Partial Gravity Biological Tether Experiment on the Deep Space Gateway. S. Wallace[1] and Lee Graham[1], NASA Johnson Space Center, 2101 NASA Parkway, Houston, TX. 77058, sarah.wallace@nasa.gov

Introduction: A cislunar platform at the L2 near-rectilinear halo orbit (NRHO) around the Moon provides an excellent opportunity for an advanced partial gravity risk mitigation experiment addressing the Human Research Program (HRP) risk of "Risk of Adverse Health Effects Due to Host-Microorganism Interactions" and HRP gap MICRO-04 "*We need to determine how physical stimuli specific to the spaceflight environment, such as microgravity, induce unique changes in the dose-response profiles of expected medically significant microorganisms.*"[1][2][3]

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Background: Specifically, this would be a first-of-its-kind study to sequentially document and define the dose-response profile between altered levels of gravity and cellular adaption. *Staphylococcus aureus (S. aureas)*, named for its golden yellow color, would be used as the experimental "subject".

Since S. aureas stops producing its pigmentation in response to the reduced gravity levels of spaceflight, a gradual decrease in gravity levels would provide important data points as to when normal terrestrial cellular processes have stopped. The primary mechanism of determining that the processes have stopped is by a color change. The importance of this pigment molecule is multifaceted and includes:

- serving as a biological indicator to evaluate the impact of varied levels of gravity
- the fact that its synthesis is universal among animals, plants, and microorganisms (e.g. cholesterol production in humans) and thereby applicable across a range of life
- providing insight towards the therapeutic disarming of pathogens on Earth, as pigmentation is a hallmark of, and is involved in, the virulence of numerous pathogenic microbes.

In addition to pigmentation, growth and metabolic data will also be collected and will increase scientific insight by providing mechanistic understanding to the observed phenotype. This data could also then be used in discussion of changes in the internal cell processes.

Mission Concept: The planned concept of operations of the "partial-g satellite" would be to provide multiple data points to identify the line equation in Figure 1. Specifically, the investigation would involve a S. aureas control population on Earth (1g), another on ISS (μg) and a population of S. aureas experiencing several gravity levels on the partial-g satellite (0.2g, 0.4g, 0.6g and 0.8g).

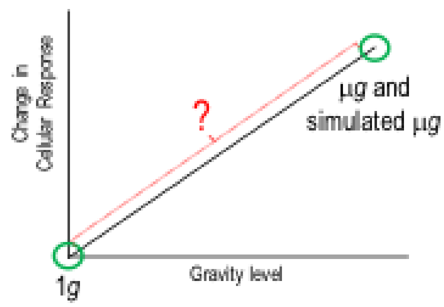
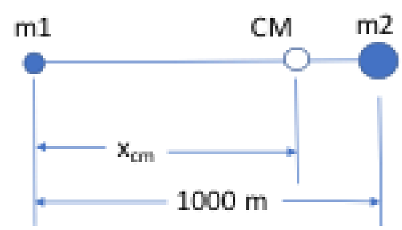


Figure 1 Bacteria-Gravity Plot

These varying g levels would be obtained by spinning a tether with different masses at each end, thus resulting in an "off center" composite center of mass. Once started in rotation by a propulsive, controlling end mass, different rotation rates and therefore different apparent gravity levels will be seen by the end mass containing the bioexperiment. For example, as shown in Figure 2, if the tether were 1 km long and the controlling (and propulsive) mass at one end was approximately 90kg and the other mass (containing the bioexperiment) had a mass of 10kg, the composite CM would be approximately 900 meters away from the bioexperiment. If the mass of the tether is neglected, and the tether were rotating at 0.015 rad/s, the apparent gravitational field at the bioexperiment end mass would be 0.20 g since $a = \omega^2 r$ where a is the centrifugal acceleration (in m s^{-2}), ω is the tether system rotation speed (in radians/s) and r is the distance from the endpoint to the CM (in meters). Table 1 shows the resulting rates to obtain the desired g levels.



$$\text{Where } x_{cm} = \frac{m_1x_1 + m_2x_2}{m_1 + m_2}$$

Figure 2 Center of Mass (CM) Equation

g-Level	r (in meters)	ω^2	ω (rad/s)	ω (deg/s)
0.2025	900	0.000225	0.015	0.859437
0.3969	900	0.000441	0.021	1.2032118
0.6084	900	0.000676	0.026	1.4896908
0.81	900	0.0009	0.03	1.718874

Table 1 Low-G Satellite Rotation Rates vs G-levels

Vehicle Configuration: The spacecraft is not complex and consists of three components. The first component is the biological experiment module. The second component is the "controlling" module (shown as m2 in Figure 2 above) and the third component is the non-conducting tether itself.

The biological module consists of a small software defined radio, several color cameras, lighting, a solar cell power subsystem, and a biological support system. For planning purposes, this biological experiment is very similar to the NASA Ames Research Center (ARC) and German Aerospace Center (DLR) *Euglena* & Combined Regenerative Organic-food Production In Space (Eu:CROPIS) [4] payload.

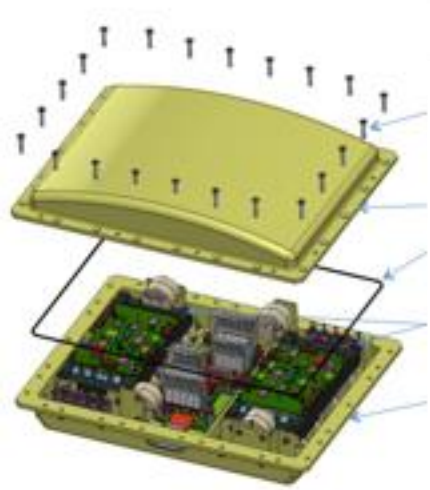


Figure 3: ARC and DLR EuCROPIS Experiment as representative S. aureas bioexperiment

The other, larger spacecraft contains all the other spacecraft functions to conduct the experiment and control the combined satellites and tether. It would also contain the tether deploy/retract reel (with tensiometer), attitude determination and control components, as well as power, communication and propulsion systems to control the spin rate of the combined satellites and tether. During test operations on-orbit, tether tension and rotation rate would be continually monitored to ensure a consistent g-environment.

In additional consideration, tether activities around the Moon are highly desirable in order to avoid triggering alarms from the United States Government (USG) *Space Fence* second-generation multistatic radar space surveillance system currently under construction. What would appear to be separate spacecraft in near vicinity to each other (i.e. 1km) would probably trigger multiple, if not continuous conjunction alarms.

Figure 4: ARC and DLR EuCROPIS Experiment as representative S. aureas bioexperment [4]

Summary: A tether-based partial gravity biological experiment deployed from the Deep Space Gateway represents a viable biological experiment to investigate the fundamental internal cellular processes. Use of the *Staphylococcus aureus* bacteria provides an advanced partial gravity risk mitigation experiment addressing the sequential documention and definition of the dose-response profile between altered levels of gravity and cellular adaption.

References:

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[2] https://humanresearchroadmap.nasa.gov/Gaps/gap.aspx?i=591 [3] Clément, Gilles; Bukley, Angelia P. (2007). *Artificial Gravity*. Springer New York. p. 35. ISBN 0-387-70712-3
[4] http://www.dlr.de/rb/en/desktopdefault.aspx/tabid-6815/11182_read-40094/