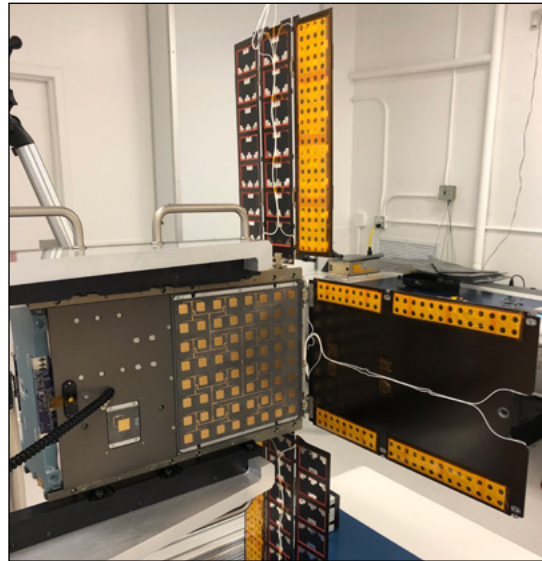




BioSentinel

The BioSentinel mission was selected as one of the secondary payloads, and the sole biological experiment, to fly on the Space Launch System's first Exploration Mission (EM-1) planned to launch in 2020. The primary objective of BioSentinel is to develop a biosensor to detect and measure the impact of space radiation on living organisms over long durations beyond Low Earth Orbit (LEO). While progress identifying and characterizing biological radiation effects using Earth-based facilities has been significant, no terrestrial source can fully simulate the unique radiation environment encountered in deep space.

The BioSentinel biosensor utilizes the budding yeast *Saccharomyces cerevisiae* to query the biological response to ambient deep space radiation, including the formation of double strand breaks (DSBs). DSBs are deleterious DNA lesions that are generated by exposure to highly energetic particles in the deep space radiation spectrum, and that are often repaired without errors by the cell. The biosensor contains two genetically engineered yeast strains: a wild type strain that serves as a control for yeast health and "normal" DNA damage repair, and a *rad51* deletion strain, which is defective for DNA damage repair, and will therefore undergo alterations to growth and metabolism as it accumulates radiation damage. These changes will be detected by the biosensor payload.



The BioSentinel spacecraft undergoes a mechanical fit-check test.

In the BioSentinel payload that will fly on the EM-1 mission, dry yeast cells are stored in microfluidic cards inside a 6-Unit (6U) spacecraft, that weighs about 30 pounds. The spacecraft will be deployed from the second stage of the launch vehicle to a lunar fly-by trajectory, from which it will enter an Earth-like heliocentric orbit. After completing the lunar fly-by and spacecraft checkout, the science mission phase begins with the rehydration of the first set of two yeast-containing microfluidic cards. Each card has 16 wells—eight containing the wild type strain, and eight containing the radiation-sensitized strain *rad51Δ*. Each set of fluidic cards is expected to be in its active mode for up to a week following rehydration;

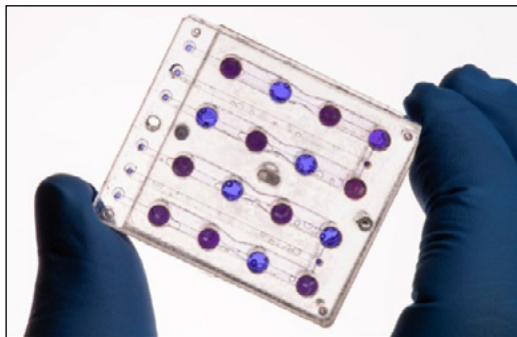


BioSentinel spacecraft leaves Earth and enters a lunar fly-by trajectory into a heliocentric orbit.

sets of cards will be activated at different time points over the 6-12-month mission. One reserve set of cards will be activated in the occurrence of a Solar Particle Event (SPE), a powerful radiation storm that poses a significant risk to astronauts on long-duration deep space missions. Payload science data will be stored onboard the spacecraft and downlinked to Earth via telemetry.

Growth and metabolic activity of the yeast cells will be measured using a 3-color LED detection system and the metabolic indicator dye alamarBlue®. Biological measurements will be compared to radiation data provided by an onboard physical sensor and dosimeter (an LET spectrometer) to obtain total ionizing radiation dose and particle characterization, and to Earth-based experiments using relevant energetic particle types, energies, and doses. Additionally, two identical BioSentinel payloads will be developed: one for the International Space Station (ISS), which will be in similar microgravity conditions but a comparatively low-radiation environment, and one for use as a delayed-synchronous ground control at Earth gravity and Earth-surface-level radiation. Thus, the BioSentinel payload will help calibrate the biological effects of radiation in deep space to analogous measurements conducted on Earth and on the ISS.

BioSentinel will conduct the first study of the biological response to space radiation outside LEO in almost 50 years. BioSentinel will address strategic knowledge gaps related to the biological effects of space radiation, and will provide an adaptable platform to perform human-

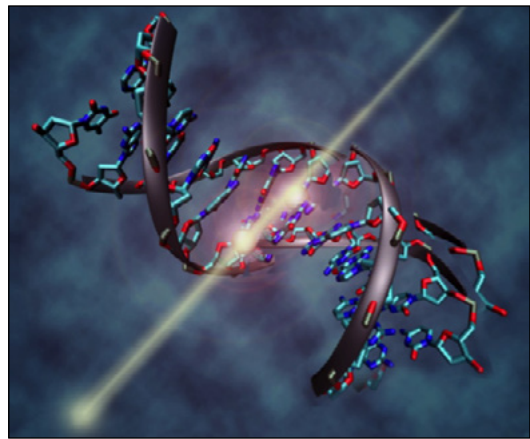


BioSentinel's microfluidics card, designed at NASA Ames, will be used to study the impact of interplanetary space radiation on yeast. Once in orbit, the growth and metabolic activity of the yeast will be measured using a 3-color LED detection system and a metabolic indicator dye. Here, pink wells contain actively growing yeast cells that have reduced the metabolic dye from blue to pink in color.

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Conceptual graphic of a radiation particle causing a DNA DSB.

relevant measurements in multiple space environments in the future, including on lunar and Mars landers and orbiters. Yeast is the ideal organism for this mission because of its spaceflight heritage, well-characterized genetic tools, and its capacity to survive long periods in a desiccated state prior to rehydration and growth activation in space. Importantly, yeast's DNA damage repair process is highly similar to that of humans, making it a robust translational model. BioSentinel's results will be critical for interpreting the effects of space radiation exposure, reducing the risk associated with long-term human exploration, and validating existing models of the effects of space radiation on living organisms.

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