Active Project (2013 - 2019)

BioSentinel Project

Advanced Exploration Systems Program | Human Exploration And Operations Mission Directorate (HEOMD)

ABSTRACT

The Advanced Exploration Systems' (AES) BioSentinel project will develop, prototype, integrate, test, and prepare for the first spaceflight mission of a broadly applicable small satellite-based instrument platform to autonomously perform a range of human-exploration-relevant life-science studies of biological consequences of the space environment beyond low Earth orbit (LEO). The small, autonomous, low-power payload (a 6 unit CubeSat) will support biological/radiation testing on uncrewed missions such as Space Launch System (SLS) Exploration Mission-1 (EM-1).

Radiation damage studies will be conducted using the yeast *Saccharomyces cerevisiae* and will report double stranded DNA breaks (DSBs) in response to ambient space radiation. The results will be critical for improving interpretation of the biological effects of space radiation exposure, and to reduce risk associated with long-duration human exploration.

ANTICIPATED BENEFITS

To NASA funded missions:

The BioSentinel project will provide:

- A radiation biosensor capability that will be utilized in future robotic and human missions to the Moon, Near Earth Asteroids (NEAs), and Mars, for evaluation of the long-term biological effects of deep--space radiation.
- A capbility to carry out microbial research on a miniaturized platform for various robotic and human missions.
- In-situ analysis and data collection

To NASA unfunded & planned missions:

The BioSentinel project will provide:

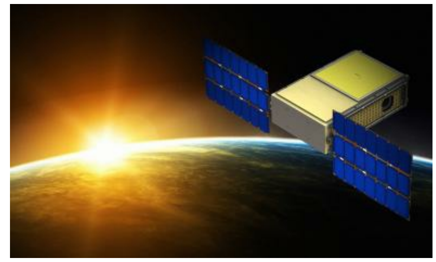

Illustration of BioSentinel flying over Earth

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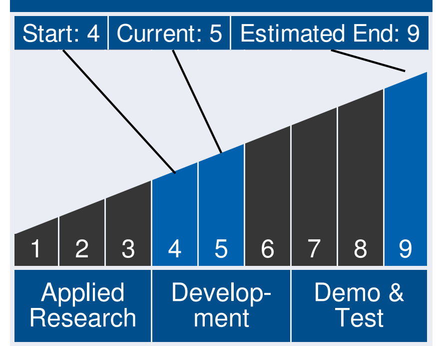
Technology Maturity



Management Team

Program Director:

- Jason Crusan

Program Executive:

- Jitendra Joshi

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- A capbility to carry out microbial research on a miniaturized platform for various robotic and human missions.
- In-situ analysis and data collection

To other government agencies:

The BioSentinel project will provide:

- A radiation biosensor capability that will be utilized in future robotic and human missions to the Moon, Near Earth Asteroids (NEAs), and Mars, for evaluation of the long-term biological effects of deep-space radiation.
- A capbility to carry out microbial research on a miniaturized platform for various robotic and human missions.
- In-situ analysis and data collection

To the commercial space industry:

The BioSentinel project will provide:

- A radiation biosensor capability that will be utilized in future robotic and human missions to the Moon, Near Earth Asteroids (NEAs), and Mars, for evaluation of the long-term biological effects of deep-space radiation
- A capbility to carry out microbial research on a miniaturized platform for various robotic and human missions.
- In-situ analysis and data collection

To the nation:

The BioSentinel project adds to the scientific knowledge base on radiation biology and demonstrates new capabilities for research and technology development.

DETAILED DESCRIPTION

The “6U” (10 x 22 x 34 cm; 14 kg) BioSentinel nanosatellite as a secondary payload to fly aboard NASA’s Space Launch System

Management Team *(cont.)*

Project Manager:
- Robert Hanel

Principal Investigator:
- Sharmila Bhattacharya

Co-Investigators:
- Diana Marina
- Gregory Nelson
- Macarena Parra
- Antonio Ricco
- Sergio Santa Maria
- Tore Straume
- Sarah Wallace

Technology Areas

Primary Technology Area:
Human Health, Life Support, and Habitation Systems (TA 6)
└ Human Health and Performance (TA 6.3)
  └ Long-Duration Health (TA 6.3.2)
    └ Cell/Tissue Culture, Animal Models (TA 6.3.2.2)

Secondary Technology Area:
Human Health, Life Support, and Habitation Systems (TA 6)
└ Radiation (TA 6.5)

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(SLS) Exploration Mission (EM) 1, scheduled for launch in Summer 2018. For the first time in over forty years, direct experimental data from biological studies beyond low Earth orbit (LEO) will be obtained during BioSentinel's 12- to 18-month mission. BioSentinel will measure the damage and repair of DNA in a biological organism and allow us to compare that to information from onboard physical radiation sensors. In order to understand the relative contributions of the space environment's two dominant biological perturbations, reduced gravity and ionizing radiation, results from deep space will be directly compared to data obtained in LEO (on ISS) and on Earth. These data points will be available for validation of existing biological radiation damage and repair models, and for extrapolation to humans, to assist in mitigating risks during future long-term exploration missions beyond LEO.

Technology Areas *(cont.)*

Additional Technology Areas:

Human Health, Life Support, and Habitation Systems (TA 6)
- Radiation (TA 6.5)
  - Risk Assessment Modeling (TA 6.5.1)
    - Degenerative Risk Projection Model (Includes Heart and Circulatory) (TA 6.5.1.3)

Science Instruments, Observatories, and Sensor Systems (TA 8)

The BioSentinel experiment will utilize the monocellular eukaryotic organism Saccharomyces cerevisiae (yeast) to report DNA double-strand-break (DSB) events that result from ambient space radiation. DSB repair exhibits striking conservation of repair proteins from yeast to humans. Yeast was selected because of 1) its similarity to cells in higher organisms, 2) the well-established history of strains engineered to measure DSB repair, 3) its spaceflight heritage, and 4) the wealth of available ground and flight reference data. The S. cerevisiae flight strain will include engineered genetic defects to prevent growth and division until a radiation-induced DSB activates the yeast's DNA repair mechanisms. The triggered culture growth and metabolic activity directly indicate a DSB and its successful repair. The yeast will be carried in the dry state within the 1-atm P/L container in multiple independent culture microwells, built into 96-well microfluidic plates with integral microchannels and filters to supply nutrients and reagents, confine the yeast to the wells, and enable optical measurement. The measurement subsystem will monitor each subgroup of culture wells continuously for several weeks, optically tracking DSB-triggered cell growth and metabolism. BioSentinel will also include physical radiation sensors based on the TimePix sensor, as implemented by JSC's RadWorks group, which record individual radiation events including estimates of their linear-energy-transfer (LET) values. Radiation-dose and LET data will be compared directly to the rate of DSB-and-repair events measured by the S. cerevisiae biosentinels.

The spacecraft bus will occupy ~2U, including command and data handling, communications, power generation (via deployable solar panels) and storage, and attitude determination-and-control system with micropropulsion. Development of the BioSentinel spacecraft will mature and prove multiple nanosatellite advances in order to function well beyond LEO:

- Communications from distances of ≥ 500,000 km
- Autonomous attitude control and momentum management of nanosatellites in deep space
- Shielding-, hardening-, design-, and software-derived radiation tolerance for electronics
- Reliable functionality for 12 – 18 months of key subsystems for biofluidics, memory, communications, power, etc.
- Close integration of living biological radiation event monitors with miniature physical radiation spectrometers
- Biological measurement of solar particle events beyond Earth orbit

In addition to providing the first biological results from beyond LEO in over 4 decades, BioSentinel will provide an adaptable small-satellite instrument platform to perform a range of human-exploration-relevant measurements that characterize the biological consequences of multiple outer space environments. BioSentinel is being developed under NASA's Advanced Exploration Systems program.

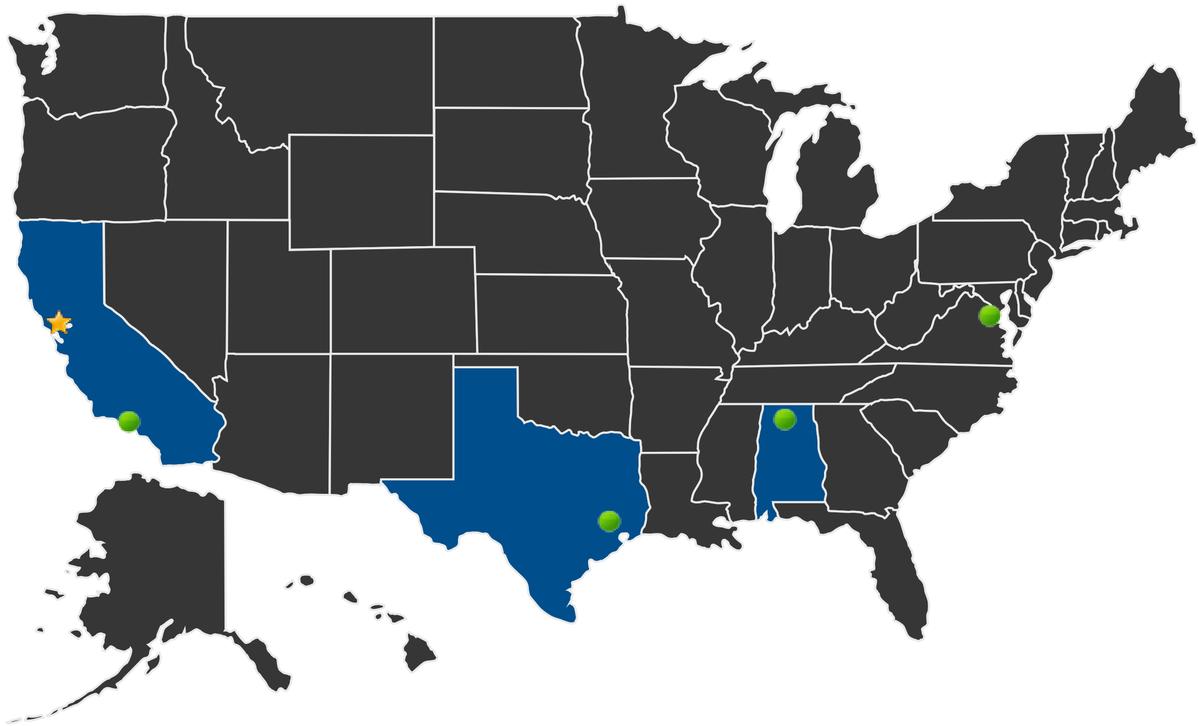
BioSentinel technology will provide critical information about how living systems, from humans down to cells, adapt, respond and survive in deep space, beyond LEO, furthering our understanding of radiation effects on biological systems and the potential countermeasures needed to enable future deep-space exploration missions. Using autonomous 6U CubeSats is an innovative, low-cost, low-risk, high pay-off approach to conduct research and technology investigations.

DSB repair exhibits striking conservation of repair proteins from yeast to humans. The BioSentinel project uses yeast not only because of its similarity to cells in higher organisms, but also because of 1) the well-established history of strains engineered to measure DSB repair, 2) yeast's flight heritage, and 3) the wealth of available ground- and flight-reference data.

One S. cerevisiae flight strain will contain engineered genetic defects to prevent growth and division until a radiation-induced DSB near (~1000 bases) the target genes activates the yeast's DNA repair mechanisms: culture growth and metabolic activity will indicate directly a DSB and its successful repair. In parallel, a different yeast strain that cannot repair DSBs will provide survival curves: increased space radiation-induced DSBs cause decreased cell survival. Each of the multiple yeast strains is carried in multiple independent culture wells, subgroups of which are activated at multiple time points over a 6 – 18-month mission. The instrument monitors each subgroup of 12 culture wells continuously for 4 weeks, tracking cell growth via optical density and metabolic activity using a viability dye: growth indicates DNA damage and repair. A payload containment designed for minimal shielding of the cells provides biologically significant radiation doses in orbits beyond LEO. Far higher doses can be expected during a solar particle event (SPE), triggering additional measurements by our biosensors. The DSB rate in space will be compared to (a) physically measured radiation dose, (b) studies conducted in terrestrial radiation facilities, and (c) models of expected DNA damage-and-repair rates. Due to the unique composition, flux, and energy distribution of space radiation, it is expected that the radiation-induced responses in space will differ from ground-based data.

The results will be critical for improving interpretation of the biological effects of space radiation exposure, and to reduce risk associated with long-duration human exploration.

U.S. WORK LOCATIONS AND KEY PARTNERS



U.S. States With Work

Lead Center:
Ames Research Center

Supporting Centers:

- Ames Research Center
- Jet Propulsion Laboratory
- Johnson Space Center
- Marshall Space Flight Center
- NASA Headquarters

Other Organizations Performing Work:

- Loma Linda University Medical College
- University of Saskatchewan

DETAILS FOR TECHNOLOGY 1

Technology Title

CubeSats; Radiation Sensors

Technology Description

This technology is categorized as a hardware system for unmanned flight

The BioSentinel payload system integrates microorganism growth, optical measurement of viability and growth, thermal control, passive control of relative humidity and pressure, active fluid management, and multiple sensors for temperature, pressure, and relative humidity. Inclusion of a Total Ionizing Dose (TID) dosimeter and a Linear Energy Transfer (LET) radiation detector allows the biological radiation response to be correlated to the localized radiation environment

Capabilities Provided

1. Novel 6U CubeSat microfluidic wells for microbial growth and in-situ measurement in space.

2. Miniaturized radaitions sensors capable of frequent measurement & caching of results

Potential Applications

Future robotic and human missions for scientific measurements and enabling new science investigations