KhepriSAT: Payload for CubeSat Mission to Explore Effects of Radiation Exposure on Cell Growth

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Research Goals
- To measure the growth of a cell population which is being exposed to radiation in orbit and compare to an identical population growing on Earth
- To continue collecting radiation data until the end of the satellite’s life to better model the space radiation environment

Introduction
The ability to sustain human habitation outside of Earth for future manned missions, requires a deeper understanding of how the space environment affects living organisms for long periods of time. To understand these effects, 12-18 biological samples will be deployed on a 6U CubeSat platform with sensors to detect radiation and cell population growth. The samples will be activated in sets of three every two weeks to allow radiation damage to accumulate. To aid with understanding the data received by the CubeSat, an identical experiment will be run on Earth to allow a comparison of the results.

CubeSat Project Overview
1. Deliver to Launch Authority
2. Launch to ISS
3. Deploy from ISS
4. Perform Science Experiments:
   1. Cell Growth
   2. Measure Radiation Environment
   5. End of Life Radiation Sampling and Orbital Decay

Payload Design
The payload will allow the cells to be stored and launched in an inert state and then activate them at a controlled time during the mission. Before activation, the cells will be kept between 20 °C and 40 °C. Once the cells are activated, the payload will allow for growth readings and keep the sample within a tight temperature range around 30 °C.

The complete payload will consist of an array of around 18 identical sample modules each containing the same type of cells. Each will be a self-contained system with its own thermal control, growth sensors, activating chemical and mixing mechanism. This module design will be repeated to achieve the desired number of samples and all modules will be combined together to form the complete payload. The central cylinder and attached components will contain the cells and their suspending fluid.

At the start of the mission, the cells will be inert and stored in the tubes connected to the cylinder. The activating agent will be stored in the cylinder itself. The two fluids will be separated by solenoid valves. When it is desired to activate the cells, the valves will open and a micro pump will start mixing the inoculated cells and the activation fluid. A red LED will be placed at one end of the sample and a photomultiplier tube at the other. This will allow for a measurement of optical density and mimics the procedure of bio-sample growth measurements taken in the lab. Temperature controls will be located along the sides of the cylinders to keep the sample temperature within the necessary range to avoid damage to the cells.

Radiation Exposure
To fulfill the mission’s primary goal, preliminary estimates for Alpha and Beta radiation were obtained using Systems Tool Kit Space Environment and Effects Tool utilizing the NASA Computational Model.

Since the primary interest is in Gamma Radiation, another software model will be needed to simulate the gamma radiation dosage in our orbit. Once software has been chosen, the simulation will be run during Solar Maximum to generate the highest possible dosage rates. Galactic Cosmic rays are also of particular interest to our Principal Investigator which is another reason that the mission will be held during a Solar Maximum cycle so that the magnetosphere will be at its weakest.

Thermal Control
- Passive thermal control deemed acceptable for the CubeSat bus leveraging thermal straps and MLI
- Active thermal control required for science payload
  - Temperature limits: 30±0.25 °C
- Active thermal control:
  - Flexible polyimide patch heater wrapped around sample cuvette, controlled using PIV controller linked to thermistor embedded within sample
  - Minimal power consumption at steady-state and initialization
  - X Surface faces the sun
  - X Surface contains science payload

Prototyping
The prototyping procedure has been broken up into three general phases. Efforts in the first phase will focus on simply constructing the plastic cuvette. In the second phase, the solenoid valves and micro pumps will be attached to the prototype cuvettes along with the necessary tubing. The final stage will see the addition of the thermal system and spectrophotometry equipment. Through funds acquired from an Embry-Riddle Spark Grant and operational funds from Dr. Castillo’s lab, most of the parts necessary for all three stages of prototyping have been acquired.

Future Testing
Facilities available for thermal and vacuum testing purposes are located in Embry-Riddle Aeronautical University’s research complex, the Micaplex. The research park has a 36'x36',x36' stainless steel chamber capable of reaching pressure levels as low as 10-7 Torr which is well within our expected orbital pressure environment. It is able to reach such low vacuum levels because it features German precision roughing and turbo pump technology.

The chamber also features thermal cycling technology that can drive the chamber as low as -80°C and as high as 200°C. These temperature are well within our expected orbital temperatures. During the prototyping phase, a functional test of the cuvette pumping and valve system will be carried out by subjecting the system to vacuum and visually checking for leaks following the test. After prototyping, the integrated payload test campaigns that will be conducted are: a thermal control system functional test, and a full functional payload test in vacuum.