

Automated Luminaire Design and Local Manufacturing for Highly Efficient, Customized Lighting Solutions



SYNOPSYS®

Lighting
Research Center
at Rensselaer



Eaton, Synopsys, Rensselaer Polytechnic Institute (RPI)
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Award Number: DE-EE0009695

Objective and outcome

The purpose of this program is to improve efficiency, reduce supply chain complexity and “reshore” American manufacturing jobs. This will be done by leveraging new design and manufacturing techniques.

Team and Partners

Eaton: Design and validation of luminaire solution

Synopsys: Design optics and develop automated optic design solution

RPI: Optical and thermal characterization



Stats

Performance Period: Oct. 1 2021 – Sep. 30 2023

DOE budget: \$2,538k Cost Share: \$634k

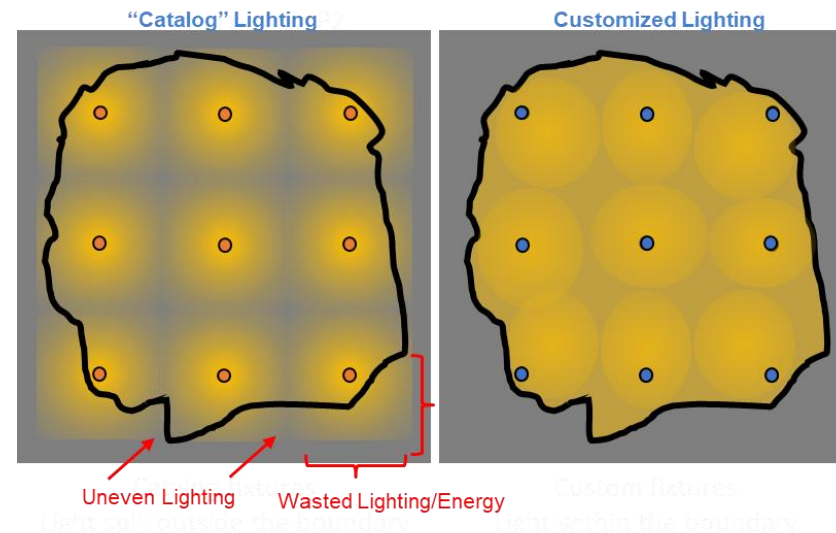
Milestone 1: Initial Prototype Complete

Milestone 2: Optical Designs Complete

Milestone 3: Prototypes Installed and Validated

Problem

- GEIS sells **100k+ champ fixtures** per year for spaces that either provide too much, or not enough lighting for specific purposes.
- Luminaire components are currently **manufactured overseas** and shipped to the US.
- This process is leads to **inefficiencies in supply chain, energy use and light use.**
- Using advanced manufacturing and novel design practices can result in **custom, efficient and locally manufactured luminaires** resulting in less wasted energy and reduced greenhouse emissions.



Alignment and Impact

EERE Goals:

Emission Reduction

Energy Justice

Improved Building Level

Efficiency

GEIS is targeting:

Increased Efficiency

Reduce Energy to Light a Given Area

Local Production

Digital Design and Inventory



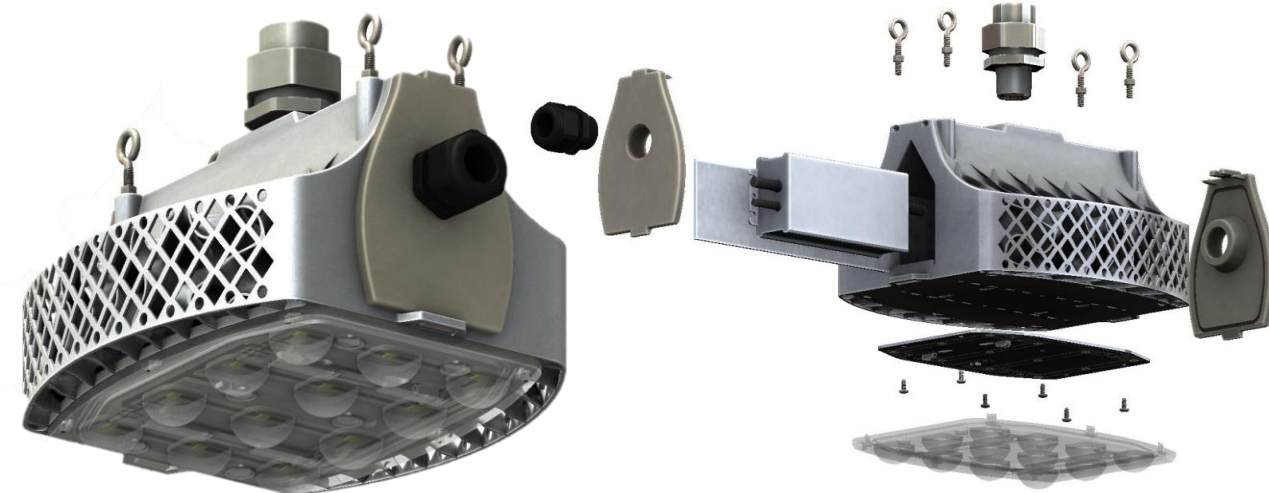
Create low volume, high mix
product lines that are cost effective

Alignment and Impact

Emission Reduction
Building Level Efficiency

Energy Equity

15% Efficiency Improvement
150 lm/W Efficacy
25% Cost Reduction
25% SKU Reduction
50% Reshoring Improvement (# of parts made locally)

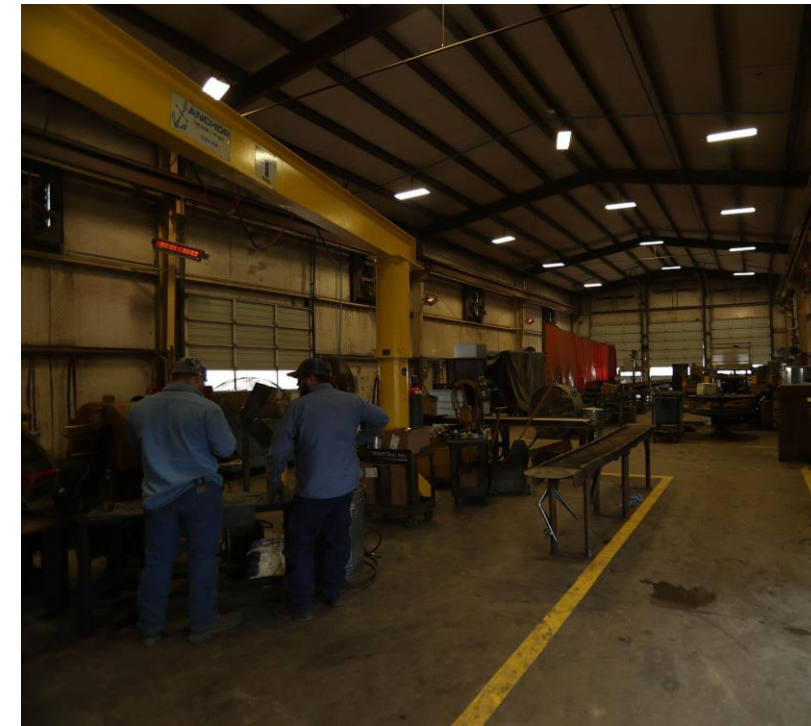
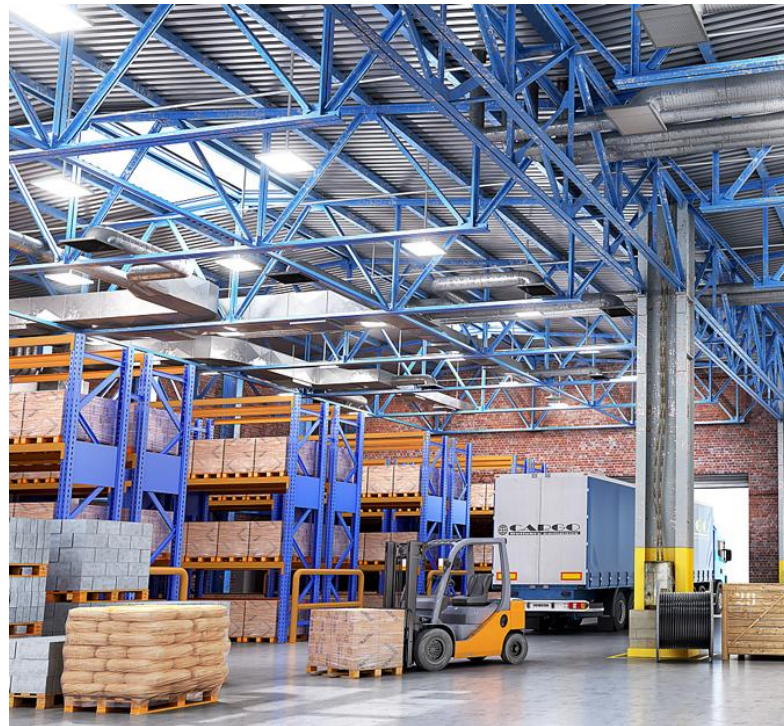


Current Lighting Solutions

Difficult to Install

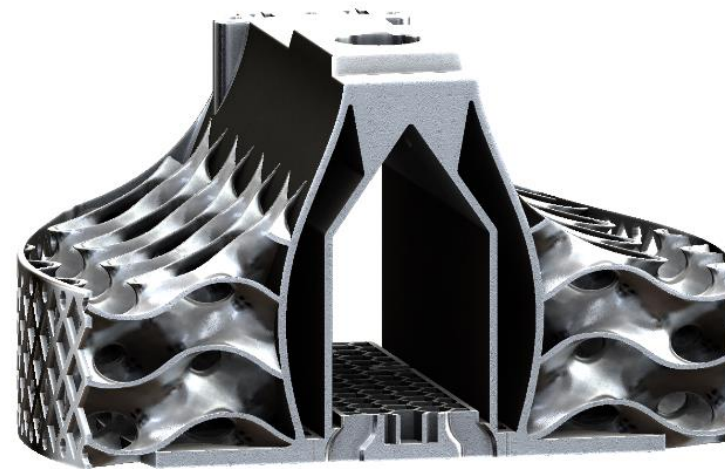
Not Efficient

Non-Application Specific



Custom Lighting at Affordable Cost

- Cost would be too high using traditional manufacturing
- **Additive** allows custom, low volume solutions that don't occupy warehouse space
- Reduces waste
- Reduces labor
- Reduces component count
- Reshores manufacturing



AM commercialization

Today – 200+ SKUs

- 10 SKUs >80% Volume
- 190 SKUs < 20% volume

- ✓ Produce unique parts that are used in 190SKUs
- ✓ Save development time and capital cost associated with these SKUs
- ✓ 5000 -10,000 units per year type of product categories
- ✓ Invert the luminaire design process
- ✓ Focus on projects where customization and total cost of system ownership is critical

Business Approach

Reducing Carbon Footprint

Eliminate Casting

Eliminate international shipping

Eliminate Warehousing

Improving Efficiency

Custom 3D Printed Optics

On Luminaire Level:

Improves energy consumption

On System Level:

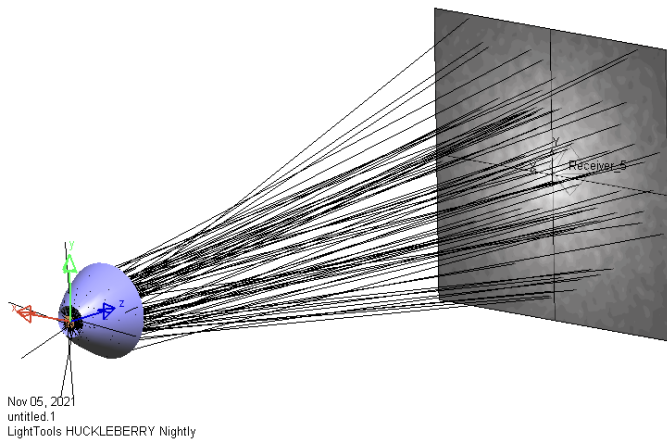
Reduces application space luminaires



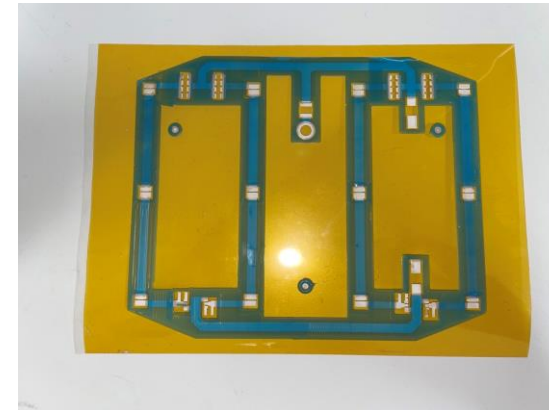
Design for Additive



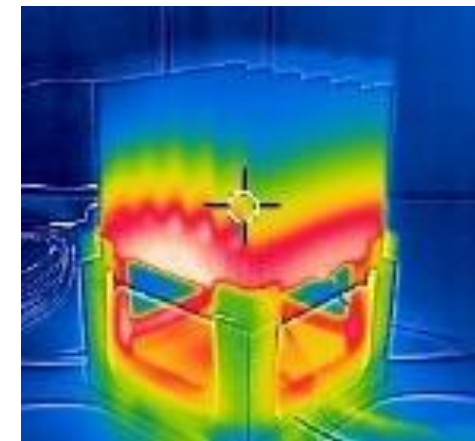
Optics Design



Printed Electronics



Polymer Development



Design for Additive Approach

Luminaire Design Evolution



Optics Design Approach

Ray tracing and subdividing application space

“Catalog” Lighting vs **Customized Lighting**

Ray Tracing Simulation

Application Space Subdividing

Custom fixtures

Light spill outside the boundary (associated with 'Catalog' lighting)
Light within the boundary (associated with 'Customized' lighting)

Optic Variants:

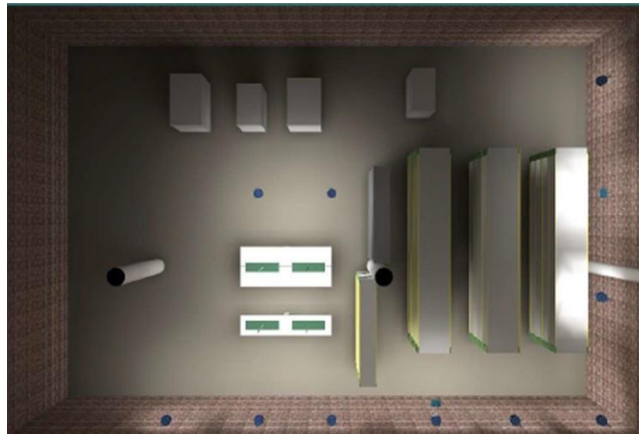
- TYPE I: Linear beam
- TYPE II: Diverging beam
- TYPE III: Focused beam
- TYPE IV: Focused beam with side lobes
- TYPE V: Radially symmetric beam

Physical Variants:

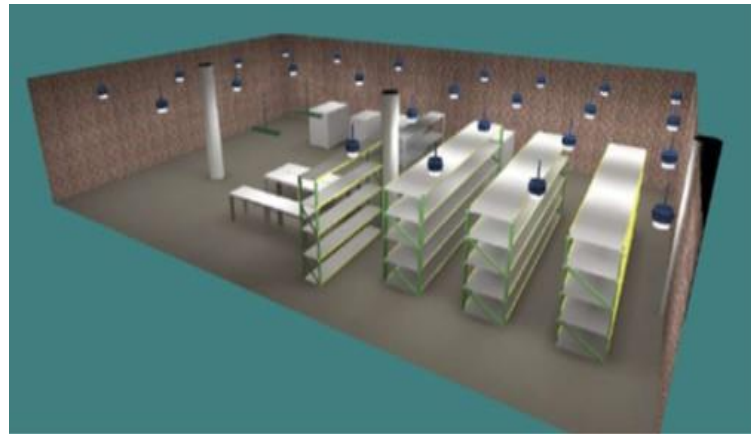
- TYPE-5 OPTIC VARIANT
- RACK OPTIC VARIANT
- TABLETOP OPTIC VARIANT

Demonstration and Validation

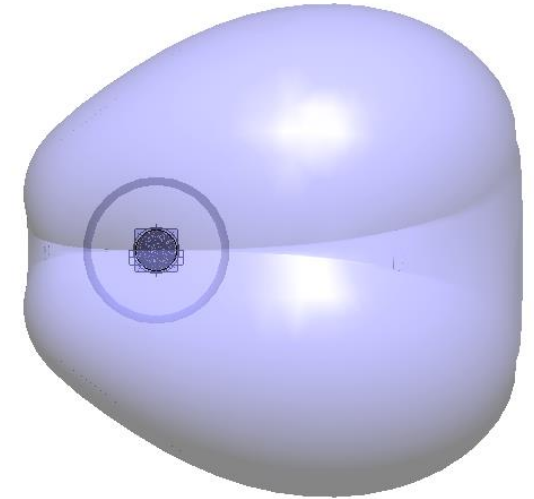
Current



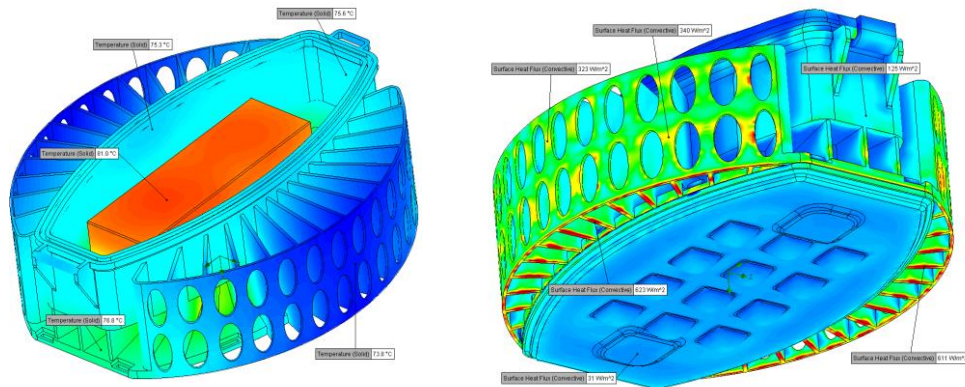
Optimal



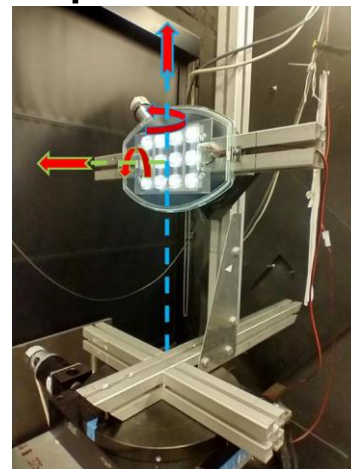
Rack Optic



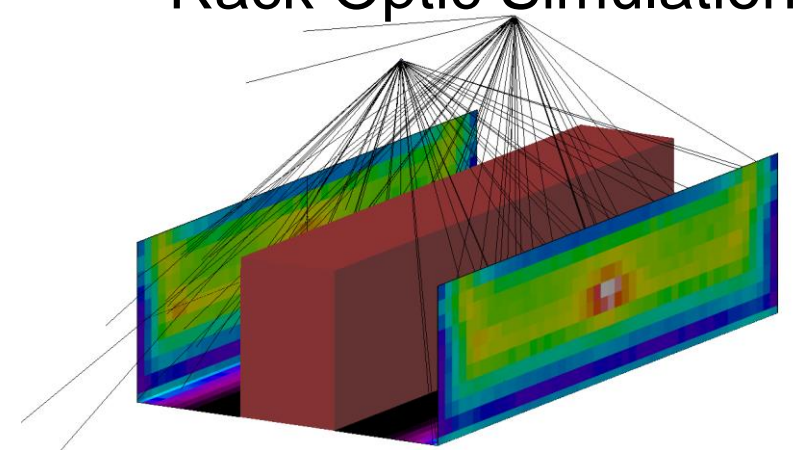
Thermal Simulation



Optic Testing

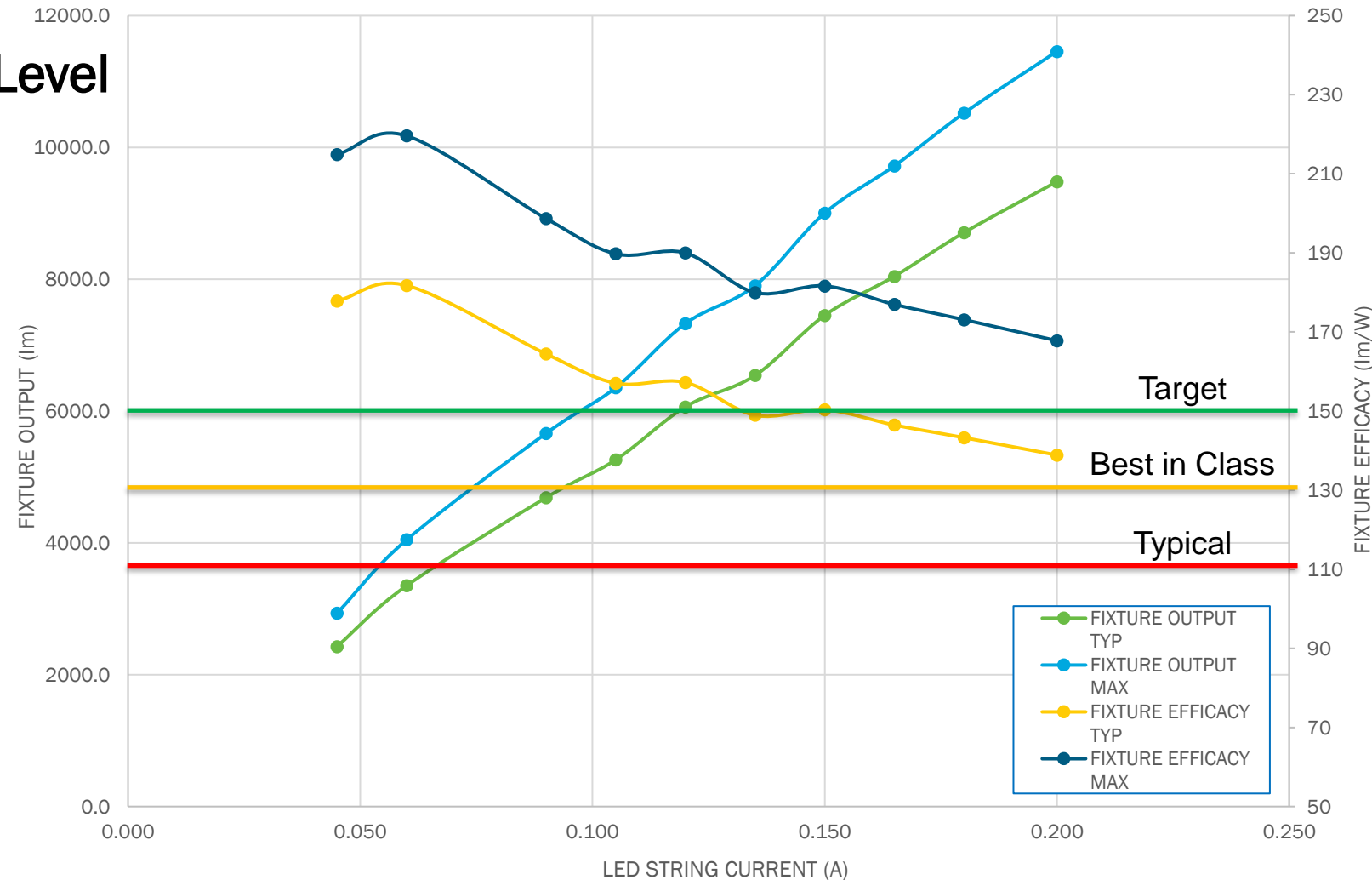
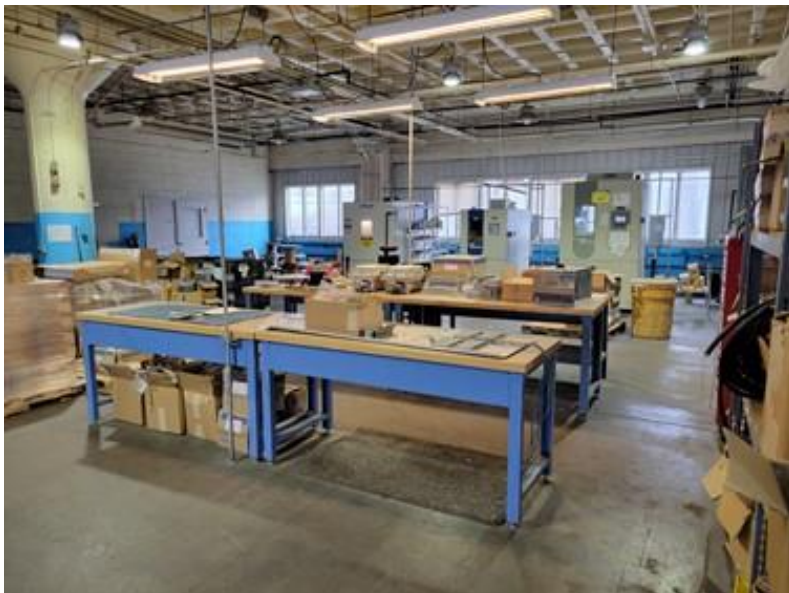


Rack Optic Simulation



EATON AM LUMINAIRE OPTICAL OUTPUT - OSRAM OSCONIC® S 5050
 [@ 86% TRANSMISSIVE WINDOW; 87% DRIVER EFFICIENCY, 25 °C AMBIENT]

- Prove Efficiency on Luminaire Level
- Install in Application Space
- Validate at System Level
- Evaluate Total Cost



Progress and Future Work

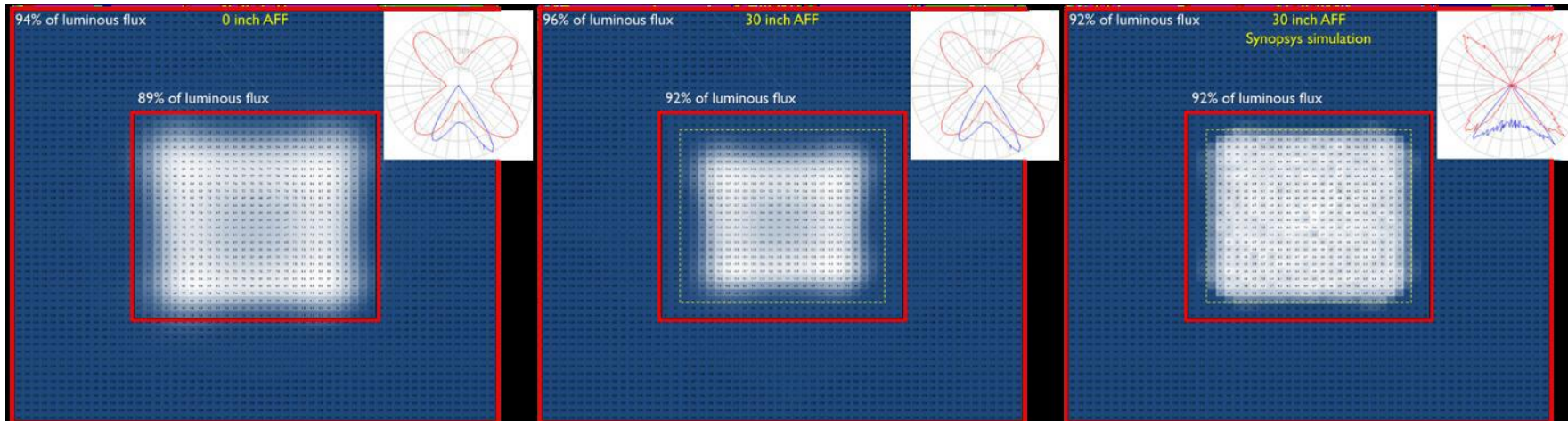
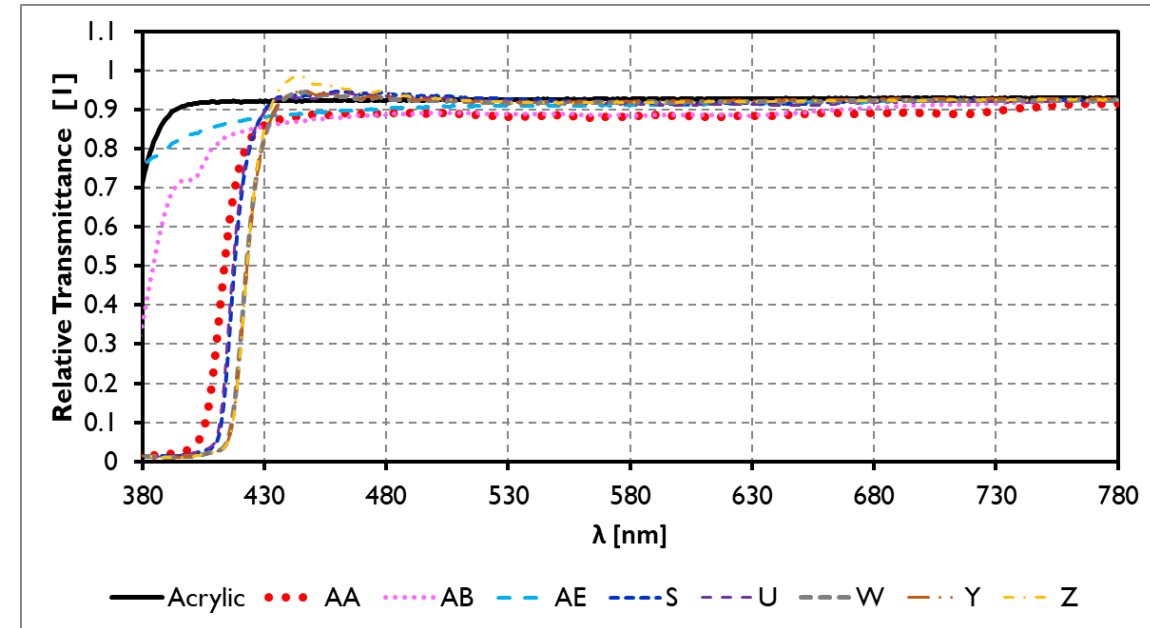
Developed Optical Materials

Printed test samples optically similar to acrylic

Printed Optics

Work to be done on post processing

Printed Luminaire



Progress and Future Work

Obstacles

Optics Printing

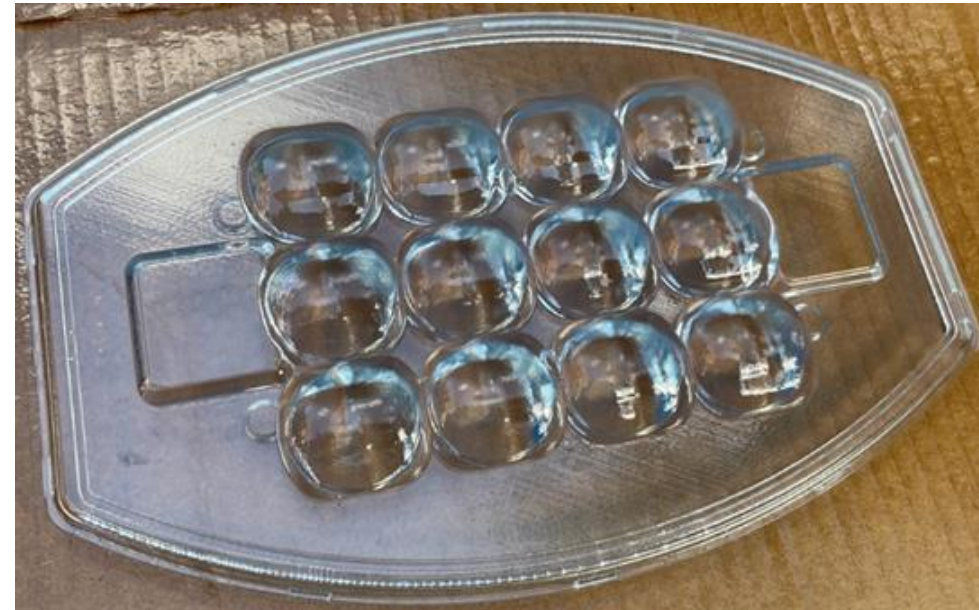
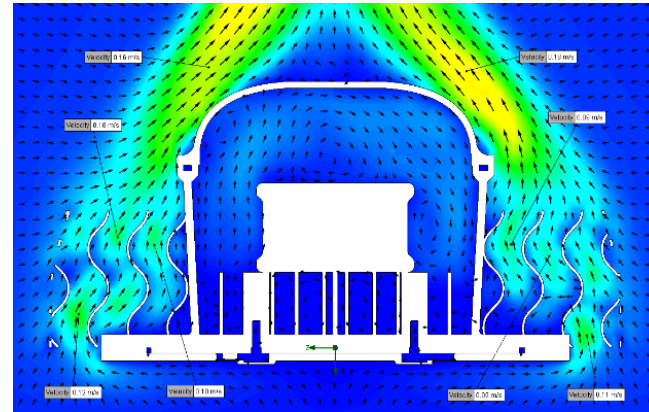
Many materials tested

Varying success with post processing

Electronics

Original prototype did not meet efficiency goal

New electronics used to meet target in application space fixtures



Progress and Future Work

Where we are winning:

Value Alignment

Improve efficiency for customers (and taxpayers)

Tech Transfer

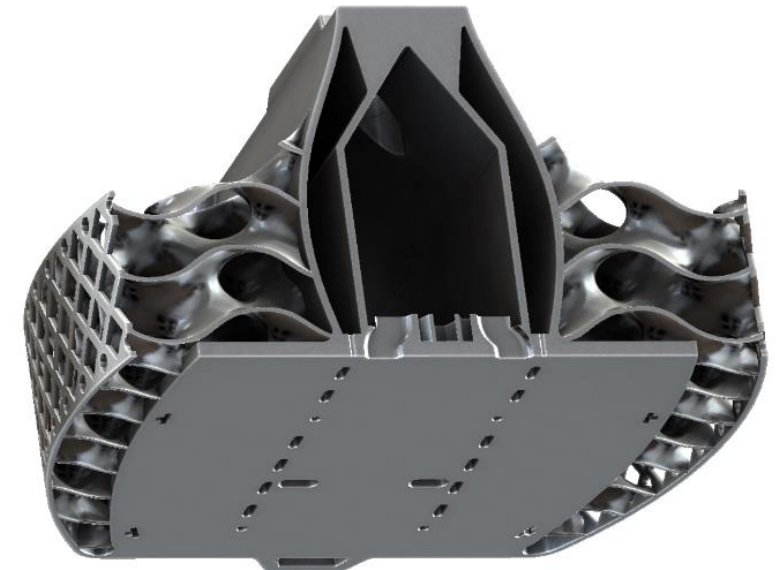
GEIS is investigating low volume, high mix product lines

Goals Met

Reshoring

SKU Reduction

Weight Reduction



Progress and Future Work

What we are working on:

Further Optics Development

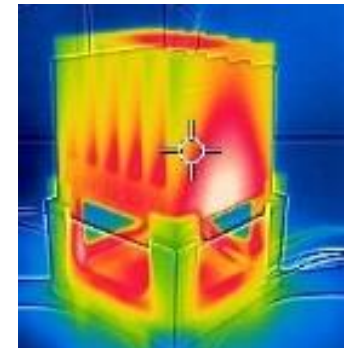
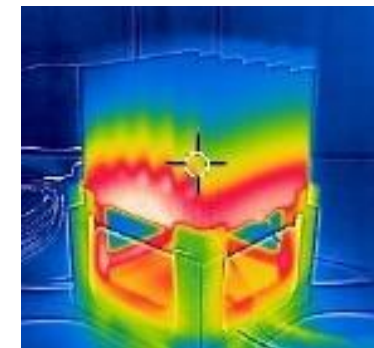
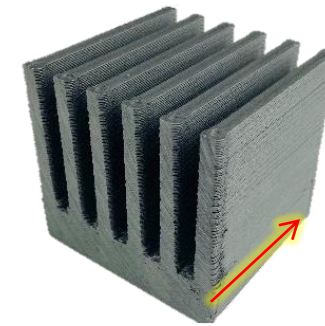
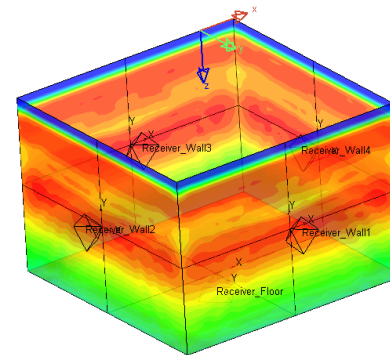
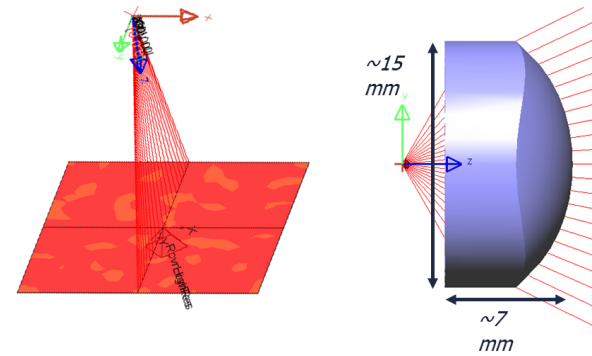
FDM

SLA

Multi-Material FDM

Thermally Conductive Polymers

Software Improvements



Thank You

Eaton, Synopsys, RPI
Dr. Sam Mills, Engineering Specialist
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Award Number: DE-EE0009695

REFERENCE SLIDES

Project Execution

	BP1: 2021-2022				BP2: 2022-2023				Total			
Planned budget	1,101,310				2,071,700				3,173,010			
Spent budget	1,101,310				256,066				1,357,376			
	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3
Past Work												
Q4 Milestone: Application Spcae Mapped	█	◆										
Q1 Milestone: Evaluate Optical Materials		█	◆									
Q2 Milestone: Complete Thermal Management Solution			█	◆								
Q3 Milestone: Test Initial Prototype				█	◆							
Q4 Milestone: DfAM Mechanical Solution					█	◆	█	◆				
Current/Future Work												
Q1 Milestone: Initiate Manufacturing for Application Space						█	◆					
Q2 Milestone: Install in Application Space							█	◆				
Q3 Milestone: Submit Final Report								█				

- Successfully built and tested BP1 prototype
 - Didn't quite meet efficacy target due to driver selection for testing
- Still on track to deliver on application space, would like to further explore polymer solutions

Team



Sam Mills, Eaton



Mike Zollers, Synopsys



Indika Perera, RPI



Jean Paul Freyssinier, RPI



Narendran Nadarajah, RPI

Chris Ring, GEIS