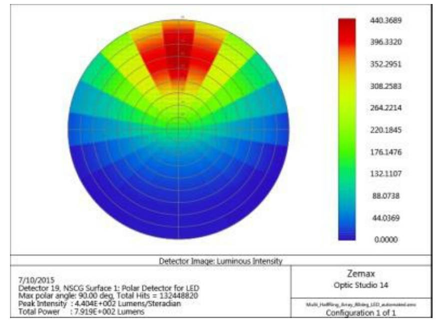
Modeling of an Adjustable Beam Solid State Light Project

Center Independent Research & Developments: JSC IRAD Program | Mission Support Directorate (MSD)

ABSTRACT

This proposal is for the development of a computational model of a prototype variable beam light source using optical modeling software, Zemax Optics Studio. The variable beam light source would be designed to generate flood, spot, and directional beam patterns, while maintaining the same average power usage. The optical model would demonstrate the possibility of such a light source and its ability to address several issues: commonality of design, human task variability, and light source design process improvements. An adaptive lighting solution that utilizes the same electronics footprint and power constraints while addressing variability of lighting needed for the range of exploration tasks can save costs and allow for the development of common avionics for lighting controls.



This image represents a hemispherical detector surface, which is set one meter away from the light source. The dectector is showing light source intensity. Light source flux is to the side instead of forward for directional spot lighting.

ANTICIPATED BENEFITS

To NASA funded missions:

This project can provide a great demonstration of how to reduce risk in development of engineered lighting systems for operations and habitats. The demonstration of developing optical models before the light source is fabricated can be an immediate benefit to Orion and ISS for optimization of standards and end item specifications. It especially can be beneficial to those projects that have increased risk to the crew because of unknown or unpredictable operational lighting conditions. It can also help NASA increase the operational capability of spacecraft lighting systems while reducing the number of different types of lights that are needed to accommodate the wide range of interior and exterior operational tasks. It will also demonstrate the advantage of modeling a light source prior to requirements development stage to increase the chances lighting requirements produce the intended product.

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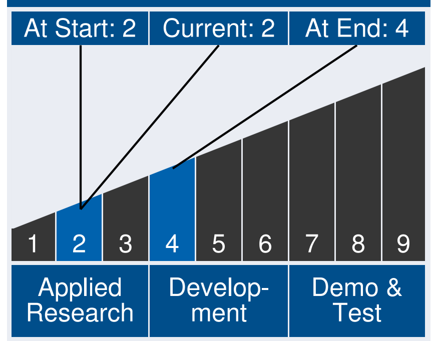
To NASA unfunded & planned missions:

This project can benefit Human Spaceflight Exploration and the Evolvable Mars Campaign by demonstrating the ability of a "one light source does it all" approach. If NASA was able to develop a modular, smart, adaptable lighting technology, the same comprehensive system can be installed throughout NASA exploration spacecraft. NASA can approach spacecraft architecture discussions from the perspective that the technology to make a lighting system fully adaptable to the needs of the crew is a standard solution with an approved standard system of parts and lighting system controls. By standardizing to a highly adaptable system, NASA can minimize fabrication of many different solutions (individual model numbers) and lighting control algorithms. Training and operations of spacecraft lighting can be standardized. Lifecycle costs and sparing can be simplified. By creating a flexible automated system that still provides the range of lighting needed for tasks, NASA can also control the power budget for crewed tasks.

To other government agencies:

This technology can benefit multiple Federal agencies and consumer markets. The FAA is potentially benefited by developing smart aircraft and airfield lighting systems. SAE (automotive headlamp design) is benefited by making light sources for car headlamps that meet highway safety constraints but can dynamically adapt spot and flood to reduce glare related highway accidents. NTSB is benefited by incorporation of dynamic roadway lighting that adjusts beam patterns for the current highway traffic. DOE is benefited by introduction of smart, adaptable, modular lighting that can be implemented by commercial, institutional, and lighting utilities that can reduce our energy footprint.

Technology Maturity



Realized Benefits

1 New Technology Report

Management Team

Program Director:
- Douglas Terrier

Program Executive:
- Douglas Terrier

Program Manager:
- Ronald G Clayton

Project Manager:
- Toni Anne Clark

Principal Investigator:
- Toni Anne Clark

To the commercial space industry:

Adaptable lighting systems are a benefit to the commercial spaceflight industry servicing human spaceflight agendas. Commercial vendors can offer their passengers innovative lighting solutions that anticipate the variety of task lighting needs. Commercial vendors can also realize savings in weight and power usage by implementing a system that puts the light exactly where it needs to be while minimizing wasted energy.

To the nation:

This innovation benefits our nation because it provides an opportunity for our nation to demonstrate innovation in the lighting sector. This technology, realized in both commercial and residential applications, allows the consumer market to fully utilize the advantages of solid state lighting systems.

DETAILED DESCRIPTION

One of the risks of a multi-system approach to reaching Mars, is the cost that is added due to unique designs driven by the use cases of each operational platform. The risk in developing a lighting solution for one platform, is that its design may not fully address the variability of tasks for other platforms, and due to vehicle time development scale, may become obsolete by the time the last vehicle component is developed. Because of the rigorous and expensive certification process for electronic hardware, it would be wise to develop lighting system components and control technologies that are modular and adaptive to a wide range of internal and external vehicle tasks. The introduction of the concept of computer based modeling of light sources prior to fabrication is a process improvement for spacecraft lighting design and its demonstration can show cost savings potential for the development of future lighting systems.

This project will use the lighting and optical modeling software, Zemax Optics Studio Premium, to build a model of an LED

Technology Areas

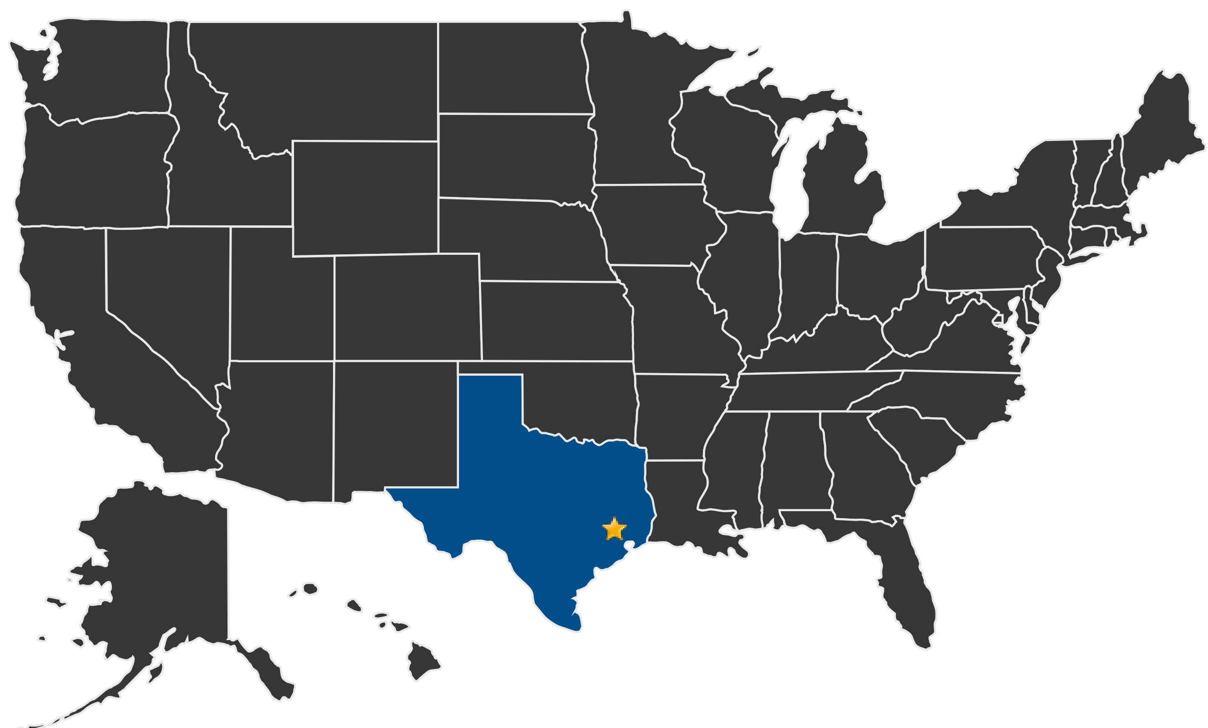
Human Health, Life Support, and Habitation Systems (TA 6)

- Space Power and Energy Storage (TA 3)
- Power Management and Distribution (TA 3.3)
- Robotics and Autonomous Systems (TA 4)
- Human Health and Performance (TA 6.3)
- Modeling, Simulation, Information Technology and Processing (TA 11)
- Materials, Structures, Mechanical Systems and Manufacturing (TA 12)

array. Zemax is a forward ray tracer that can model light source beam distribution, light source spectral wavelength, and material reflectance/transmittance properties. It can predict final beam distribution based on the designed optical system. Each LED in the array developed will represent currently manufactured LEDs intended for white light illumination. The light output of the LEDs will be controlled individually, while maintaining the same total flux output. The goal is to develop beam pattern distributions, from the same source that represent flood, spot, and directional lighting while consuming approximately the same power.

The deliverable will be a Zemax computational lighting model that can be interpreted, as a future project, into an end item specification for a variable beam light source. The computation model will show the type and number of LEDs, LED spacing, intensity of the LEDs used to generate each beam pattern, and constraints on diffuser optics. In addition to the computational model, Illumination Engineering Society (IES) beam pattern files for each beam type will be published. Beam pattern data will be interpreted for potential application in an installation as it relates to human task performance.

U.S. LOCATIONS WORKING ON THIS PROJECT



U.S. States With Work

Lead Center:
Johnson Space Center

Other Organizations Performing Work:

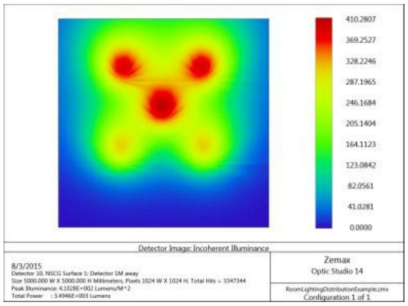
- Lockheed Martin
- Wyle Laboratories, Inc.

PROJECT LIBRARY

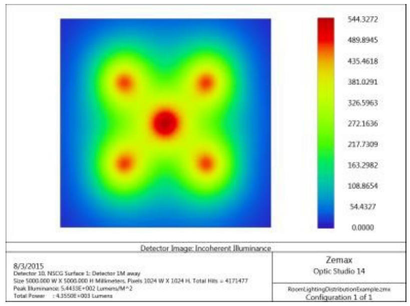
New Technology Reports

- MSC-26042-1

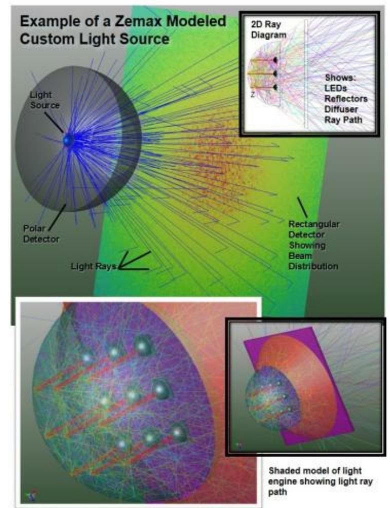
IMAGE GALLERY



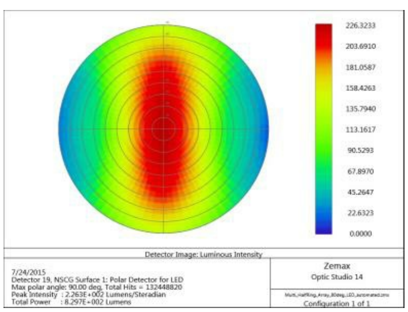
This example shows the light distribution on a 5x5 meter detector located 1 meter from ceiling. Each lamp is one meter from the other. Note how the light intensity is shifted.



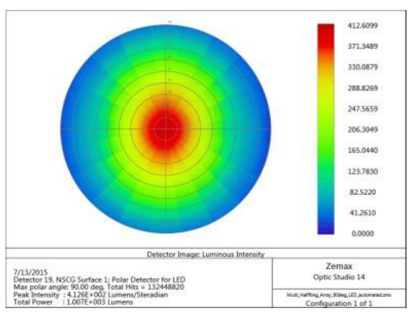
This example shows 5 spot lights where the flux is coming out of light such that it is normal to the floor. The lamps are each 1 meter from each other on ceiling. Center is brighter because of overlap of light.



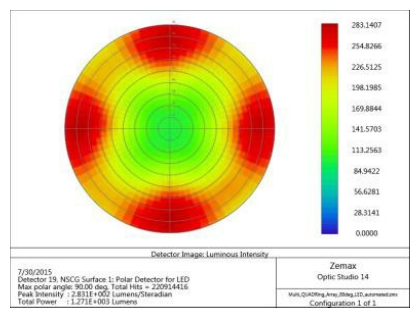
This image illustrates some of the capabilities possible with optical computational analysis software. This project will utilize those capabilities to explore the possiblity of a variable beam solid state light source.



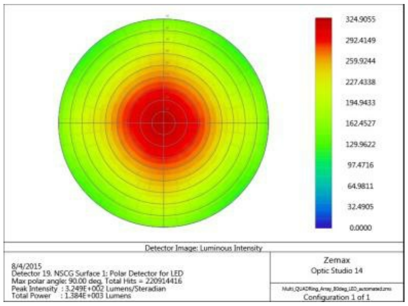
This image represents light intensity at 1 meter from the light source on a hemispherical surface. It demonstrates an application in flood lighting.



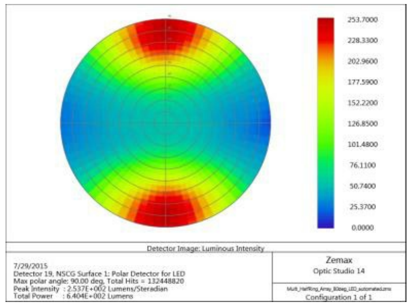
This image represents intensity sampled at a constant radius from light source, with flux focused at center. This is an example of spot lighting.



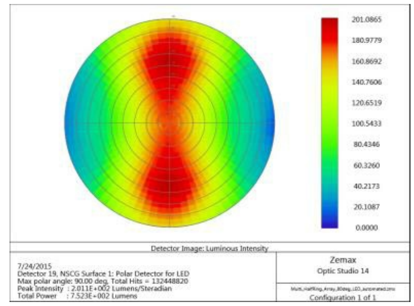
This false color polar detector shows light flux at 4 distinct directions intended for spot lighting.



This hemispherical intensity map shows the same light source but constant intensity at wide angles. The application is flood lighting.



This false color intensity map shows flux from the same light source but split in two radial directions. It demonstrates the ability to make two spotlights.



This false color intensity plot of a polar detector shows light from the same light source distributed radially across the hemisphere. This represents a light configured for ambient flood lighting.

DETAILS FOR TECHNOLOGY 1

Technology Title

Controllable Variable Beam Shaping of Static Solid State Lighting

Technology Description

This technology is categorized as a hardware subsystem for manned spaceflight

Technology that uses an opto-electronic and automated (intelligent) means to dynamically adjust spacecraft lighting solution (in particular beam shape) for interior and exterior lighting address changes in near, far, and directional lighting and address need for modular light source design.

Capabilities Provided

Address Human Spaceflight Architecture (HAT) Performance target needs: TA 3.2, 4.5-7, 6.1-3, 11.2, 12.1.

Potential Applications

Rover Lighting

Spacecraft EVA, and docking/berthing lights.

Spacecraft cabin and cockpit lighting.

Lander external habitat lighting.

Exploration habitat terrestrial "street" and external workzone lighting.

Performance Metrics

Metric	Unit	Quantity
Working optical computer model of light source	ea	1