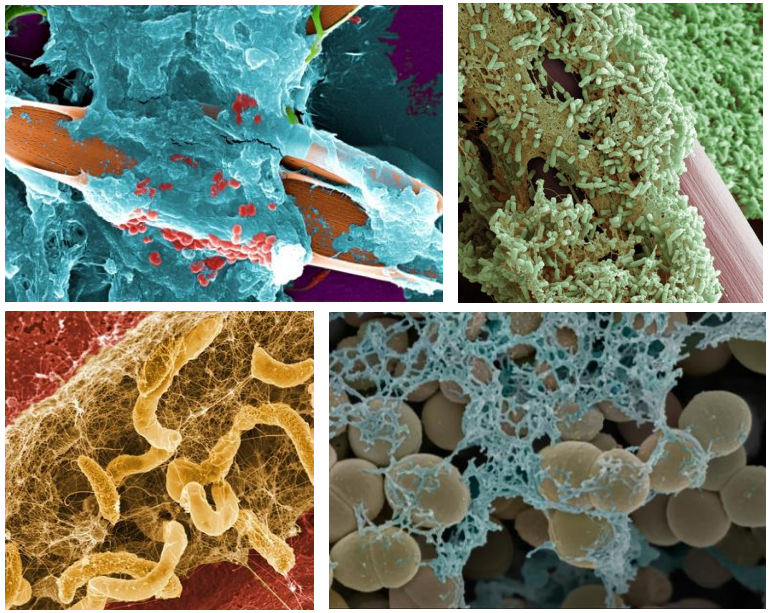
BOREALIS aims to carry out a ***CubeSat scientific mission*** for:

- assessing the combined effects of microgravity and ionizing radiation on microbial populations in biofilms
- testing in a real environment the effectiveness of radiation protection, combining physical shielding and treatment with a 'bioinspired' pharmacological agent
- elucidating the mechanism of generation of high-dose factor secondary particles during the interaction of shielding and/or structural materials of the satellite with the high-energy tail of cosmic radiation.

BOREALIS: cell-based monitoring

The BOREALIS biological experiment will study different ***microbial populations in biofilms***:

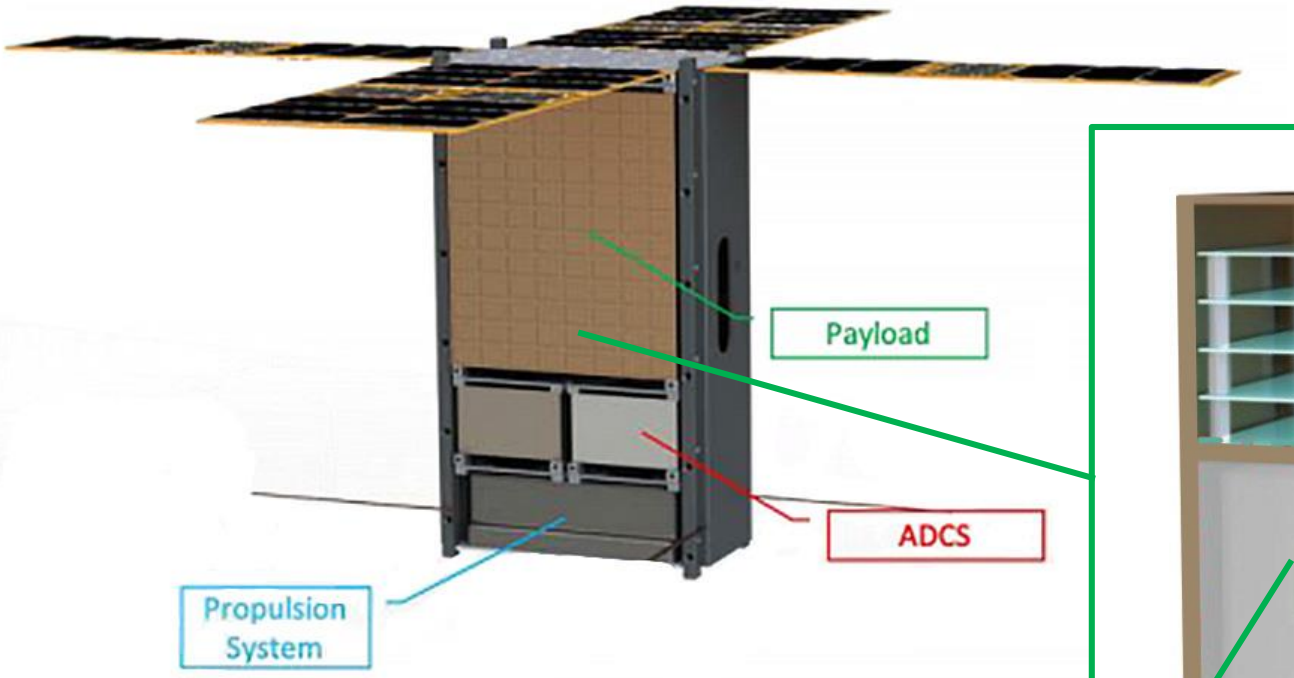
- Pathogenic bacteria, single-cultured or co-cultured with probiotic bacteria
- Probiotic bacteria with or without a radiation-protection agent
- Radiation-resistant yeast with or without a radiation protection agent
- Cyanobacteria (*Chroococcidiopsis* sp. 029) as an extremophile positive control



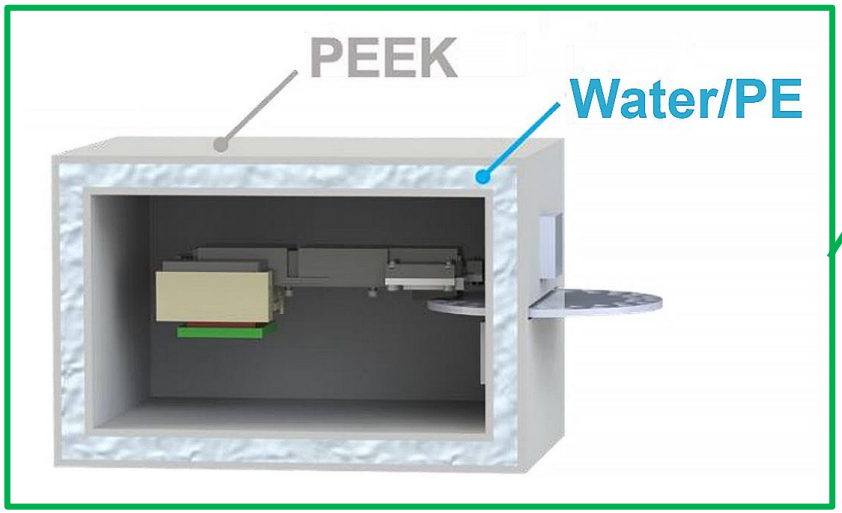
All microorganisms will be genetically engineered to express Green Fluorescent Protein (GFP) variants and observed at the microscope.

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

The project BOREALIS: scientific payload



Payload



Payload

Conclusions

- The development of scientific payloads based on the lab-on-chip technology for executing biological experiments on CubeSats exploiting luminescent genetically engineered cells opens new scenarios where minor effort will be required to plan multiple low-cost missions for increasing the statistical significance of experiments and testing new protection strategies.

- The proposed approach builds on the heritage of other projects funded by ASI, such as In Situ, Pleiades, AstroBio CubeSat, and Aphrodite.

- A much wider range of applications can be envisaged for the proposed technology, since the scientific payloads will be highly versatile, able to operate in Cubesats but also easily implemented in robotic and manned exploration missions.

Open issues

Because CubeSats usually reach space as secondary payloads, there is often a long stasis period (weeks to months) between loading the biology and launch.

Acknowledgements

Project partners

SAPIENZA
UNIVERSITÀ DI ROMA

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

TOR VERGATA
UNIVERSITÀ DEGLI STUDI DI ROMA

UNIVERSITY
OF TWENTE.

Funding

Funded by the
European Union

The **ALCYONE project** is funded by the European Union's Horizon Europe programme under grant agreement No. 101082679

The **BOREALIS project** is funded by the Italian Space Agency's Future Missioni per Cubesat programme

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

Dipartimento Chimica "Giacomo Ciamician"

mara.mirasoli@unibo.it