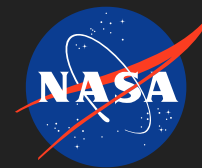


Spacecraft Lighting to Mitigate Microbial Growth

Completed Technology Project (2019 - 2019)

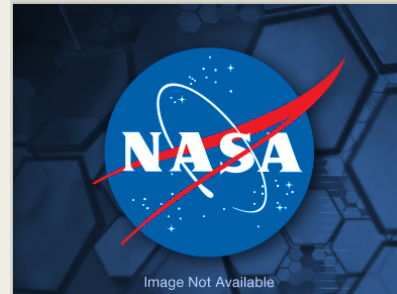


Project Introduction

ISS crew health research indicate risk for immune system degradation for long duration missions, necessitating the need to maximize countermeasures on microbial growth (1). This project will investigate applications using violet (400nm) LEDs to mitigate growth of bacteria on architectural surfaces. The application is primarily for architectures and surfaces where a higher amount of bacterial growth is expected. The project will build two different types of violet light sources that represent lamp types that could be installed in spacecraft applications. Under a controlled setting, using violet LEDs, the evaluation will test the effectiveness of a glowing work surface using LED Panel versus an LED array overhead lamp. The effectiveness of the lighting systems to attenuate bacterial growth will be compared to a control. The results of this study can be used to inform spacecraft system architects on novel ways to improve habitat health, and reduce reliance on manual cleaning methods.

Anticipated Benefits

Industry is beginning to use violet (400nm) LEDs to enhance microbial growth countermeasures in hospitals and restrooms. The light impacts the growth rate of bacteria, and when used in conjunction with standard cleaning procedures, enhances the control of the growth of bacteria without introducing anti-bacterial compounds that contribute to resistance. Standard practice with this technology is to alternate from white light when a space is occupied to violet light when it is not in use. This ICA investigation will evaluate the applicability and effectiveness of 400nm violet light sources used as biological countermeasures but configured for integration into difficult architectures that have a higher risk for microbial growth due to human use or cleanability problems



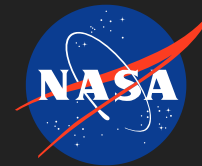
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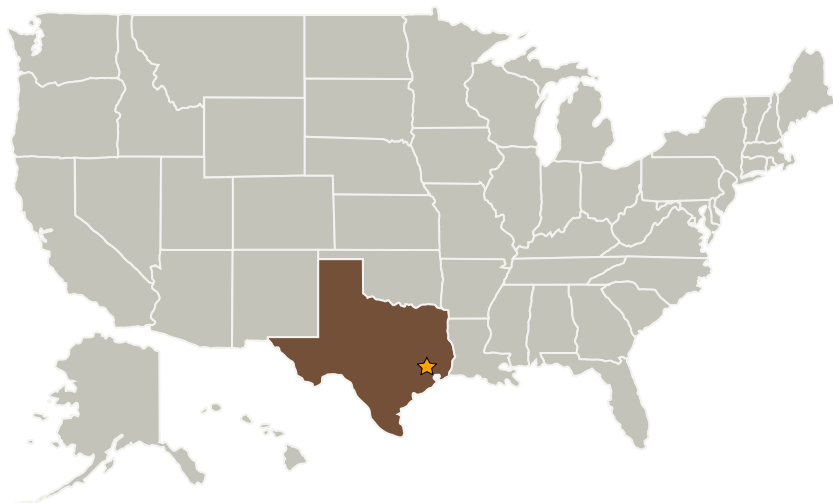
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Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
★ Johnson Space Center(JSC)	Lead Organization	NASA Center	Houston, TX

Primary U.S. Work Locations
Texas

Closeout Summary

Investigating Novel Ways to Curb Microbial Growth in Spacecraft:

In this innovation project, we investigated the usage of narrow band violet light (408 nm) to attenuate the growth of bacteria typically found on ISS. Violet light is less hazardous than UV light and it can transmit through plastics, such as clear acrylics, making it possible to incorporate into large surface lamps and acrylic or polycarbonate based optical light guides. This study built a custom LED surface panel that was edge lit by an array of 408 nm violet LEDs. The optical light guide technology used in the lamp and the 408 nm violet LEDs are available on the market from multiple vendors. The application of the concept of using violet light driven LED panels and optical light guides is to integrate the paneling into spacecraft architectural surfaces for the automation of a light based microbial countermeasure that could enhance current cleaning methods

Organizational Responsibility

Responsible Mission Directorate:

Mission Support Directorate (MSD)

Lead Center / Facility:

Johnson Space Center (JSC)

Responsible Program:

Center Independent Research & Development: JSC IRAD

Project Management

Program Manager:

Christopher Culbert

Project Manager:

Ronald G Clayton

Principal Investigator:

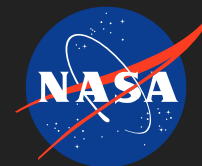
Toni A Clark

Co-Investigator:

Christian Castro

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used in areas on spacecraft prone to microbial growth.

Why Direct Surface Irradiation?

Microbes such as bacteria tend to grow on surfaces, especially where there is moisture present. A typical small "lamp" housing, where the LED array is directly facing the aperture of the lamp, can emit light over a volume, with that light eventually striking a surface. Any objects in the way of the planned surface will block light to that surface. The inverse square law of light also causes a diminishing return on intensity the farther the intended surface is away from the lamp. New LED optical light guide technologies, allow for the realization of unique lamp configurations where the lamp can be the architectural surface to be treated while also providing beneficial light to irradiate objects within a volume.

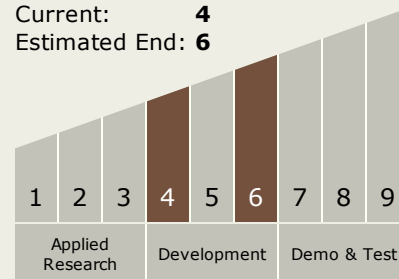
Evaluation Process:

- Four 1x1 foot violet LED panels were manufactured. Each panel is less than a quarter of an inch thick.
- Each lamp was installed in flat, black interior, "pizza box", that had lid who's interior surface was lined with black velvet. The box was necessary to ensure testing of specimens was limited to the violet light source.
- The lamps were connected to a precision pulse-width-modulation (PWM) LED dimmer driver to precisely control percent intensity output.
- The lamp's spectral irradiance was measured using a 350-1000nm spectral irradiance meter for a range of programmed intensity levels.
- At JSC's microbiology lab, bacteria cultures (*Enterobacter aerogenes* & *Staphylococcus aureus*), in clear Petri dishes, were placed directly onto the lamp surface, enclosed in the box, and irradiated for different amounts of time and intensity.
- Growth was compared against a "Control" (no light) vs. "Light" (violet light ON)
- Bacteria was counted before and after irradiation to determine impacts.

Bacteria Test Methods:

Technology Maturity (TRL)

Start: **4**
 Current: **4**
 Estimated End: **6**



Technology Areas

Primary:

- TA6 Human Health, Life Support, and Habitation Systems

Target Destinations

The Moon, Mars

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- Bacteria were streaked out onto TSA plates and maintained in culture.
- An isolated colony was then inoculated into 3 mLs of TSB and cultured at 35°C while shaking to either logarithmic phase or stationary phase.
- Cultures were then serially diluted and 100 µL was spread onto plates in duplicate.
- Plates were then irradiated by violet light panels for either 1, 2, or 3 hours.
- The control plates and irradiated plates were then incubated at 35°C over night.
- Plates were then enumerated using a plate count method.

Application Design Concerns:

There is no guarantee that surface lamps, such as the ones tested, will represent the energy output of lamps NASA might fly in the future. Spacecraft have lots of rules on weight, power, and heat emission that could limit the intensity and size of lamps we could integrate into an architecture. Consideration needs to be made that there will be some applications where both the lamp surface is the treatment area and surfaces beyond the lamp need treatment. ISS corridors provide approximately two meters of clearance. If sanitation procedures are done during sleep time or non-use time periods, the potential exposure or "on-time" of a violet light protocol, could be 6 or more hours. Time consideration should be made for time not in waste-hygiene-compartment, not in crew quarters, and not exercising.

Findings:

Bacteria *Enterobacter aerogenes* and *staphylococcus aureus* both exhibited significant reduction in colony size pending on the lamp intensity and length of exposure. The greater the lamp intensity and/or exposure time, the more substantial effect was observed. With the lamp set to an irradiance level of 617 mW/m² @ 407/nm for 3 hours, the *staphylococcus aureus* bacteria colonies cultured in a logarithmic phase of growth, were eliminated. For the same intensity and duration both bacteria types, in a "stationary growth phase" had their colonies reduced by half. Both bacteria types in both logarithmic and stationary phase of growth phases exhibited a loss in colony size when exposed to the violet light as compared to the control (no light).

Discussion:

Enterobacter aerogenes is less susceptible to violet light when compared to *Staphylococcus aureus*. *Staphylococcus aureus* is sensitive to violet light disinfection. Bacteria growth is still impacted but appear to be more resistant to violet light when in stationary growth phase as compared to logarithmic phase. Initial testing shows much potential for the technology. Successful application of this potential technology requires planning on targeted zones for a microbial countermeasure, determination on required irradiance levels, and development of practical exposure times that accommodate both crew activities and effective light-dosage.

Forward Work:

The initial findings from testing and analysis performed for this Innovation Charge Account project has shown that usage of violet light to curb the bacteria tested does make an impact. Future larger studies need to be performed on more complicated light emitting surfaces and optical light guide implementations. Future testing at different exposure levels and a larger range of microbes (other bacteria, fungus, and virus species) should be run to determine the extent of the usability of the countermeasure. Conceptual architectural and end-item lamp design concepts and analysis needs to be performed to determine effective implementation and design requirements.

End Notes: Detailed graphics and additional data are provided in this project's library.

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Closeout Documentation

Poster: Spacecraft Lighting to Mitigate Microbial Growth
(<https://techport.nasa.gov/file/38065>)