Space Biology Research in CubeSats

Marta Del Bianco

www.asi.it

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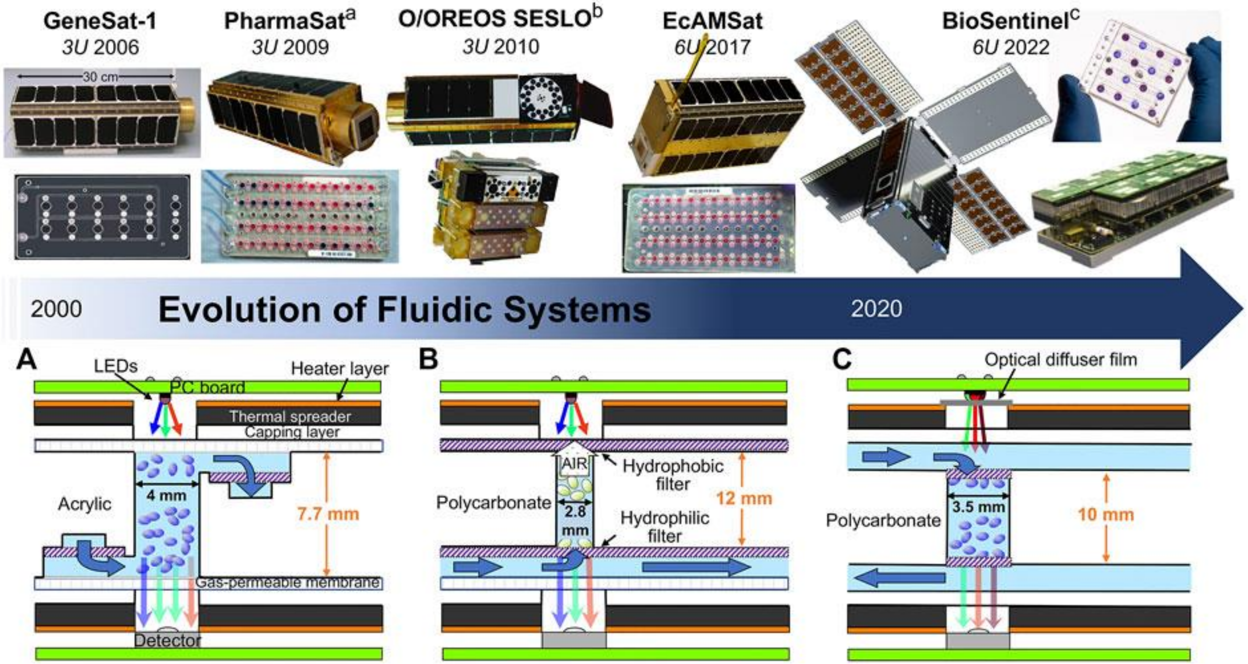


GeneSat-1

NASA 3U CubeSat

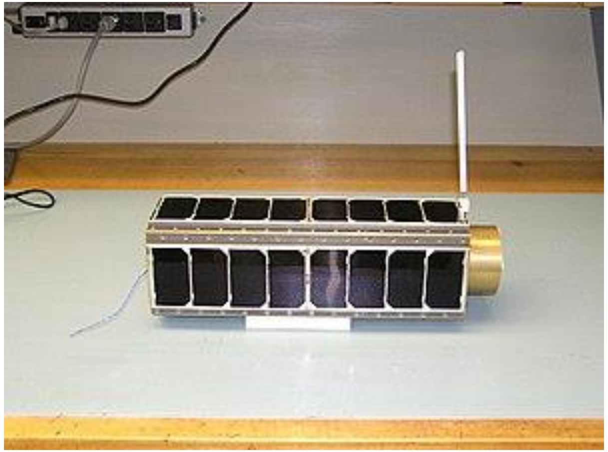
Launch mass	4.6 kg
Dimensions	10cm × 10cm × 34cm
Power	4.5 watts
Launch date	16 December 2006, 12:00:00 UTC
Rocket	Minotaur 1
Launch site	Pad 0B at the Mid-Atlantic Regional Spaceport on Wallops Island
Contractor	Orbital Sciences Corporation
End of Mission	4 August 2010 (Decay date)

Orbital parameters

Reference system	Geocentric orbit
Regime	Low Earth orbit
Average altitude	416.5 km
Inclination	40.0°
Period	92.9 minutes

NASA first fully automated, self-contained biological spaceflight experiment on a satellite of its size.

The nanosatellite contained an onboard micro-laboratory system that provided life support for bacteria E. coli K-12 and carried sensors and optical systems to detect fluorescence proteins.



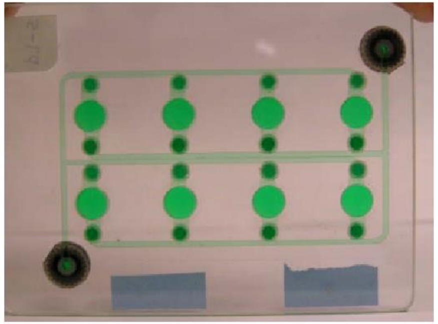


Figure 4 Fluidics card

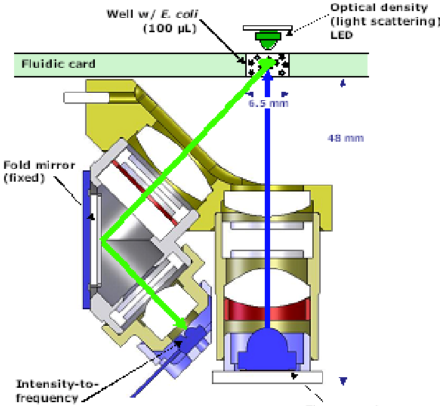


Figure 5 Fluorescent/visible optical detector

https://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=1502&context=smallsat

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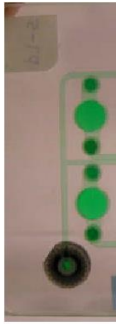


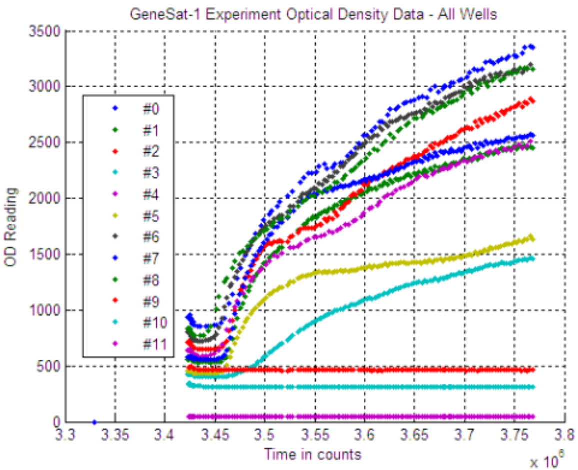


Figure 15: 96-hour Optical Density

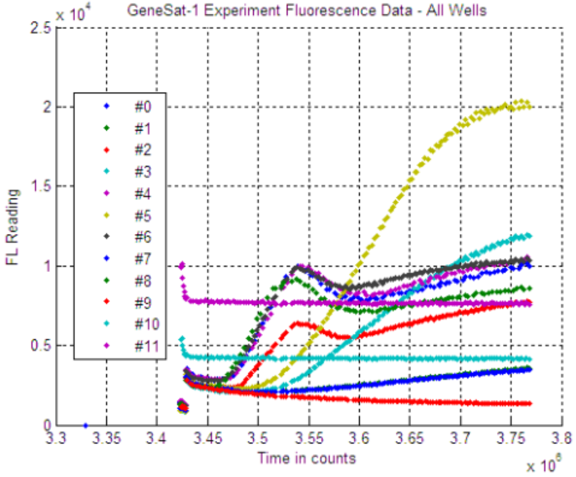
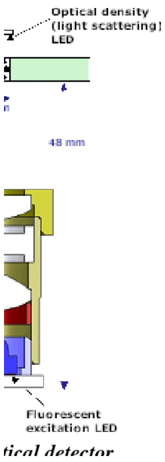


Figure 16: 96-hour Fluorescence



O/OREOS SESLO

NASA 3U CubeSat

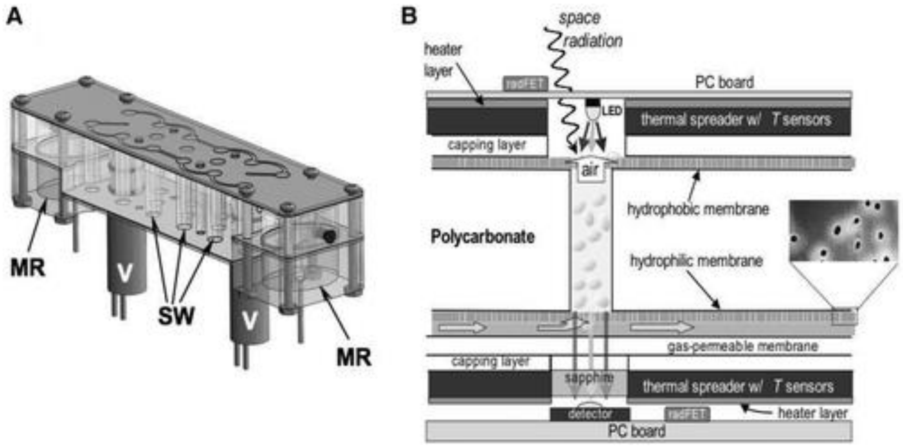
Launch mass	5.5 kg
Dimensions	10cm × 10cm × 34cm
Power	4.5 watts
Launch date	20 November 2010, 01:25 UTC
Rocket	Minotaur IV
Launch site	Kodiak, LP-1
Contractor	Orbital Sciences Corporation

Orbital parameters

Reference system	Geocentric orbit
Regime	Low Earth orbit
Average altitude	630 km
Inclination	72°
Period	97.7 minutes

A self-contained pressure vessel which provides life support (air pressure, humidity, growth media, and temperature control) for *B. subtilis* for six months. The samples, in 24 wells on a rotating carousel, were imaged regularly with UV/VIS spectroscopic instrumentation.

Additional payload: amateur radio beacon (437.305 MHz)



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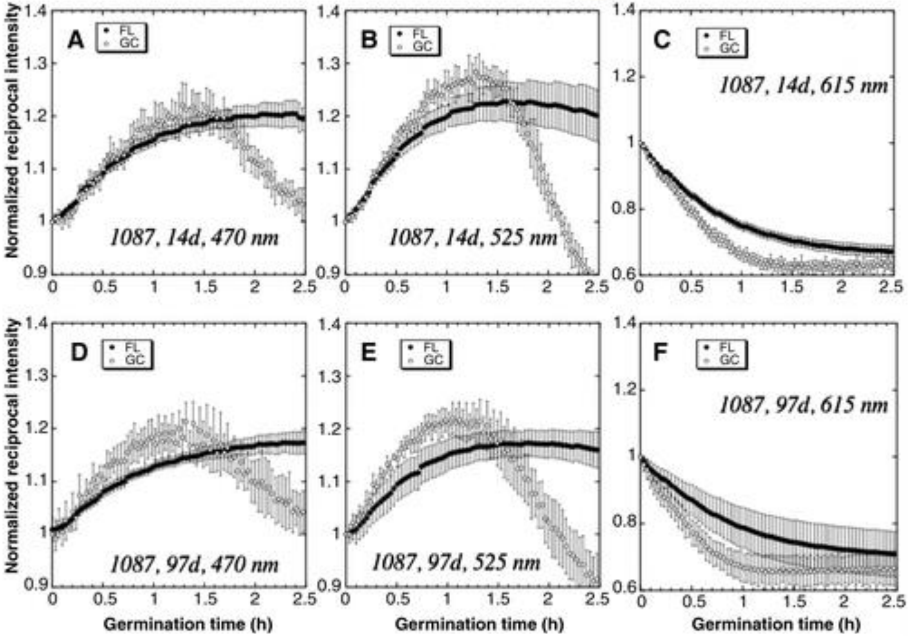
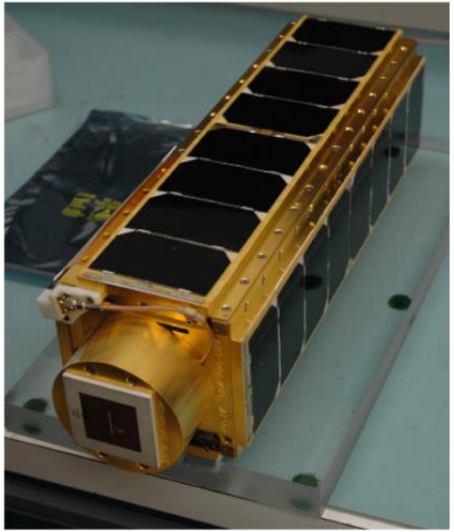


FIG. 4. SESLO data, B. subtilis ykoUykoV mutant strain WN1087 spores. Flight (FL; filled circles) and ground control (GC; open circles) data for SESLO bioblock module 1, activated at Day 14 post-launch (top row A–C) and bioblock module 2 activated at Day 97 post-launch (bottom row D–F). Data were taken at 470 nm (A, D), 525 nm (B, E), and 615 nm (C, F). Data points are averages ± standard deviations (n=4 for B/FL; n=5 for E/FL; n=6 for all others).

PharmaSat

NASA 3U CubeSat	
Launch mass	4.5 kg
Dimensions	10cm × 10cm × 34cm
Power	4.5 watts
Launch date	19 May 2009, 23:55 UTC
Rocket	Minotaur 1
Launch site	Pad 0B at the Mid-Atlantic Regional Spaceport on Wallops Island
Contractor	Orbital Sciences Corporation
End of Mission	14 August 2012 (Decay date)
Orbital parameters	
Reference system	Geocentric orbit
Regime	Low Earth orbit
Average altitude	459 km
Inclination	40.4°
Period	93.52 minutes

It contained a controlled environment micro-laboratory with a microfluidics system consisting of a 20.32x10.16 cm plastic card with 48 wells for yeast growth and tubes for growth solution and anti-fungal agent input. It also contained sensors and optical systems to detect the growth, density and health of yeast cells.
Additional payload: amateur radio beacon (437.465 Mhz)



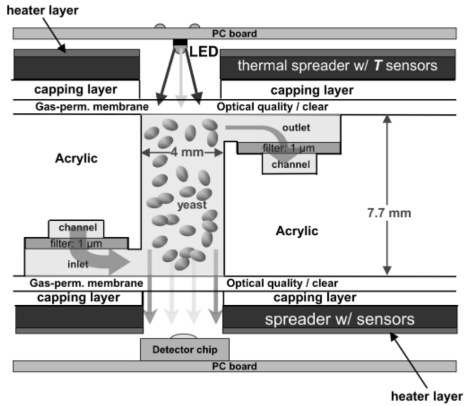
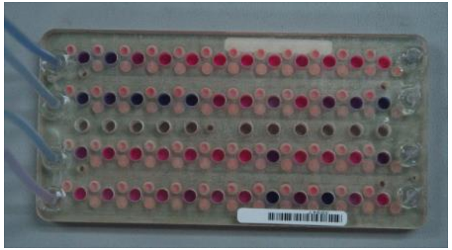


Figure 3: Microfluidic, optical, and thermal cross section of one of 48 wells; each contains 100 µL and has integral 1.2-µm filter membranes at inlet and outlet to confine the yeast. RGB LED and detector pair at opposite ends of each well measure 3-color transmittance. Patterned Kapton heaters plus aluminum thermal spreaders give < 0.3 °C temperature uniformity across the card.



https://doi.org/10.31438/trf.hh2010.31
https://www.nasa.gov/pdf/331108main_pharmasat_Fact%20Sheet_FINAL.pdf

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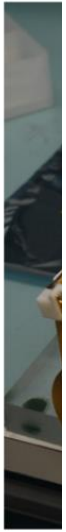


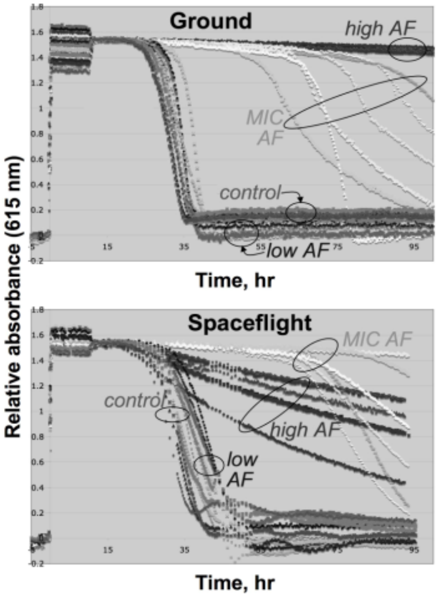


Figure 8: Terrestrial (top) and spaceflight (bottom) growth curves for S. cerevisiae at 27 °C in RPMI growth medium as a function of voriconazole antifungal concentration. 6 wells are tracked for each condition: "Control" includes no AF; "low AF", "MIC", and "high AF" correspond to 0.13, 0.50, and 2.0 μg/mL concentrations of voriconazole, respectively. (Circles and ellipses indicate sets of growth curves for each labeled condition).

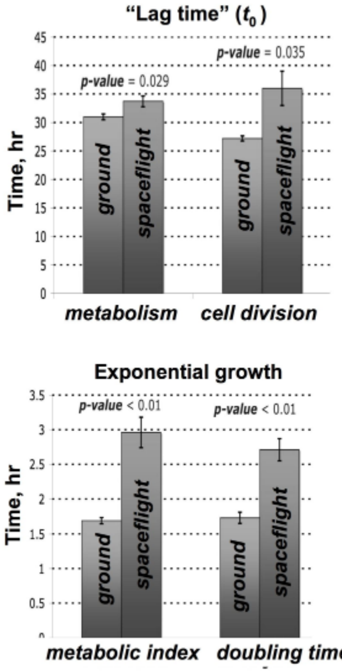


Figure 9: Comparison of "lag time" before yeast growth begins (top) and the time constant of the exponential growth phase (bottom) for ground and spaceflight measurements with zero antifungal agent concentration.

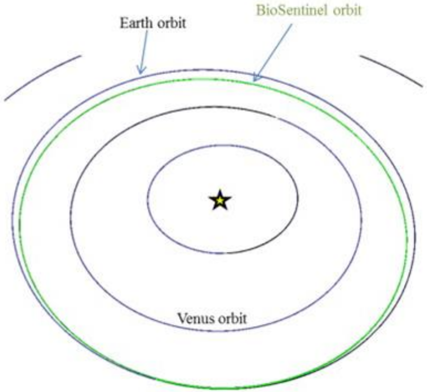
https: s:/ 31 masat_Fact%20Sheet_FINAL.pdf

BioSentinel

NASA 6U CubeSat
Launch mass 14 kg
Dimensions 10cm × 20cm × 34cm
Power 30 watts
Launch date 16 November 2022, 06:47:44
Rocket SLS Block 1
Launch site Kennedy Space Center LC-39B
Orbital parameters
Reference system Heliocentric orbit

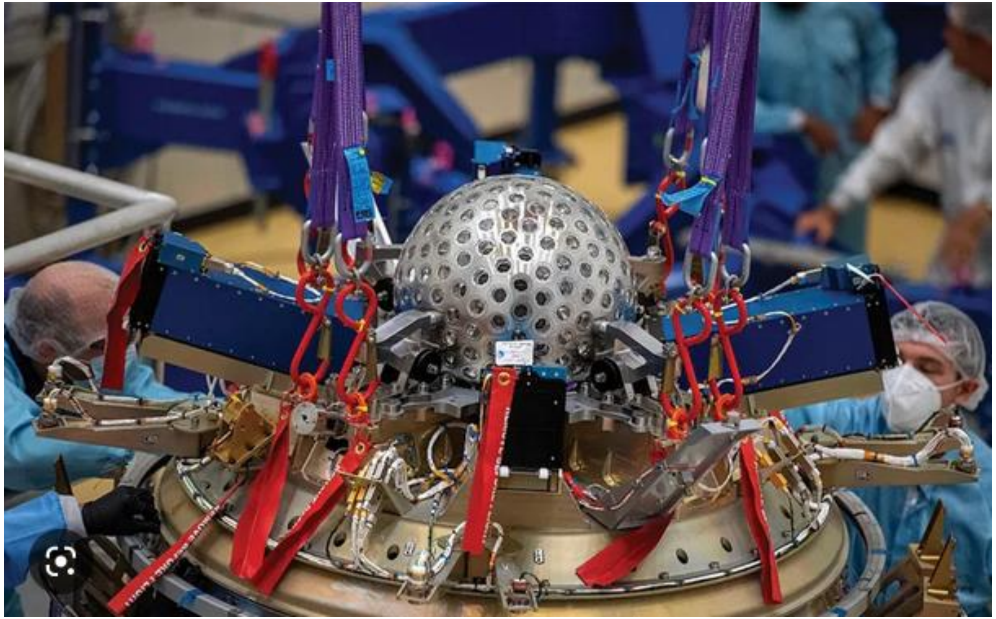
Of the total 6 Units volume, 4 Units held the science payload, including a radiation dosimeter and a dedicated 3-color spectrometer for each well; 0.5U housed the ADCS (Attitude Determination and Control Subsystem), 0.5U housed the EPS (Electrical Power System) and C&DH (Command and Data Handling) avionics, and 1U housed the attitude control thruster assembly, which was 3D printed all in one piece: cold gas (DuPont R236fa) propellant tanks, lines and seven nozzles.

The BioSentinel biosensor uses the budding yeast Saccharomyces cerevisiae to detect and measure DNA damage response after exposure to the deep space radiation environment.



- Final orbit of secondary's to be determined
- Will likely be Earth-interior, heliocentric orbit
- Far outside the LEOs typically occupied by CubeSats
  - Range to Earth of 0.73 AU at 18 months
  - Far outside the protective shield of Earth's magnetosphere

Vega-C Maiden Flight – Kourou, French Guiana 13/07/2022



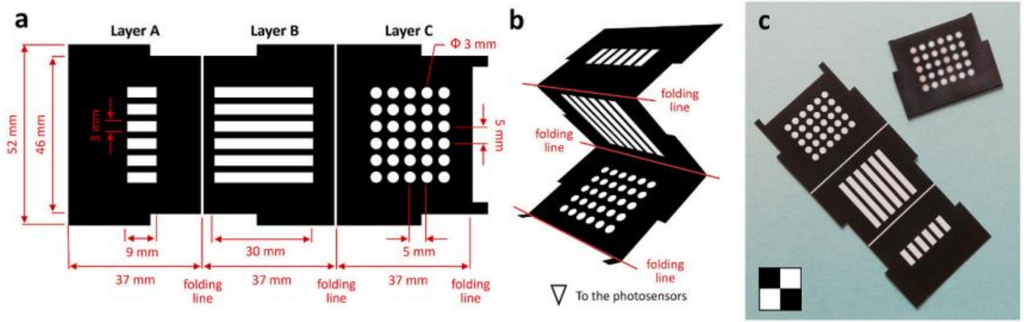
Vega-C Maiden Flight – Kourou, French Guiana 13/07/2022

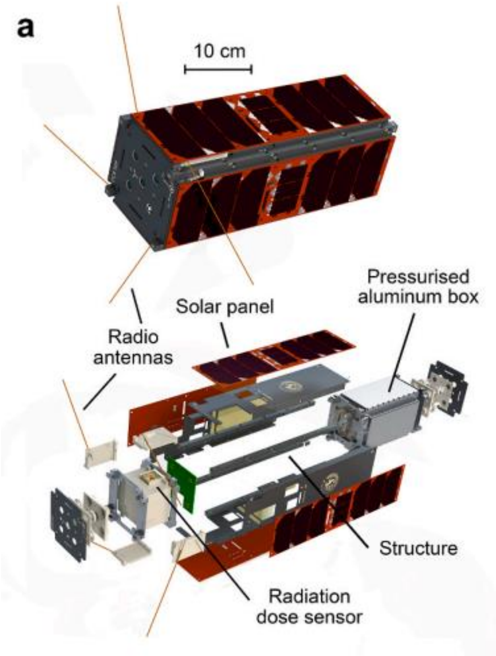
AstroBio Cube Sat (ABCS)

- 3U CubeSat design (30x10x10 cm)
- Mission VEGA-C Maiden Flight (LARES2) 13 July 2022
- 6000 km circular orbit

Fully autonomous lab-on-chip platform for performing chemiluminescence-based bioassays in space.

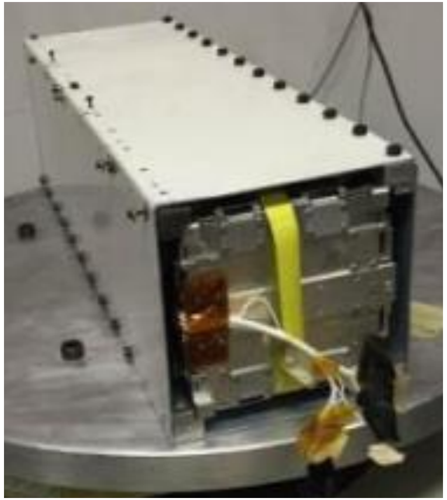
An origami-like microfluidic paper-based analytical format allowed preloading all the reagents in the dried form on the paper substrate, thus simplifying device design and analytical protocols, facilitating autonomous assay execution, and enhancing the stability of reagents.

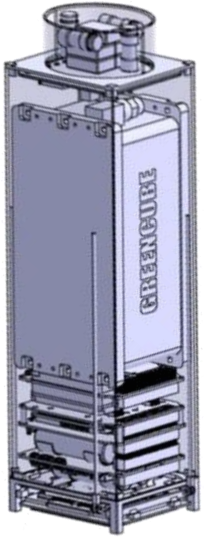




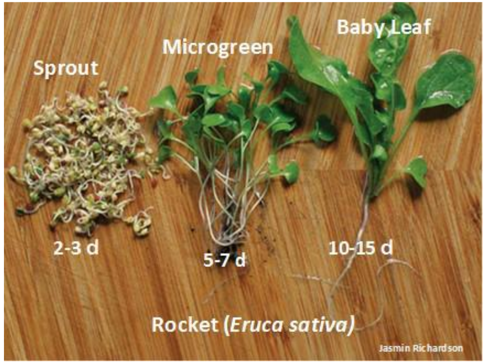
https://doi.org/10.1016/j.bios.2023.115110

Green Cube

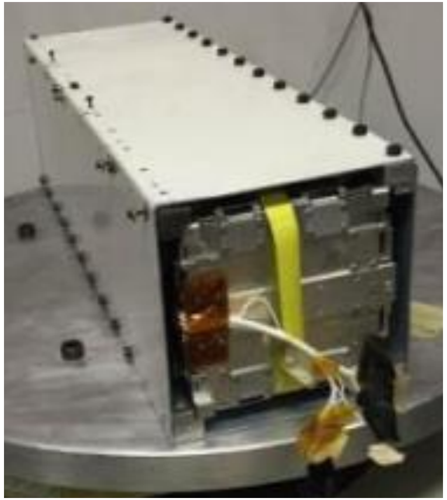


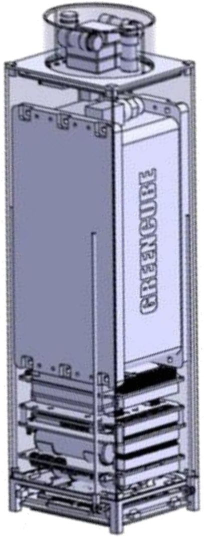


- 3U CubeSat design (30x10x10 cm)
- Mission VEGA-C Maiden Flight (LARES2) 13 July 2022
- 6000 km circular orbit
- Closed hydroponic system
- Growing room with O_2, VOCs, Pressure, Temperature, Humidity, CO_2 sensors to monitor plants state
- Equipped with IR and VIS cameras
- Growth to Microgreen stage



GreenCube





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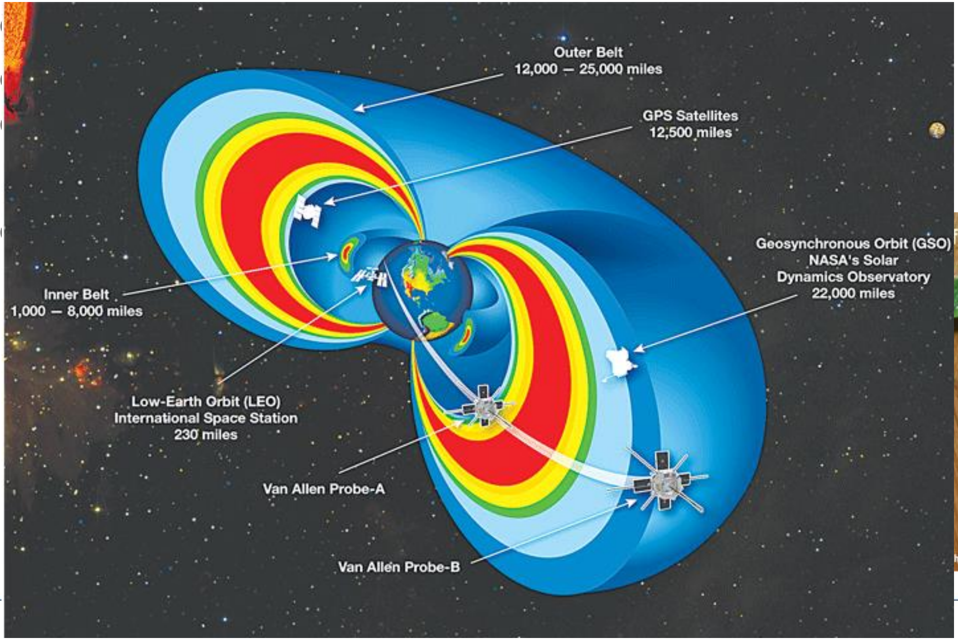

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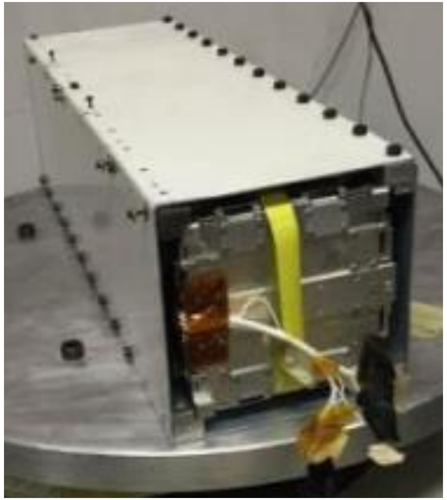

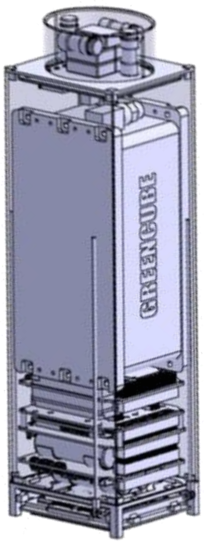

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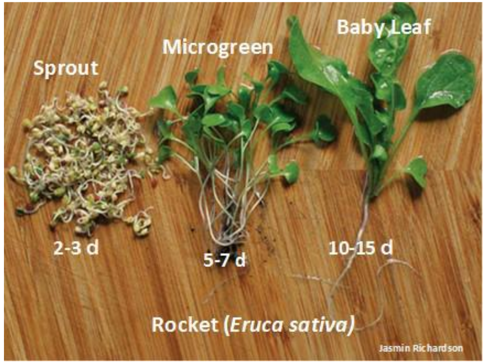
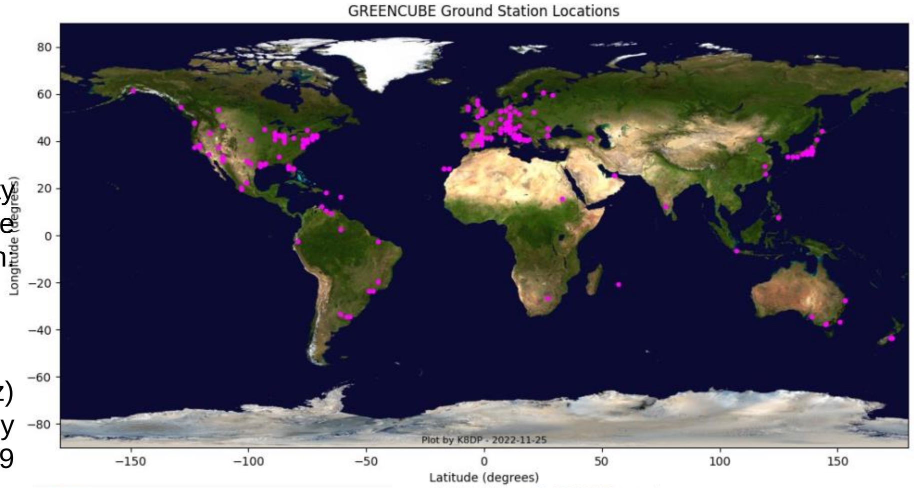


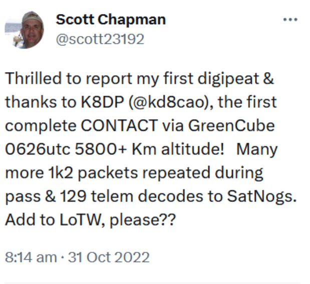
GreenCube

GreenCube - Digipeater

GreenCube telecommunication subsystem has a digipeater functionality available to the radioamateur community. It can operate in real-time mode and in "store & forward" mode and requires an amateur radio station with:
– Windows PC
– Directional antenna (10 dBi at least recommended)
– Audio connection between transceiver and PC.
The frequency is the same used in the telemetry channel (435.310 MHz) and the activation of the digipeater function is scheduled at least every week during the weekends (from Friday at 00:01 UTC to Sunday at 23:59 UTC), with possible extensions.
The software needed to communicate with the satellite, plus technical guide of the setup and the GUI features (GreenCube_Digipeater.zip), is for download here: https://www.s5lab.space/index.php/digipeater/ . It contains the user manual, Graphical User Interface (GUI), Terminal Node Controller (TNC) software, and GNURadio script to receive and transmit. Alternative software can be found online.
The **GreenCube** satellite also has the name **IO-117**, given by AMSAT https://www.amsat.org/greencube-designated-italy-oscar-117-io-117/ .
The unique feature of the high altitude of the orbit results in a much longer visibility time than in the case of the LEO satellite IO-117, which will enable communication at distances of up to 12,500 km.

https://hf5l.pl/en/greencube-satellite/





Conclusions

The CubeSat technology can be a cost-effective way of performing biological experiments in Space.

CubeSats allow to access conditions that would otherwise be impossible to simulate on ground or onboard the ISS, like MEO.

While the use of off-the-shelf CubeSat components are the reason why this technology is affordable, new technologies for miniaturized microfluidic systems, sensors and imaging systems should be developed to enable more in-depth biological studies. These systems could also be used for applications in orbiting stations, where the drive for miniaturization is still very strong.

KAYSER ITALIA | DI C Ma PI | FONDAZIONE E.AMALDI

Fluorescence Microscope | Cytometer | Raman-based Spectrometer

Cubesat Technology can be used as payload hardware for experiments onbard the ISS.

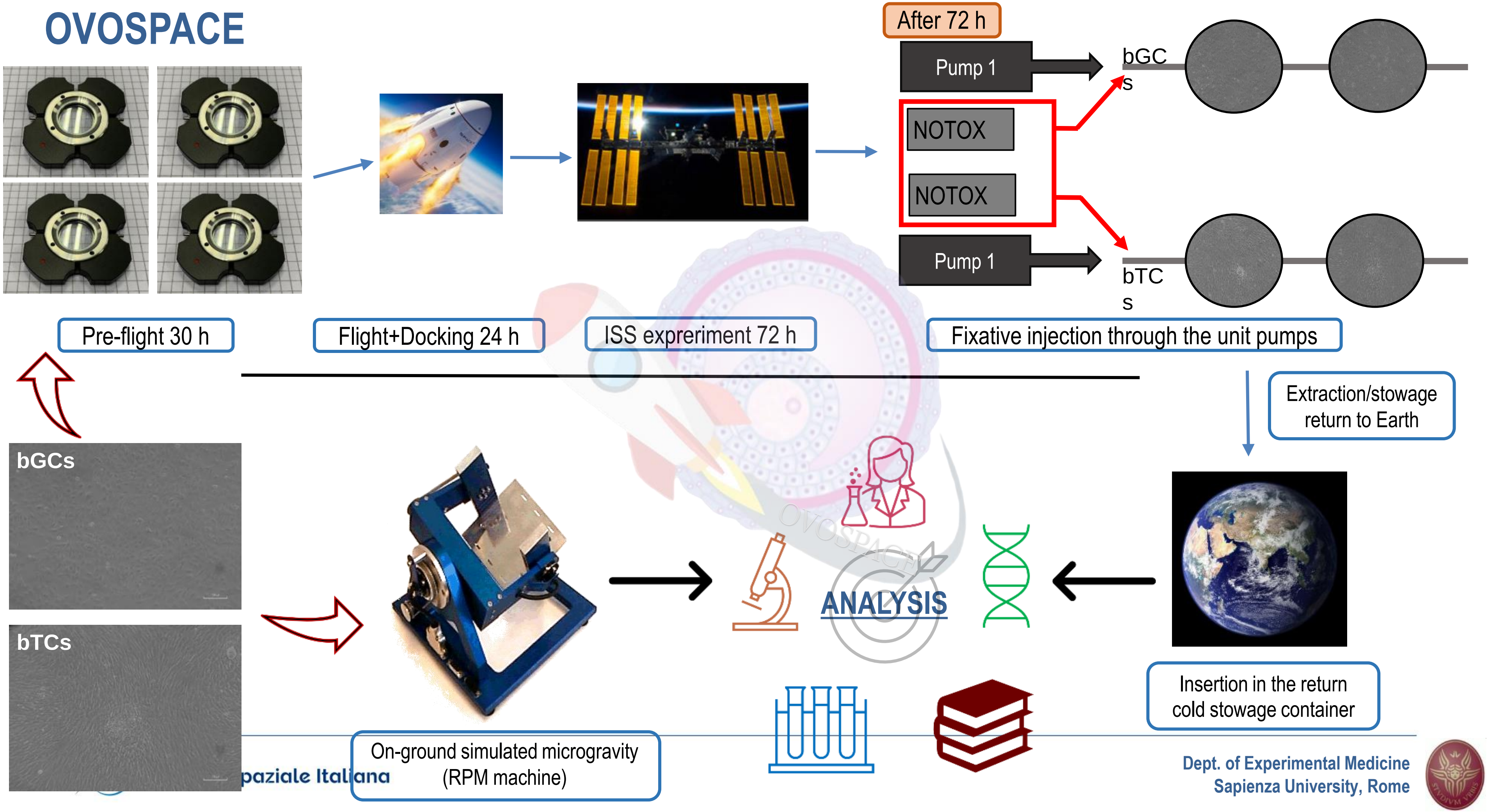
OVOSPACE

Human settlements in other satellites (Moon) or planets (Mars) could impair the **fertility** of Astronauts (both men and females) living for prolonged times in a condition of weightlessness. This threatens the objective of establishing permanent/extended settlements outside the Earth.

How microgravity influences ovary cells **maturation**.

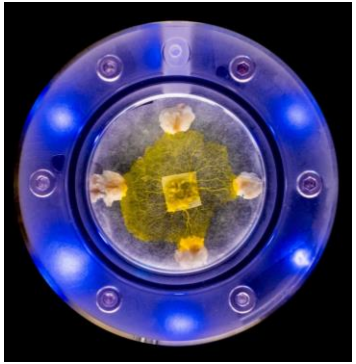
The **OVOSPACE** project will investigate how Granulosa cells (GCs) and Theca cells (TCs) from mammalian ovaries could be affected in their **endocrine function** when exposed to microgravity

OVOSPACE



Dept. of Experimental Medicine
Sapienza University, Rome

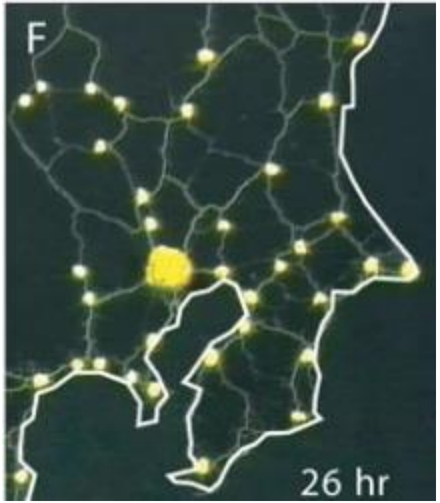
SpaceSlime



Plates containing dormant (dehydrated) slime mould (P. polycephalum) will be uploaded to the ISS. Slime mould does not require temperature control or gas exchange, the hardware will be completely automated and self-contained.

After activation (addition of water), the experiment runs for 2-4 days: the slime moulds will be let to grow and imaged regularly. Image download, at least partial, would be preferable for experiment monitoring.

The experiment is stopped by fixation (RNAlater).



Thank you for your attention

ASI
Agenzia Spaziale Italiana
Via del Politecnico snc
00133 Roma, Italia

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