National Aeronautics and Space Administration

Innovations in Spacecraft Proximity & Navigation Lighting

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HAT: 4.7.a, 6.3.e TA: 7.4.1.6, 7.4.3.1, 7.5.3.1, 5.4.4.1 **TRL: start 3 / current 4**

OVERVIEW

New spacecraft bound for the Moon and Mars should be exploring lighting technologies that can reduce safety risks while increasing capability. The operational lighting environment for these new missions will not have the forgiving 90 minute orbit of the International Space Station. Advances in solid state lighting and optics design are yielding new form factors for lamps that have the potential to reduce operational risk for both humans and imaging systems that are impacted by high contrast lighting environments. This project evaluated light source form factors and control innovations for spacecraft exterior proximity and navigation lighting by building a demonstration test rig and testing the effectiveness of the light sources and their controls to increase visibility and usability.

INNOVATION

The innovation is a paradigm shift in how spacecraft navigation and proximity light sources are defined, configured, and controlled. If "pixelated" light sources are installed on the spacecraft, and each one can be turned on/off, dimmed, and utilize red/green/blue light source color mixing, then the navigation and proximity lighting system on the spacecraft could be visualized and controlled like a graphics display device.

PARTNERSHIPS / COLLABORATIONS

Photogrammetry of camera interface performance with the lighting test rig was provided by Michael Rollins, Image Science Analysis Group (XI4/Jacobs).

INFUSION SPACE / EARTH

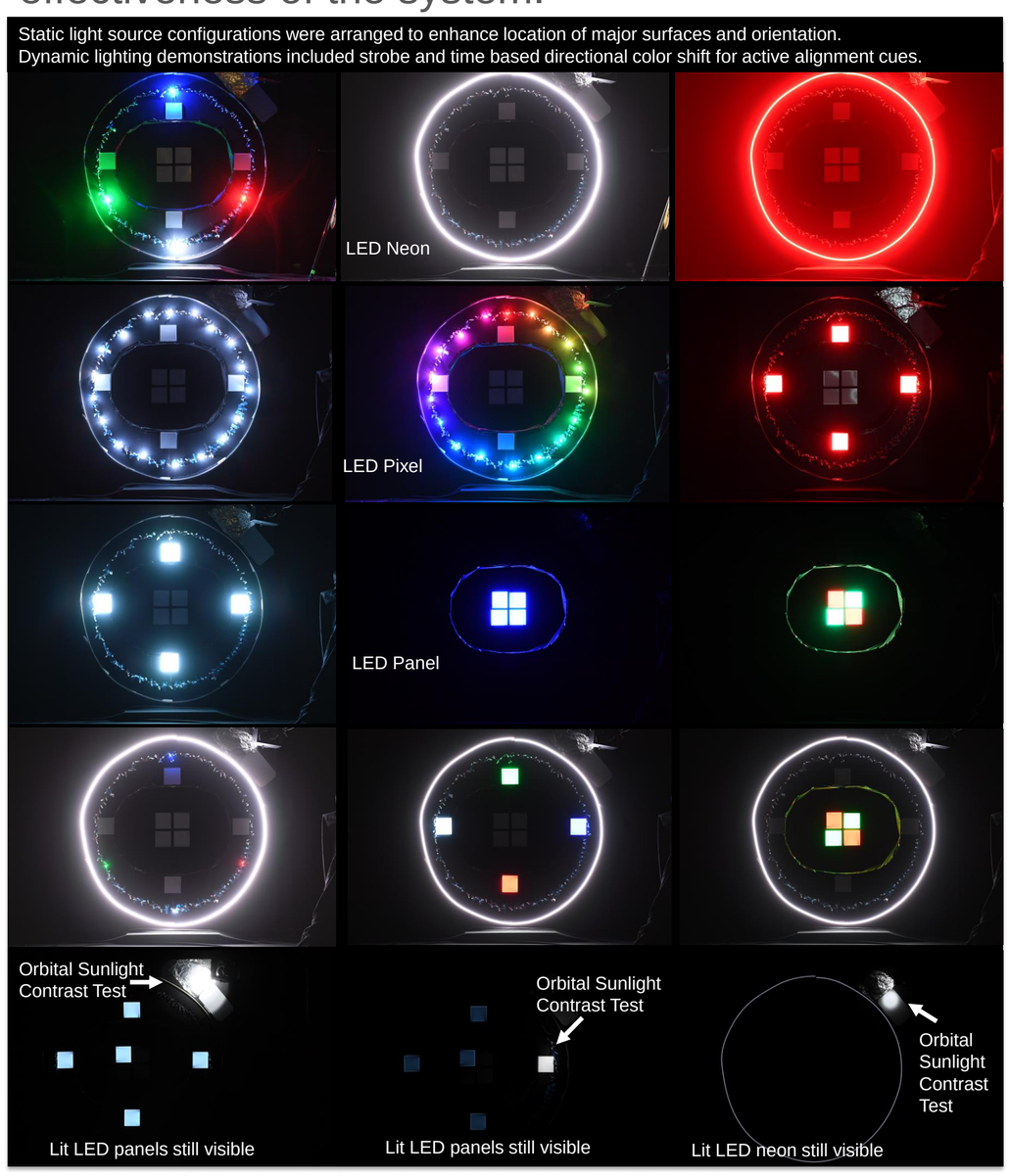
By applying innovations in automotive adaptive lighting systems to increase driver and pedestrian safety, NASA in turn, could provide to the market additional technology innovations for proximity operations.

FUTURE WORK

We will look for future research grant opportunities as well as ways to infuse these findings into future vehicle, program, and subsystem requirements updates.

OUTCOME

Using a ring truss with an opening about the size of an International Docking Adapter, the project built a mockup and mounted LED Neon, LED Panel, and LED Pixel light sources. The red, green, blue tunable light sources were controlled by a DMX512 command interface. A range of static and dynamic light source patterns were generated to showcase how the lights could enhance visibility over historically standard lighting configurations. The lighting system was also imaged against high contrast orbital lighting conditions for both direct orbital sunlight and the background luminance of the Earth. Additionally a subjective engineering evaluation was performed to collect observer feedback on the effectiveness of the system.



PAPERS / PRESENTATIONS

The project conducted hardware demonstrations that served to showcase technology potential while also collecting subjective operational feedback. We plan to develop a technical paper that summarizes findings.

Center Independent Research & Development: JSC IRAD

Innovative Proximity & Navigation Lighting

Active Technology Project (2018 - 2018)

Project Introduction

New spacecraft bound for the Moon and Mars should be exploring technologies that can reduce safety risks while increasing capability. Advances in solid state lighting and optics design are yielding new form factors for lamps that go far beyond the conventional bulb. The automotive industry has applied these technologies to increase driver and pedestrian safety, producing headlamps and taillights with completely different form factors than those available ten years ago. Despite this opportunity, new spacecraft exterior lighting systems continue to be proposed with bulb type form factors. This proposal will evaluate new light source form factors for spacecraft exterior proximity and navigation lighting, while also demonstrating light control innovations. The project will build a demonstration test rig to evaluate the effectiveness of the light sources and their controls to increase visibility and usability, while reducing glare.

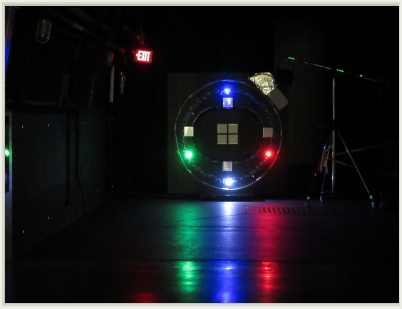
Anticipated Benefits

This project seeks a paradigm shift to maintain our leadership in human exploration as it applies to the form factor and usage of spacecraft exterior proximity and navigation lighting. Light sources are often designed to be small bulb shapes, are arranged near camera sensor packages, and include color to indicate orientation. Because of their small form factor, these same lamps can create glare to the opposing observer, and be obstructed by larger spacecraft structure located within the beam path of the lamp. Assuming a classic round docking structure, this project will build a demonstration test article to evaluate alternate lamp form factors such as LED Neon, LED Panel, and other lensing technologies

Project Closeout - Executive Summary

Overview:

This project evaluated light source form factors and control innovations for spacecraft exterior proximity and navigation lighting by building a demonstration test rig and testing the effectiveness of the light sources and their controls to increase visibility and usability. Using a ring truss with an opening about the size of an International Docking Adapter, the project built a mockup and mounted LED Neon, LED Panel, and LED Pixel light sources. The red, green, blue tunable light sources were controlled by a DMX512 command interface. A range of static and dynamic light source patterns were generated to showcase how the lights could enhance visibility over historically standard lighting configurations. The lighting system was also imaged against high contrast orbital lighting conditions for both direct orbital sunlight and the background luminance of the Earth. Additionally a subjective engineering evaluation was performed to collect observer feedback on the effectiveness of the system.



Innovation Lighting Test Rig at Lighting Environment Test Facility - set for "standard spacecraft lighting configuration"

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Active Technology Project (2018 - 2018)

Static Lighting Configurations:

- LED Neon, which is a bendable light strip with an integrated flexible diffuser, looks just like neon glass but does not use frangible parts. LED Neon was configured in a 6 foot diameter circle on the ring truss. It was set up to represent the curved edge of typical conical and cylindrical form factors. The concept is that by clearly identifying the major forward leading surface of the spacecraft such that it can be seen in full sunlight or full darkness, the crew would have better information on spacecraft orientation and distance. For static test patterns, the project configured their LED Neon to for red, green, blue, and white colors.
- LED Panel is a thin, less than 1/4 inch thick, optical panel with embedded edge lit LEDs. The panel is designed to redirect the horizontal light from the LEDs forward from the surface so that it looks like a luminous surface, but without the bulk of standard lamps. The light source flux of the LED panel is distributed across the surface which allows the lamp to output a significant amount of forward light while minimizing glare. Additionally because this type of technology can be specified in any shape, and because it is thin, innovations in design of spacecraft targets critical for alignment cues (such as docking targets) can be considered. Docking targets currently rely on direct sunlight or opposing spacecraft lighting to be seen by opposing observers. For this project we used LED Panel to enhance the location of the exterior edge of a docking hatch and we used it to explore concepts for luminous docking targets. For static test patterns, the project configured their LED Neon for red, green, blue, and checkerboard patterns.
- LED Pixel represents a range of light source optical form factors that have embedded communication IC/drivers for each LED in the lamp assembly, allowing each LED to be individually controlled by lighting communication protocols such as DMX512 and Art Net. For this project we used LED Pixel string lights where each pixel had a classic bulb shape and were connected by a short wire interface. LED Pixel provides for maximum dynamic control of a large array of lights. For static scenes we configured the LED Pixel in a 6 foot diameter circle. Light scenes included a classical, "minimalist", spacecraft lighting configuration, and single color and chromatic coloration of a large number of LEDs.
- Combination Patterns of LED Panel, LED Pixel, and LED Neon were also demonstrated to show how these technologies could be used in conjunction with each other.

Dynamic Lighting Configurations:

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

Principal Investigator:

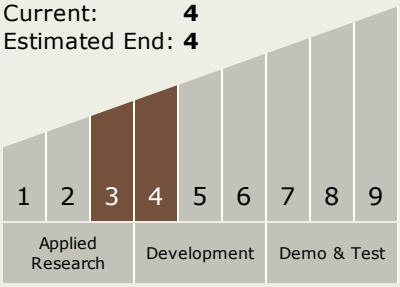
Toni A Clark

Co-Investigator:

Andrei A Kolomenski

Technology Maturity (TRL)

Start: **3**
Current: **4**
Estimated End: **4**



Technology Areas

Primary:

Continued on following page.

- Usage of DMX512 allowed the project to demonstrate lighting automation and reconfiguration of "static" lights to "dynamic lights". The same lights that were use for static patterns were configured for a range of patterned strobe light demonstrations. Additionally, the project wanted to explore the "what if" concept of a lighting system interface with a hypothetical proximity sensor feed. We demonstrated a dynamic "red to green" pattern change on our LED Pixel configuration to showcase that the lighting system could be used to provide a type of augmented reality feedback to the crew on alignment status while performing proximity operations.

Photogrammetry Evaluation:

- Camera systems are used extensively during spacecraft docking, berthing, and robotics tasks. Proper camera functionality to see surfaces and spacecraft exterior lighting systems while dealing with the extreme orbital lighting environment are paramount.
- A photogrammetry team led by Michael Rollins, Image Science and Analysis Group (XI4\Exploration Science Office) was invited to image the project test rig at the Lighting Environment Test Facility, which has a controlled dark room and is integrated with a 300 foot tunnel. Orbital lighting test conditions included total darkness, full sunlight at 125,000 lux on specular and diffuse surfaces near the lighting system, and a large diffuse luminous backdrop with a luminance bright enough to mimic reflected light off the earth.
- The camera team also videoed the strobe light demonstration.
- The LED Neon and LED Pixel were especially good at remaining visible to the camera, even with other extreme luminance areas in the field of view from the direct sunlight and earthshine demonstrations.

Subjective Observer Demonstration:

- Before the project was completed, the project team invited stakeholders and interested parties to see a demonstration of the lighting system. Subjective feedback from observers was requested. Requesters generally felt that usage lighting to enhance the shape and surfaces while also providing dynamic feedback on orientation cues would be improvement over current spacecraft navigation and proximity lighting formats.

Summary:

This project was very limited in scope in the number of enhancements and arrangements of lights and spacecraft models it could represent. However, for the lighting configurations shown and lighting control automation innovations demonstrated, the project concludes that the lighting technology of today has significant potential to increase crew safety and mission success even under less

Technology Areas *(cont.)*

- Human Exploration Destination Systems (TA 7)

Other/Cross-cutting:

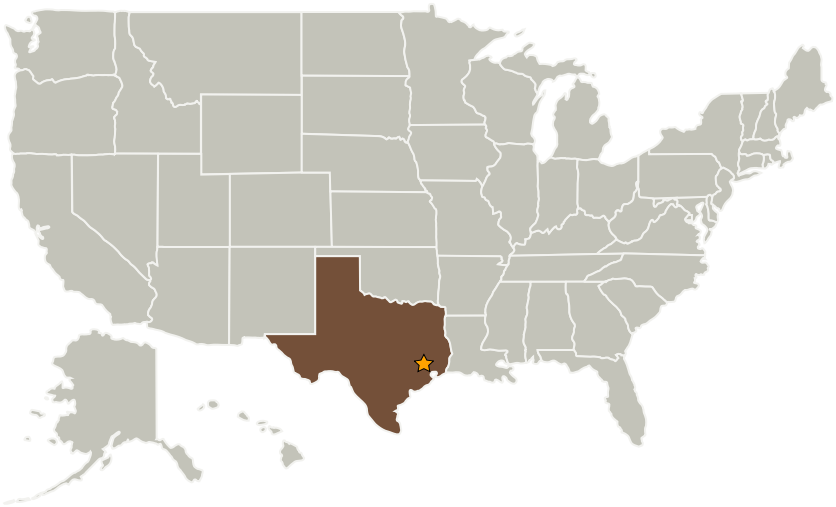
- Communications, Navigation, and Orbital Debris Tracking and Characterization Systems (TA 5)

Target Destinations

Earth, The Moon, Mars

than favorable orbital lighting conditions. Future exploration spacecraft missions will not have the 90 minute reset on the orbital lighting environment. Poor lighting conditions with extreme shadow and sunlight in the same field of view could remain for an extended period of time. Rethinking of the types of lights used for navigation and proximity lighting and the automation system used to control them is a worthwhile endeavor.

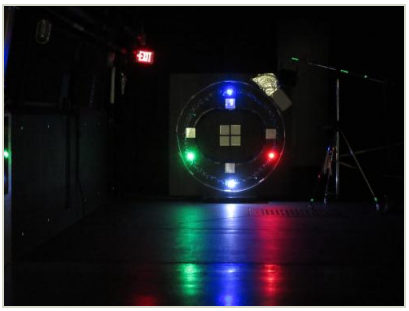
Primary U.S. Work Locations and Key Partners



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

Primary U.S. Work Locations
Texas

Images



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