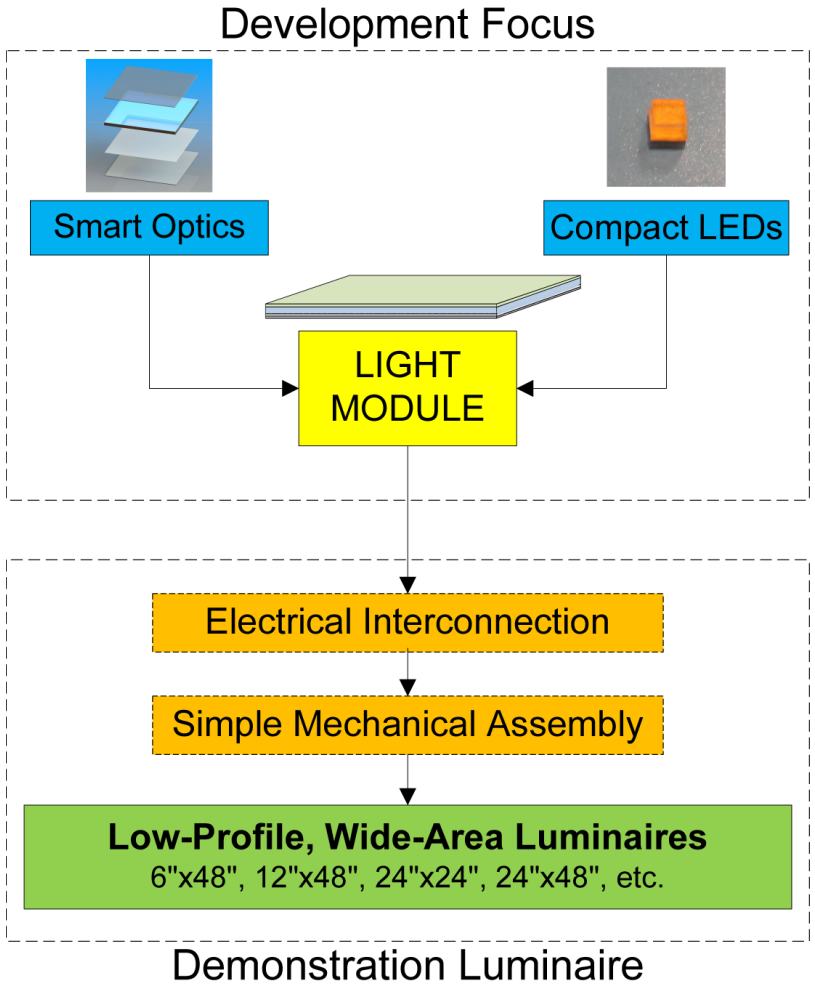
Scalable Light Module for Low-Cost, High Efficiency LED Luminaires

2015 Building Technologies Office Peer Review



Award #DE-EE0006264

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

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CREE, Inc.

Project Summary

Timeline:

Start date: 8/1/13

Planned end date: 7/31/15

Key Partners:

None external to CREE

Key Milestones:

1. LED efficacy of >150 LPW at 25°C, 35 A/cm^2, 3000K CCT, >90CRI [Met by 7/31/14 due date]
2. Identify two or more viable candidate manufacturing processes [Met by 7/31/14 due date]
3. Achieve net Light Module optical efficiency of > 90% [Due 5/15, met ahead of time]

Budget:

Total Federal funds to date: $1.95MM

Total future Federal funds: $305K

CREE Cost Share: **50%**

Project Goal:

Develop a scalable, versatile **Light Module** architecture which enables high luminaire optical and thermal efficiency. This platform will reduce LED count, result in fewer mechanical piece parts, and simplify integration and assembly. The result is **lower cost per lumen** delivered.

Target Market/Audience:

Target Market: high-efficacy, low-cost general illumination with a focus on broad-area luminaires

Purpose and Objectives

Problem Statement: despite recent reductions in SSL normalized price ($/klm), further progress is needed to encourage adoption of this high-efficacy technology.

Target Market and Audience: high-efficacy, low-cost general illumination with a focus on broad-area luminaires. For example, linear fluorescents had **2.4B** units installed in 2012, and efficacy values from 50-85 lm/W.

Impact of Project: a low-cost, high-efficiency optical architecture applicable to numerous high-efficacy, broad-area LED luminaire form factors

- *By end of Project:*
  Demonstration luminaire with broad area (~24”x48”x0.5”), warm-white (3000K) and high color quality (> 90 CRI) light output at **>116 lm/W**, and an estimated end-user price of **<$30/klm**
- *1-3 Years after project:*
  Proliferation into other retrofit/replacement fixtures, as well as development of **novel form factors** enabled by this cost-effective, lightweight architecture

Approach

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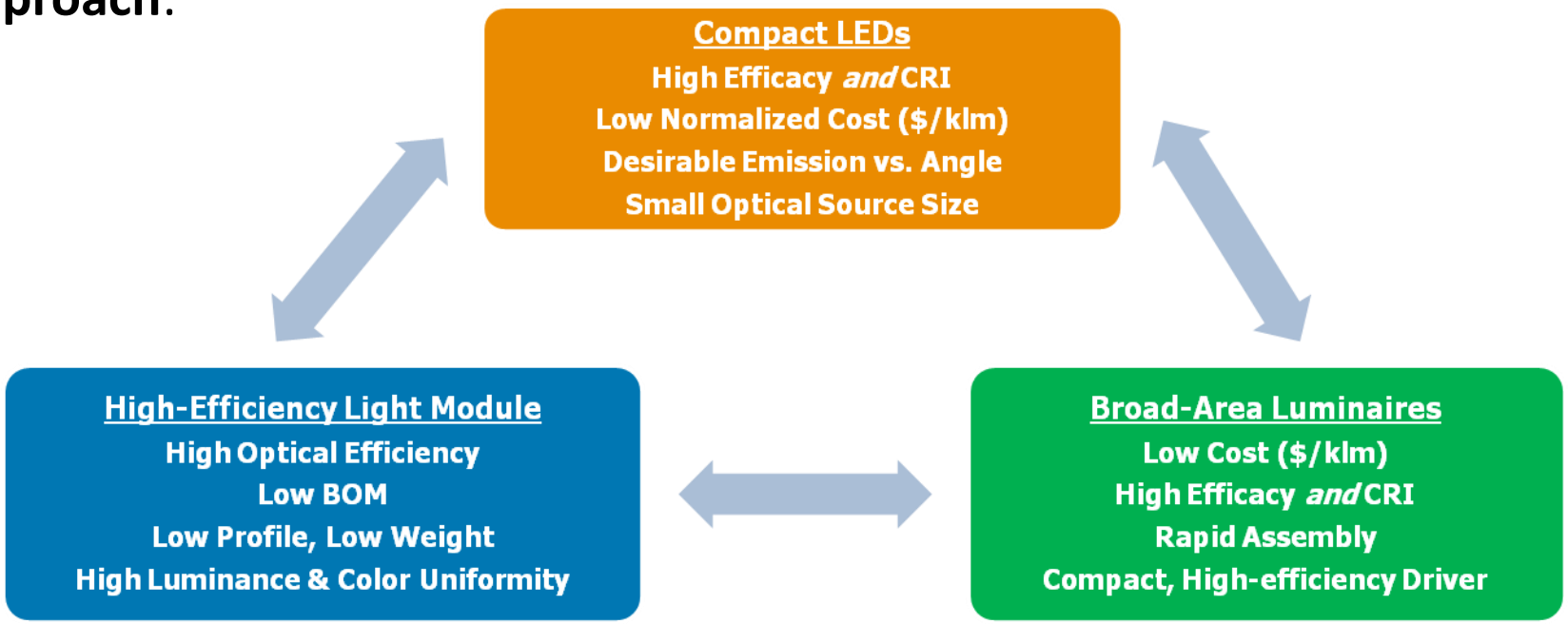
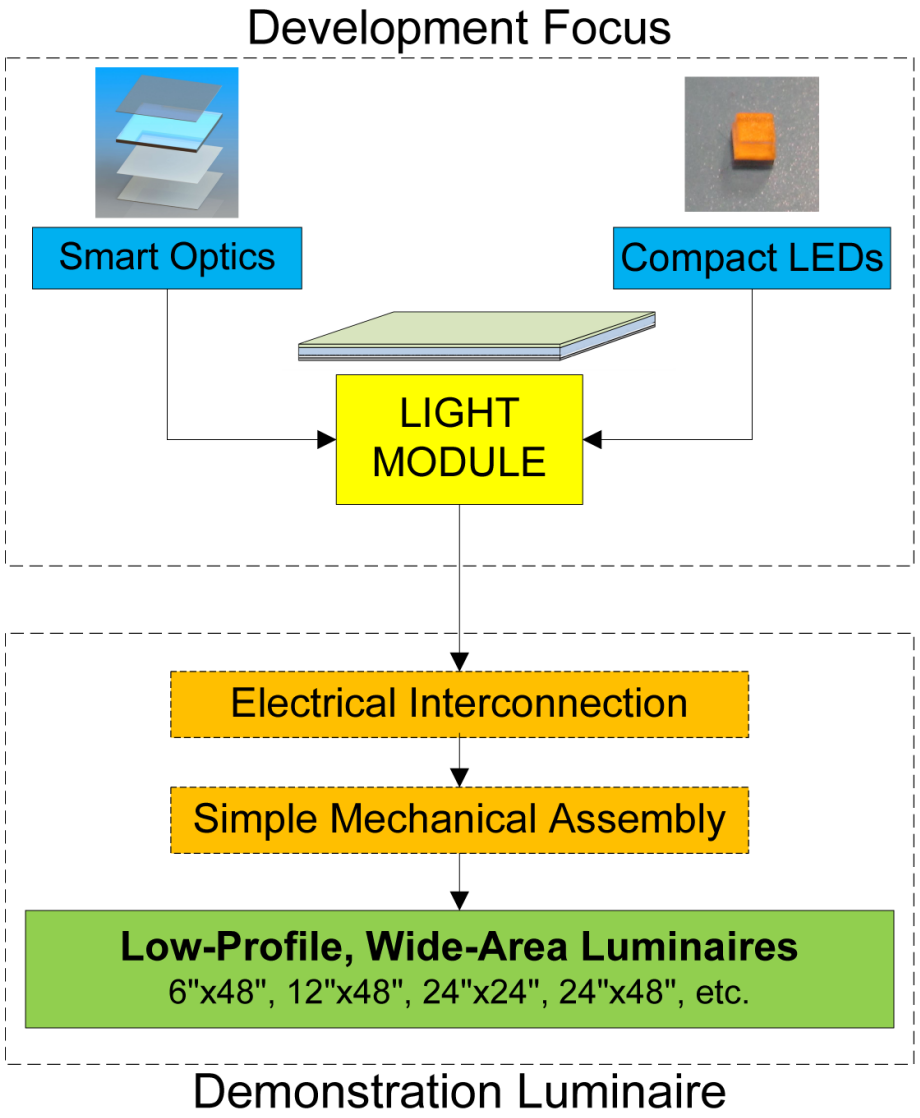


This new Light Module architecture will simultaneously enable:

- High optical, thermal efficiency
- Reduced LED count
- Fewer mechanical piece parts
- Simplified integration and assembly

} **Lowered $/klm**

Approach (cont.)



CHALLENGES

- Compact, high-efficacy *and* high-CRI LED
- LED intensity, color vs. emission angle
- Light spreading, extraction, diffusion

- Achieving > 90% net optical efficiency
- Very low (< 0.5") overall thickness
- Manufacturable fabrication processes
- Low bill of materials, assembly costs

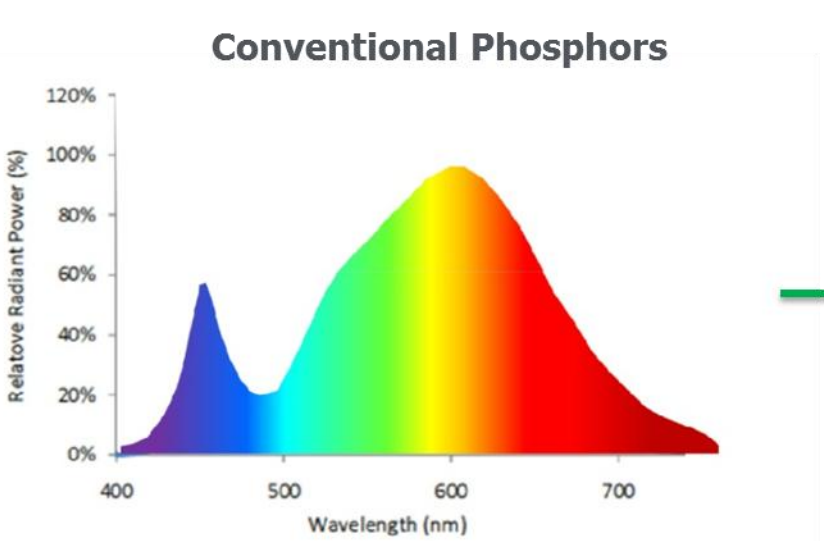
- Low-profile electrical interconnections
- Highly compact > 90% efficient driver

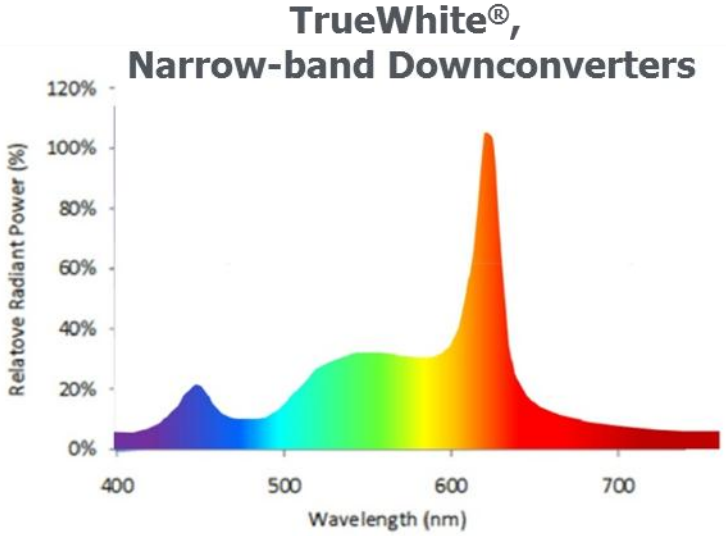
- Minimized handling & number of steps

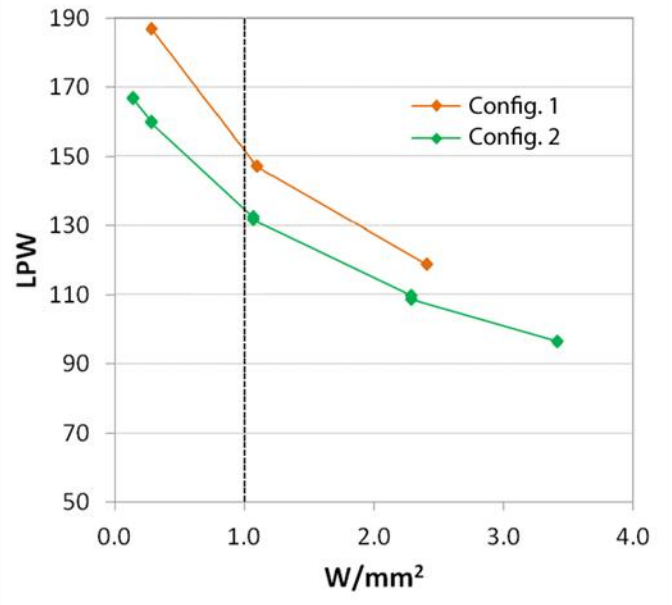
- Simple, rapid assembly
- Mechanical stability with minimal BOM

Progress and Accomplishments

LEDs: higher efficacy *and* color quality through spectral engineering



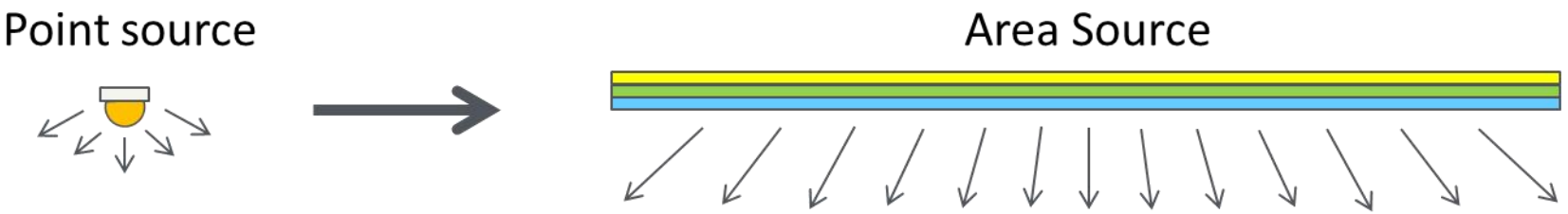


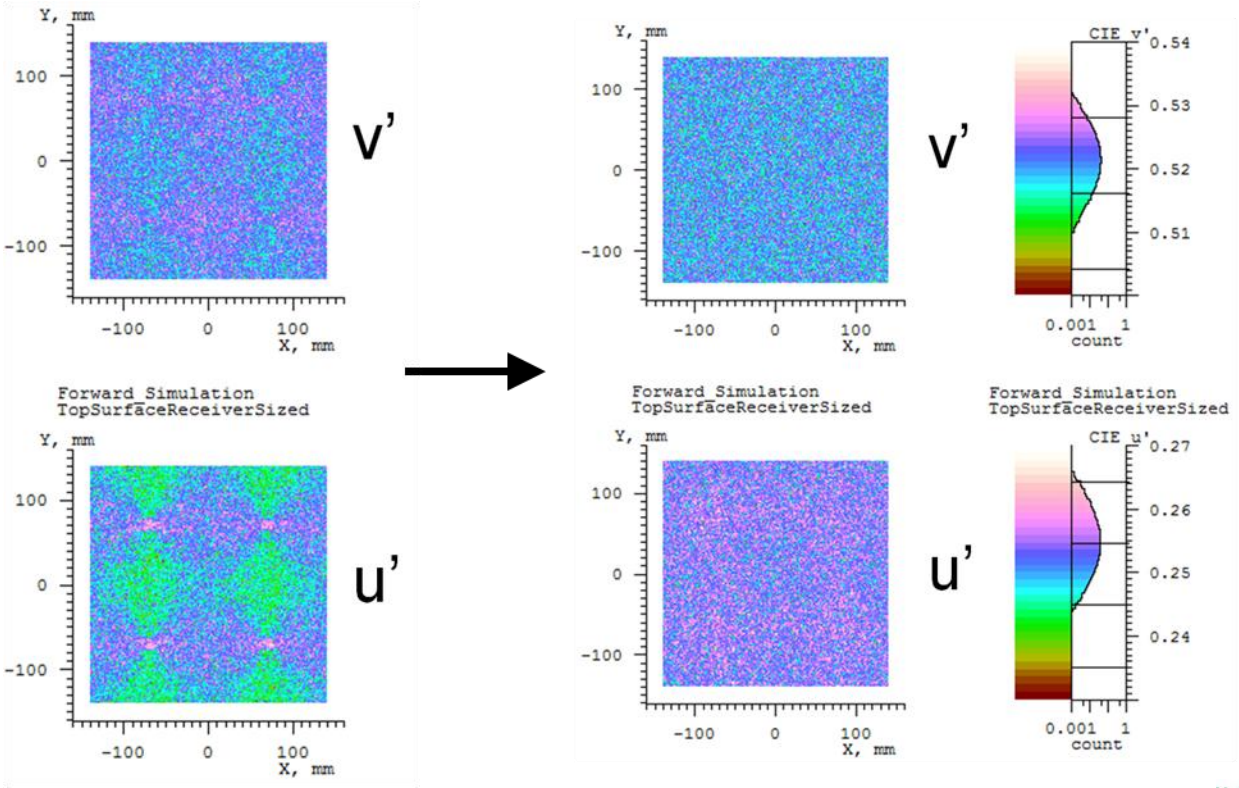


✓ **Milestone met: >150 LPW at 25°C, 35 A/cm² (= 1 W/mm²), ~3000K, >80CRI**

Progress and Accomplishments (cont.)

Light Module: an optical "repeat unit" that optimally couples and extracts light

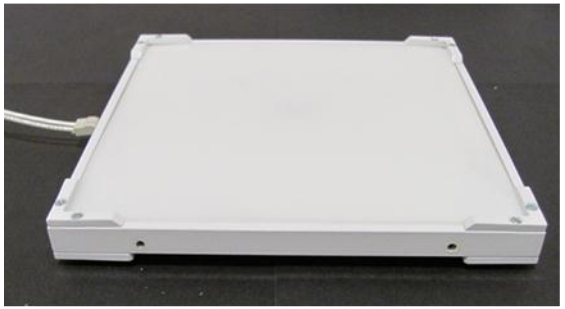




- ✓ **Milestone met: < 0.005 u',v' color point variation over the Light Module surface.**

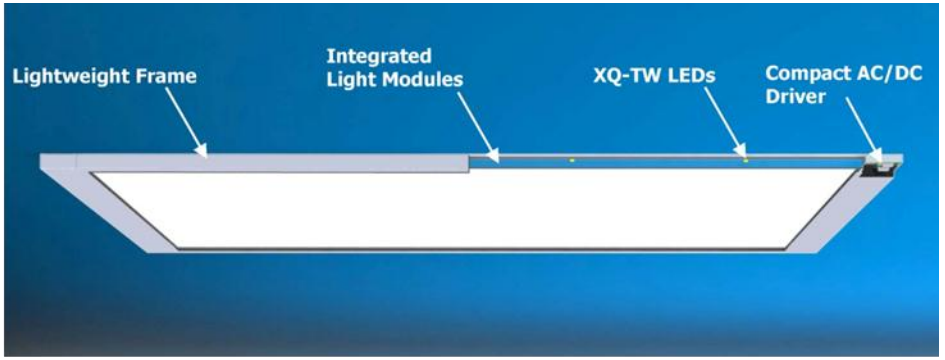
Progress and Accomplishments (cont.)

Light Module prototypes: verify modeled optical efficiency



6x6" prototype

Scalable fabrication methods



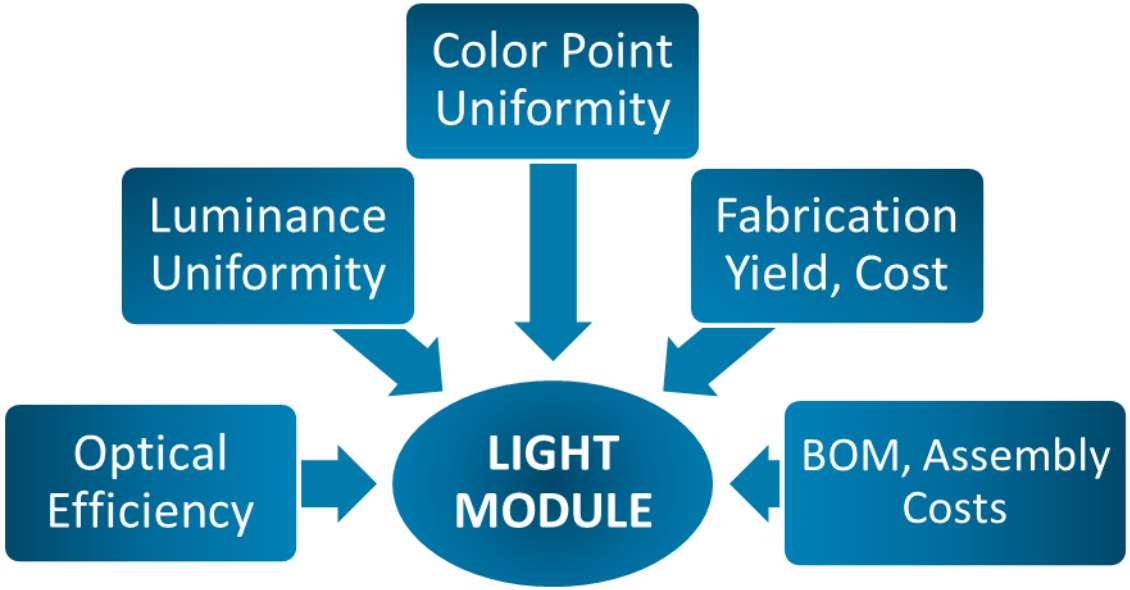
End-of-program 24x48" demonstration

	Description	LumFlux lm	Relative %	u'	v'	CCT K	CRI
No Waveguide	LED only	105.6	100%	0.2570	0.5268	2820	80
Waveguide	Without diffuser	102.5	97.0%	0.2560	0.5267	2843	80
	With diffuser	99.3	94.1%	0.2562	0.5270	2837	80

✓ **Milestone met: >90% optical efficiency from LED to ambient**

Project Integration and Collaboration

Project Integration: CREE SBTC personnel are working closely with CREE R&D and product development groups at all stages of project to ensure viability for commercialization



Partners, Subcontractors, and Collaborators: no external partners, but collaborative groups within Cree's R&D and product development teams

Communications: project results have been presented at recent DOE SSL Manufacturing and R&D Workshops

Next Steps and Future Plans

Next Steps and Future Plans:

- Refine Light Module optical design and fabrication techniques with focus on co-optimizing **uniformity, yield, and cost**
- Assemble and test a **demonstration luminaire** to demonstrate benefits of this new platform
- Continue to work closely with CREE product development groups on transition to **product commercialization**
- **Technology proliferation**: identify new form factors and applications enabled by **lowered $/klm** offered by this platform

REFERENCE SLIDES

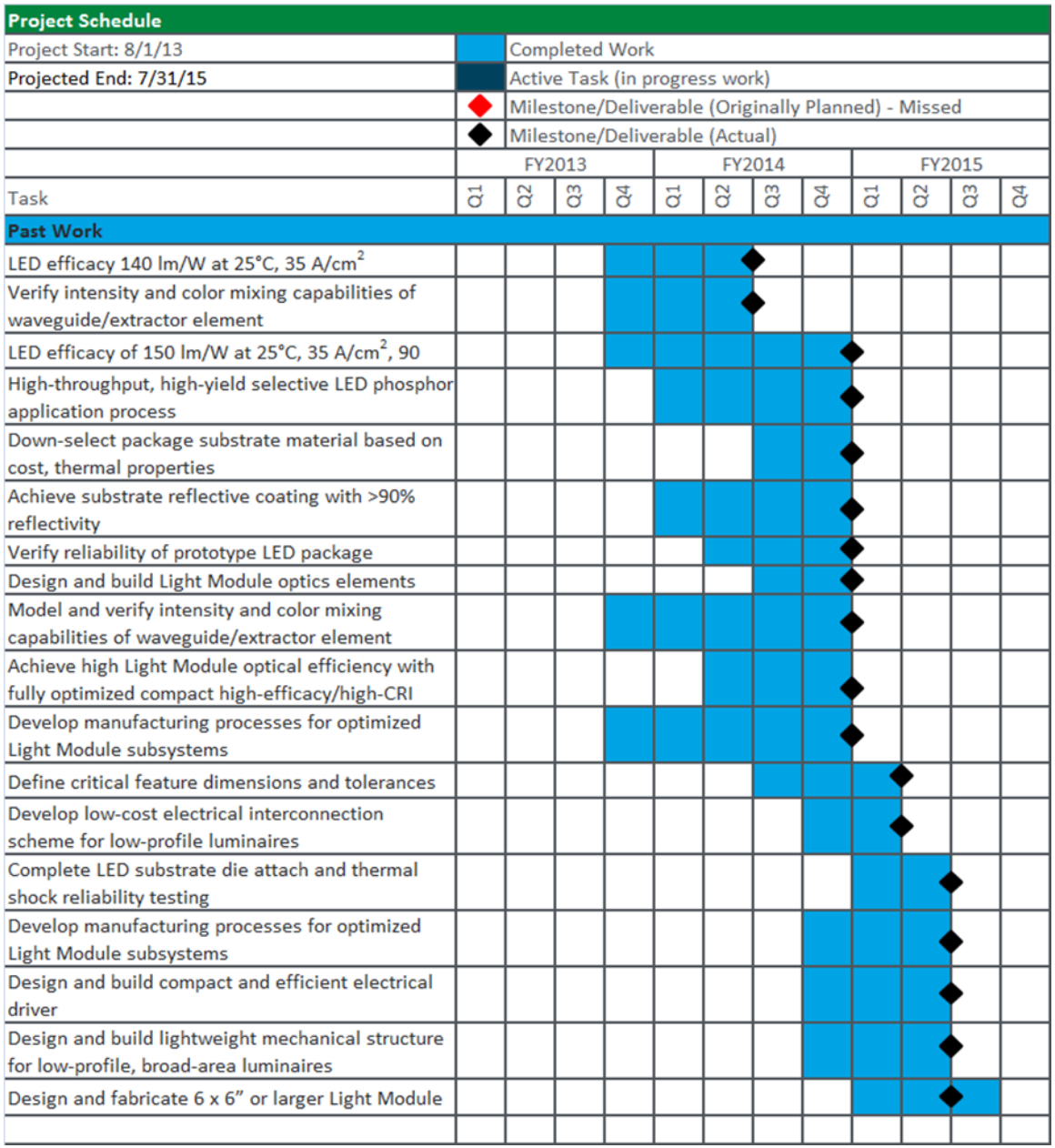
Project Budget

Project Budget: $4.7MM total over two years, with $2.35MM Federal Share
Variances: none of note.
Cost to Date: $1.95MM in Federal Share to date*, or 83% of total allocated.
Additional Funding: 50% Cree Cost Share ($2.35MM)

Budget History			
8/1/13 – 9/30/14 (past)		10/1/14 – 2/28/15* (current)	
DOE	Cost-share	DOE	Cost-share
$ 1,427,299	$ 1,427,299	$ 833,714	$ 833,714

* March 2015 spending has not been included in this total, since it has not yet been verified by CREE Accounting.

Project Plan and Schedule



Project Plan and Schedule (cont.)