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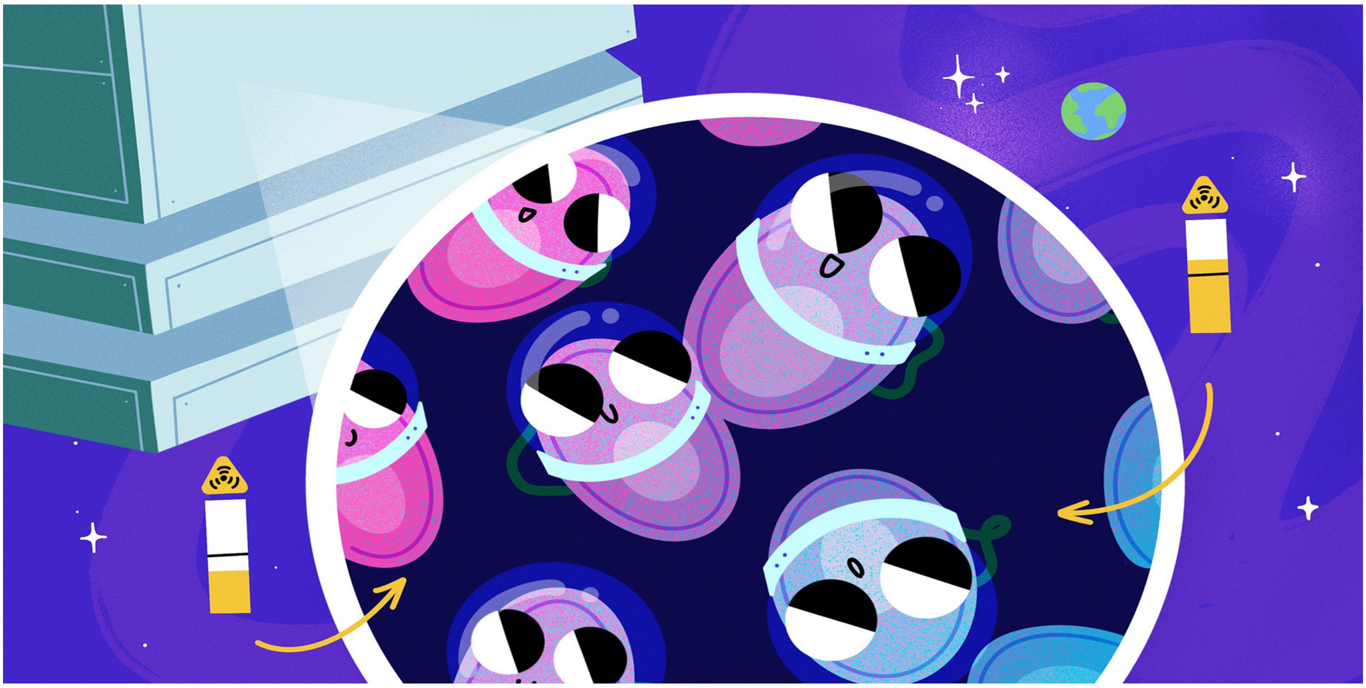

MEET BIOSENTINEL: THE FIRST BIOLOGICAL EXPERIMENT IN DEEP SPACE

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AGE: 13


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AGE: 10


RANJAI
AGE: 14


RANVIR
AGE: 14

Recently, NASA launched a rocket called Artemis-I toward the Moon! The mission objective was to test the safety of the Space Launch System for future human travel into deep space. But vehicle safety is not the only concern for space travelers. Space radiation is an invisible danger to astronauts because it can damage the body's cells and potentially lead to serious health problems. How do we study the effects of space radiation on cells? Meet BioSentinel! BioSentinel is a small satellite deployed from Artemis-I that carries yeast cells and a sensor to measure space radiation. The job of BioSentinel is to transmit data from the cells in deep space back to Earth. In this article, we will explore the BioSentinel mission, discuss how the data are obtained and transmitted, and give examples of how the data from BioSentinel will help scientists better understand the effects of space radiation on living things.

Did you know that scientists are sending living organisms into space, to study how space **radiation** affects life forms [1]? It is true! Recently, the National Aeronautics and Space Administration (NASA) deployed a small **satellite**, called BioSentinel, from the Artemis-I rocket. BioSentinel carried yeast cells into space, to help scientists learn more about the effects of space radiation. This article will explore the BioSentinel mission and why it is important for space travel.

RADIATION

Transmission of energy through waves or traveling fast particles.

SATELLITE

An object that goes around (orbits) a planet.

WHAT IS THE BIOSENTINEL MISSION?

The Artemis-I rocket (Figure 1A) started its journey to the Moon on November 16, 2022. The aim of the mission was to test the safety of the Space Launch System for future human journeys into deep space. Vehicle safety, however, is not the only risk for space travelers. Astronauts are exposed to radiation while they are in space, which can lead to serious health effects. Therefore, alongside the primary launch objectives of Artemis-I, small satellites were also deployed to test other risks of space travel, with BioSentinel being one of them. The BioSentinel satellite consists of a shoe box-sized unit (Figures 1B, C) that holds yeast cells and the necessary electronics and solar panels to power the satellite in space.

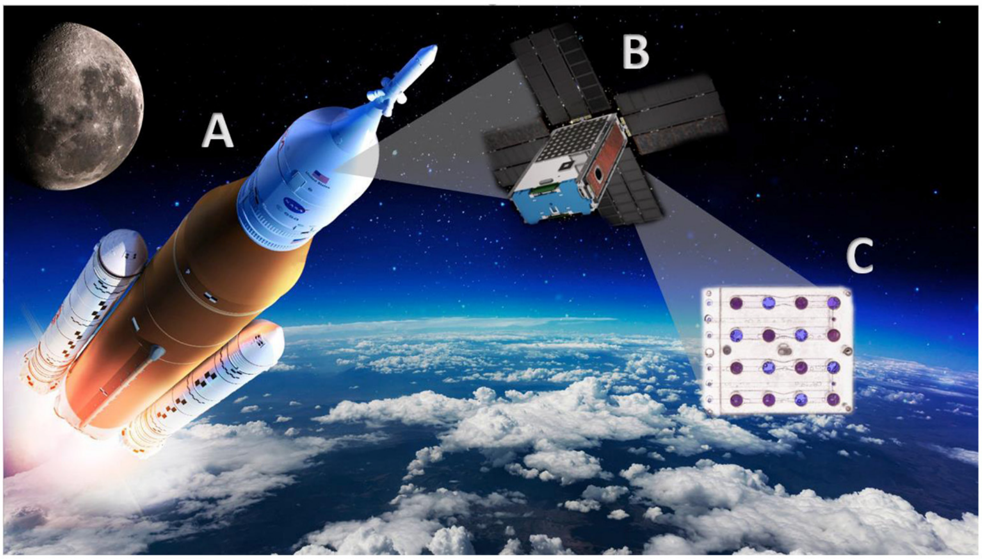

Figure 1

Figure 1

(A) The Artemis-I rocket was sent to space with the main mission of testing the safety of the Space Launch System. **(B)** Artemis-I also deployed BioSentinel, a shoe box-sized satellite. **(C)** BioSentinel was loaded with yeast cells, to study the effects of space radiation on living things in deep space. BioSentinel also has solar panels for power and contains the electronics necessary to send information back to Earth (Image Credit: adapted from NASA.gov).

WHY STUDY SPACE RADIATION?

Space radiation consists of **solar particles** originating from the Sun and **galactic cosmic rays** originating outside our solar system. (For more information on space radiation, see this Frontiers for Young Minds article.) Space radiation includes high-energy particles that travel through space at very high speeds and can pass through things like

SOLAR PARTICLES

Energetic particles released from the Sun into space.

GALACTIC COSMIC RAYS

High energy particles of different types originating from outside of our solar system that travel through space at very fast speeds.

spacecrafts and the spacesuits of astronauts [2]. Space radiation can harm humans and other living things if they are exposed to it for too long, because it can damage **DNA** and other important cell parts. (To learn more about space flight health risks see this Frontiers for Young Minds article.) DNA damage can lead to serious health problems like cancer. Most of the time, cells fix damage correctly; but in some cases, damage is too complex for the cell to repair. In these cases, the cell might die or repair itself incorrectly, leading to **mutations** in its DNA. Cells with mutations can start multiplying uncontrollably, and that is how cancer forms over time. Many of the health problems caused by space radiation, like cancer, are delayed effects—so astronauts would not get sick until later in their lifetimes, after they have returned to Earth. By studying space radiation, scientists hope to learn more about how it affects living things and how to protect astronauts.

DNA

A molecule found in the nucleus of living organisms that contains genetic information (genes) telling living organisms how to look and function.

MUTATION

Changes in the DNA of organisms that can make the cells function differently.

HOW DOES BIOSENTINEL STUDY SPACE RADIATION?

BioSentinel uses yeast cells (Figure 2D) to study how living things respond to space radiation [3]. Yeast cells are single-celled organisms commonly used to help bread dough rise or in the fermentation process used to make beer. The type of yeast used in BioSentinel is frequently used in research in many types of labs around the world. It was the first organism to have its DNA fully sequenced, for example. Yeast cells are important in scientific experiments because they share many similarities with human cells, and therefore the results obtained from yeast cells can give us clues about human health. Yeast cells can withstand the rigors of space travel, especially since they can be dried out and only activated by liquid when they are needed. Yeast cells can also be modified to make them either more sensitive or more

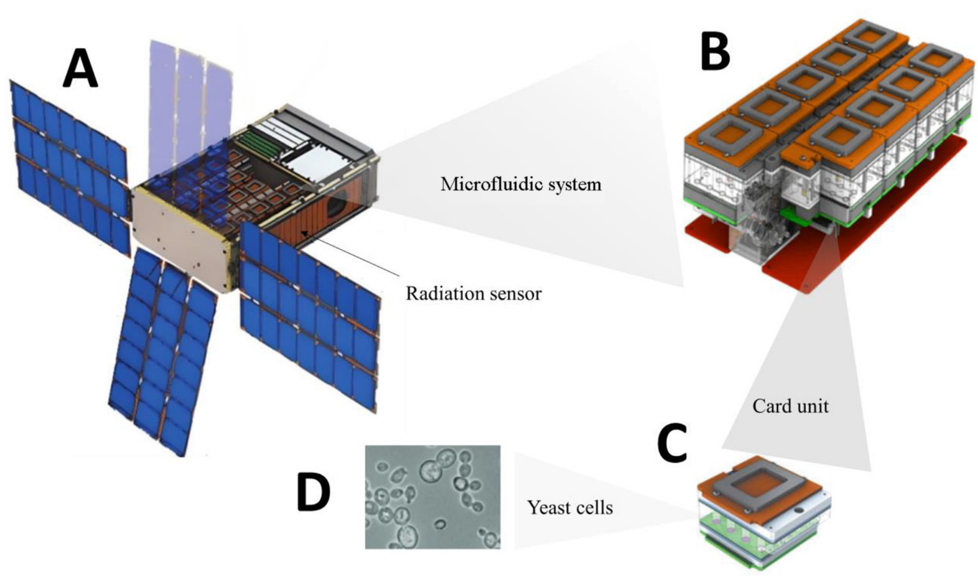

Figure 2

Figure 2

(A) BioSentinel contains a radiation sensor, to measure space radiation, and microfluidic cards containing yeast cells, to monitor the effects of space radiation on living cells. **(B, C)** The microfluidic system is made up of multiple smaller card units, and it can deliver nutrient-containing fluids to the yeast cells to help them survive. The microfluidic system also delivers the dye used for measuring DNA damage in response to space radiation. **(D)** Yeast cells (Image Credit: Adapted from NASA.gov).

resistant to space radiation, to better understand how human cells might respond to space missions.

In BioSentinel, the yeast cells are placed in special containers called **microfluidic cards**, where the cells receive the nutrients needed to stay alive (Figures 2B, C). As discussed earlier, space radiation can damage DNA. Damage to yeast DNA can change their **metabolic activity**, meaning how they change nutrients into energy. A special dye is delivered to the microfluidic cards, which changes color based on the metabolic activity of the yeast cells [1, 3]. Monitoring the change in metabolic activity allows scientists to see how space radiation affects the yeast cells (Figure 3). Additionally, there is a radiation sensor inside BioSentinel that measures the space radiation (Figure 2A). Data from the microfluidic cards and the radiation sensor are sent back to Earth, where scientists can analyze those data to see how radiation causes DNA damage and how the yeast cells respond.

MICROFLUIDIC CARD

Container in the BioSentinel that provides fluid and nutrients to keep the yeast cells alive.

METABOLIC ACTIVITY

The chemical reactions in cells that help to convert nutrients into energy for survival.

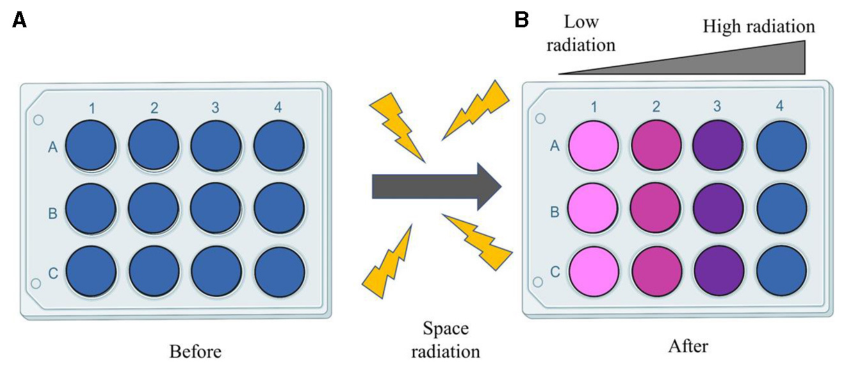

Figure 3

Figure 3

(A) To monitor the response of yeast cells to radiation during the BioSentinel mission, a special blue dye is added to the microfluidic cards. **(B)** When yeast cells are healthy and metabolically active (using nutrients to survive and grow), the dye changes from blue to pink. **(B)** However, if radiation damages yeast DNA, the rate of metabolic activity can change. The cells with damage remain blue longer, while the cells not affected by radiation turn pink faster.

WHAT HAPPENS AFTER THE BIOSENTINEL MISSION?

The Artemis-I spacecraft has safely returned to Earth, but BioSentinel will remain in space collecting data. The mission is set for 6 months, during which data from the radiation sensor and microfluidic cards are periodically transmitted to Earth. After the mission is complete, scientists will analyze all the data to learn more about how space radiation affects living things. Furthermore, the data will be compared to experiments on Earth and on the International Space Station, and also compared with computer simulations of the radiation-containing space environment. These data, together with information from other space studies, could be used to develop new ways to protect astronauts from radiation during long space missions—to the Moon, Mars, and beyond! Data could also have important implications for cancer research and other areas of human health related to space travel.

CONCLUSION

The BioSentinel mission is an exciting project that aims to study the effects of space radiation on living organisms. By sending yeast cells into deep space, scientists hope to learn more about how radiation affects cells and how to protect astronauts on long-duration space missions, as NASA prepares astronauts to return to the Moon and eventually travel to Mars and beyond. The results of the BioSentinel mission could have important implications for human health, and we cannot wait to see what scientists learn from this groundbreaking mission.

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CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS

ABYAN, AGE: 13

Hi, I am Abyan! I like science, specifically space related science, and physics! I also like mathematics and English. I would say that I am an independent person who loves new challenges. An example would be that I just recently started playing competitive tennis. I have a pet cat named Astro and I love spending time with him! In my free time, I play and interact with my friends and read about new space discoveries.

BAIRON, AGE: 10

I am from Beaverton, Oregon. I love learning different fun facts about science. In my leisure time, I like playing tennis and coding. I also love to participate in events outside the science field. I participated in the event called "Oregon Battle of the Books" last year, 2023, and our team represented our elementary school in the regional contest. I also submitted an essay for the essay competition held by the Oregon government and my essay was selected to publish in the Oregon Blue Book 2023. I was also invited to the Capital of Oregon for a ceremony and saw lots of Senates.

RANJAI, AGE: 14

Ranjai loves math, chess, and physics and is especially a big fan of the NASA labs and space explorations.

RANVIR, AGE: 14

Ranvir loves origami models, reptiles, insects, and every specimen in his biology lab.

AUTHORS

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TONY SLABA

Dr. Tony Slaba is a research physicist at NASA Langley Research Center, working in the areas of space radiation physics, particle transport, experimental radiobiology, and risk assessment. He received his Ph.D. in computational and applied mathematics from Old Dominion University in 2007, and he has authored or contributed to over 60 peer reviewed journal articles since 2010. He currently serves as a council member for the National Council for Radiation Protection and Measurements.

TORE STRAUME

Dr. Tore Straume recently retired from NASA, where he served as senior scientist for the Space Biosciences Division at the NASA Ames Research Center in Mountain View, CA. During his almost 50-year career in science, Dr. Straume served in various senior scientist positions at the Lawrence Livermore National Lab and also as a university professor. Dr. Straume holds an M.S. in radiological sciences from the University of Washington and a Ph.D. in radiation biophysics from the University of California.

SHARMILA BHATTACHARYA

Dr. Sharmila Bhattacharya was originally the principal investigator for the BioSentinel mission, and she now serves as the program scientist for space biology in the Biological and Physical Science Division at NASA Headquarters. Dr. Bhattacharya has served as the space policy advisor to the U.S. Senate Committee for Commerce, Science, and Transportation. She has been a principal investigator and senior scientist at NASA, conducting research on the space shuttle, the International Space Station, and small satellites journeying beyond low-Earth orbit. Dr. Bhattacharya conducted her post-doctoral research in neurobiology at Stanford University and earned her Ph.D. in molecular biology at Princeton University.

SERGIO R. SANTA MARIA

Dr. Sergio Santa Maria is a research scientist at the Space Biosciences Division, NASA Ames Research Center. He is currently the principal investigator for the BioSentinel mission in addition to other NASA Space Biology projects. He is also a co-principal investigator in an upcoming mission to the Moon named LEIA, which will use similar technologies originally developed for BioSentinel to investigate the response of living organisms to the reduced gravity and radiation environment of the lunar surface. Dr. Santa Maria is originally from Lima, Peru, and earned his Ph.D. in molecular genetics from the University of Texas Medical Branch, Galveston, Texas.