



Jeffrey Nelson

Senior Manager, Semiconductor and Optical Materials

TECHNOLOGIST IN RESIDENCE PROGRAM

Council of Technologists Meeting

August 3rd, 2017: National Renewable Energy Laboratory

Wouter Soer

Director, R&D illumination Systems



LUMILEDS

Sandia National Laboratories

Facilities

Albuquerque, New Mexico



Livermore, California



Kauai Test Facility

Kauai, Hawaii

Waste Isolation Pilot Plant

Carlsbad, New Mexico

Pantex Plant

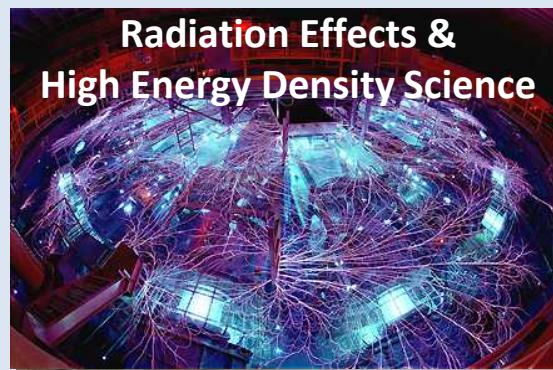
Amarillo, Texas

Tonopah Test Range

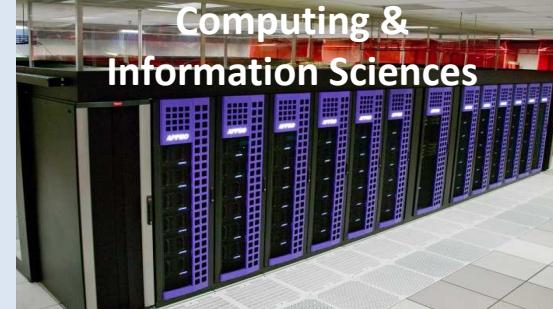
Tonopah, Nevada

Research Foundations

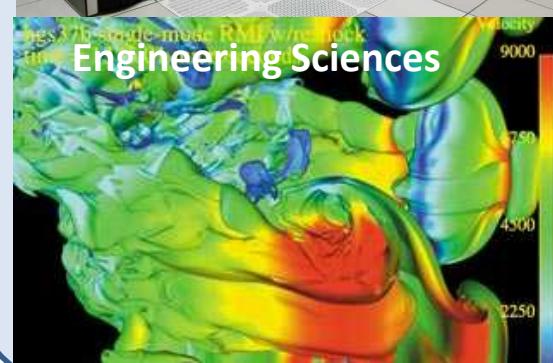
Radiation Effects &
High Energy Density Science



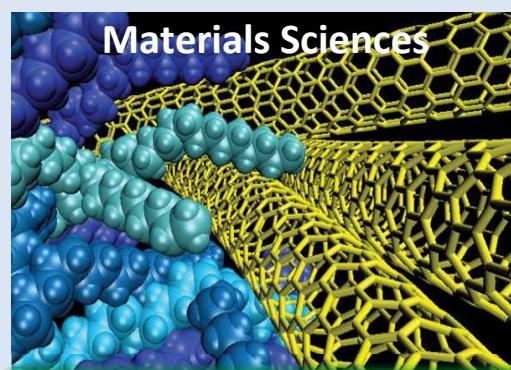
Computing &
Information Sciences



Engineering Sciences



Materials Sciences



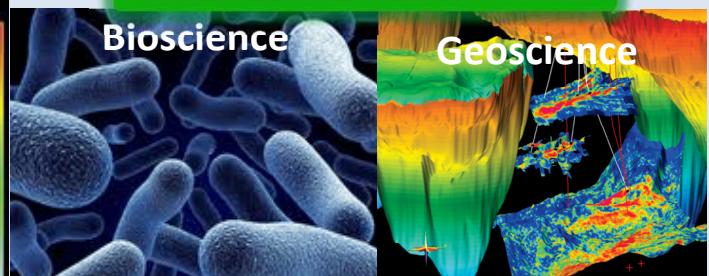
Nanodevices &
Microsystems



Bioscience



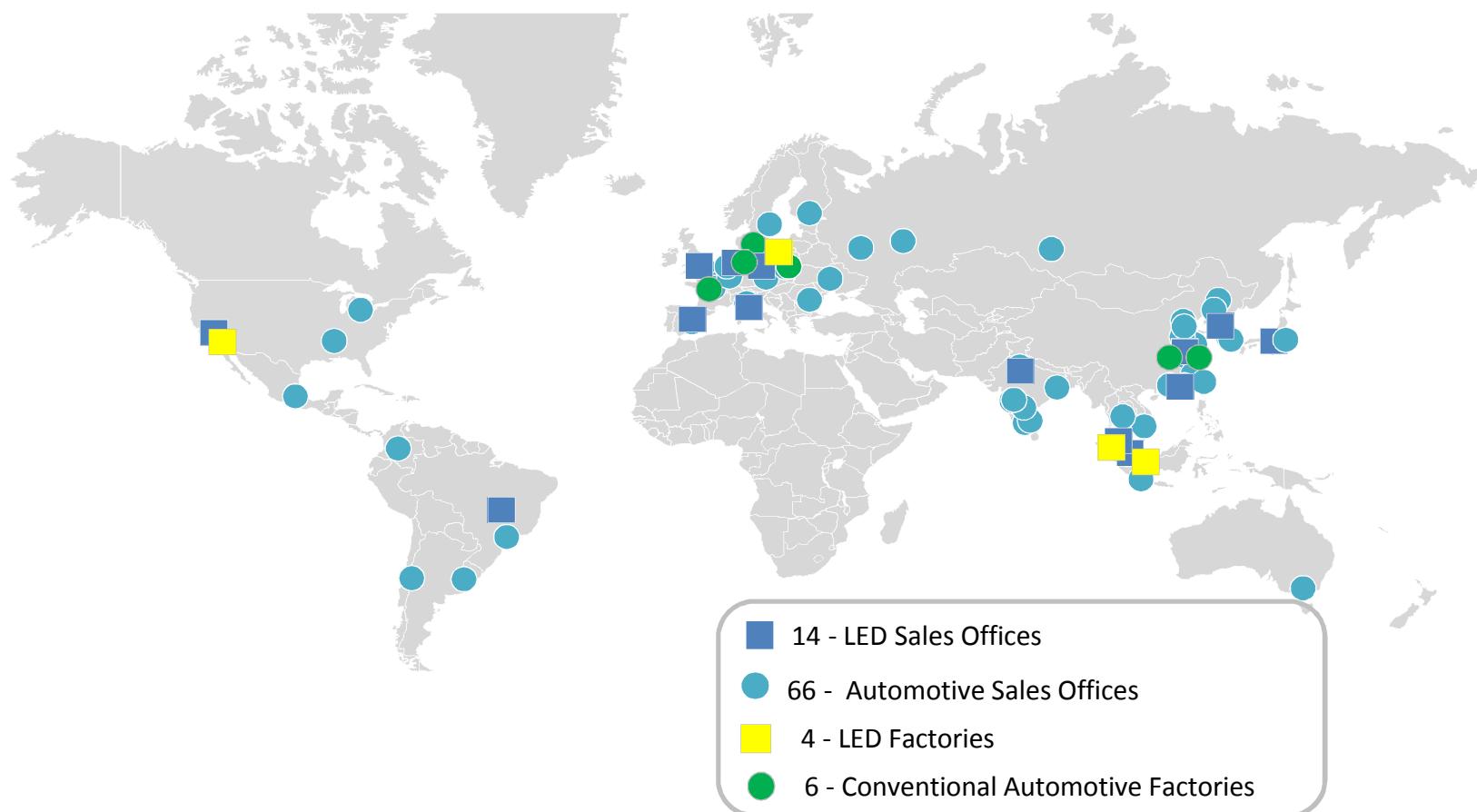
Geoscience



Lumileds, LLC

A Truly Global Footprint with Proximity to Our Customers

We are 8,500 people operating in 32 countries



100+ Years of Shaping the Lighting Industry Through Innovation and Product “Firsts”

1914

1999

2000-2014

2015-2017

- **1914:** Start of automotive lighting activities with the assembly of incandescent lamps from caps sourced from Middelburg
- **1960s:** Introduction of Halogen technology (first in market); First H1 Halogen bulb
- **1968:** Commercialization of LEDs by HP optoelectronics division
- **1970:** First H4 Halogen bulb
- **1970-1972:** HP LEDs used in HP-35 calculator and first digital watch (Hamilton Pulsar)
- **1990s:** Pioneering AllInGaP LED innovation
 - First publication and commercial introduction of red and yellow AllInGaP LEDs
 - Continual performance breakthroughs
 - First high power LED (0.5W red LUXEON LED)
 - First 100 lm/W LED
- **1992:**
 - First in market Xenon HID bulb (BMW 7-Series)
 - Rear applique (Ford Thunderbird)
- **1993:** First H7 Halogen bulb
- **1999:**
 - Lumileds became a joint venture between Philips and Agilent (HP)
 - First LED front turn



- **2000:**
 - First full automotive rear lamps (Cadillac DeVille)
 - First aftermarket Halogen upgrade (Bluevision+)
- **2001-2003:** Introduced white high power LEDs
 - First 1W power LED (LUXEON I)
 - First 3W and 5W LUXEON power LED families
 - Industry's first warm white LED
- **2002:** First large volume HiPer (Mercedes E-Class)
- **2004:**
 - First TV backlit with LEDs
 - First LED for functional cell phone camera flash
 - First LED DRL (Audi A8 W12)
- **2006:** Philips acquired Agilent Technologies' interest in Lumileds
- **2007:**
 - First full LED headlight (Audi R8)
 - World's smallest, lowest cost power LED introduced: LUXEON Rebel
- **2008:** First Xenon upgrades
- **2009:** Launch of accessory business (air purifiers, dash cams)
- **2010:**
 - World's first to ship 1 billion high power LEDs
 - Enabled first 60 watt, 90 lm/W, true replacement DOE L-prize bulb
- **2011:** First fully integrated HID system (D5S)
- **2013:**
 - World's first Chip Scale Package LED
 - First combined daytime running light / front turn



- **2015:**
 - Lumileds independent
 - New state-of-the-art 2-filament Halogen
 - Introduced nitride red phosphor with record-low FWHM: SLA
- **2016:**
 - RacingVision: most powerful halogen ever
 - Tire pressure monitoring system (TPMS) launch
- **2017:**
 - First illumination-grade LEDs with quantum dots
 - LED H7: 1st LED retrofit headlight



Lumileds Operates in Diverse Segments in Automotive and LED

Continued Track Record of Technology Leadership

LED – General Illumination



Automotive – Original Equipment Market



LED – Consumer



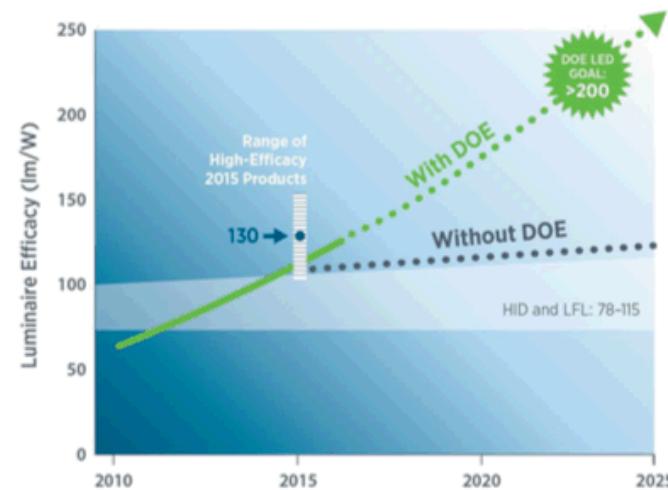
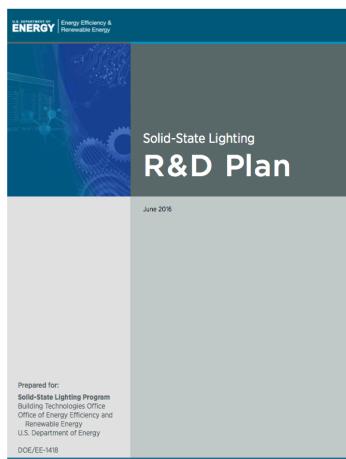
Automotive – Aftermarket



Customer proximity and joint development strengthen long-term relationships

Note: Automotive OEMs are partners and customers via Tier 1 suppliers

DOE-EERE Technology and Market Leadership



Relative Cost for LED 800 lm A19 Lamp

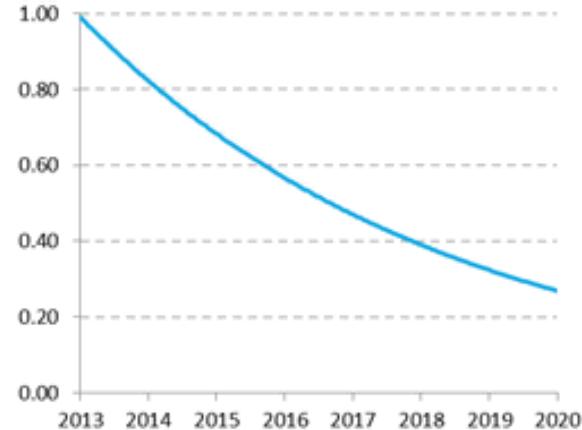


Figure 2.2 Cree Edge Area Square, Edgewater Marketplace, Edgewater, CO
Source: John Edmond, Cree Inc., SSL R&D Workshop, San Francisco, CA, January 2015 [11]

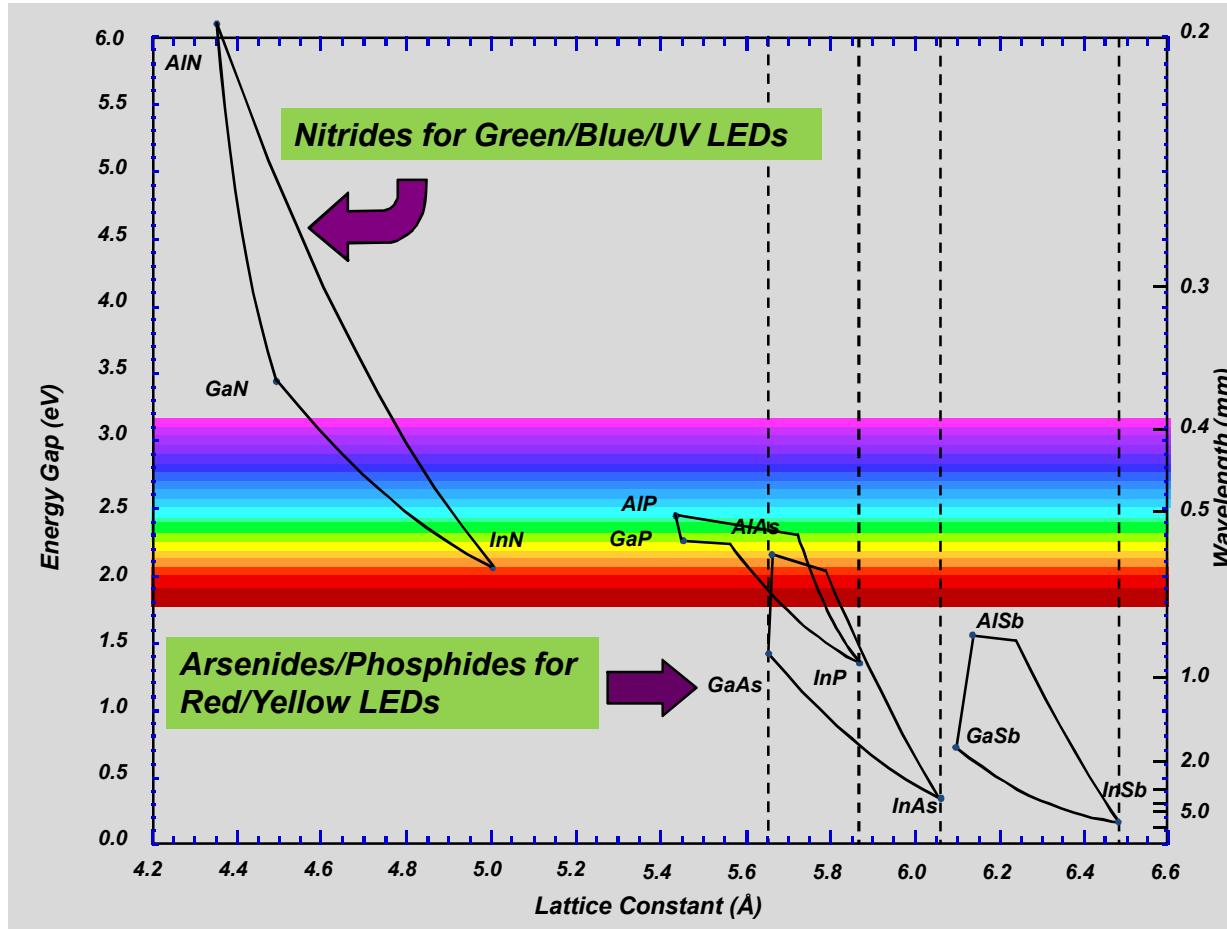
2015 Product Type	Luminous Efficacy (lm/W) ²	Correlated Color Temperature (CCT) (K)	Usable Life ¹ (hours)	Price (\$/kW)
LED A19 Lamp (Dimmable, Warm White) ²	78	2700	25,000	\$10
LED PAR38 Lamp (Warm White) ²	70	3000	28,000	\$19
LED T8 Tube (Neutral White) ²	107	4100	50,000	\$10
LED 6" Downlight (Warm White) ²	64	3000	40,000	\$29
LED Troffer 2' x 4' (Warm White) ²	94	3500	56,000	\$29
LED High/Low-Bay Fixture (Warm White) ²	102	4000	90,000	\$23
LED Street Light ²	96	5000	50,000	\$49
OLED Luminaire ³	43	3000	40,000	\$870
HID (High Watt) System ⁴	115	3100	15,000	\$3
Linear Fluorescent System ⁴	108	4100	25,000	\$4
HID (Low Watt) System ⁴	104	3000	15,000	\$4
CFL A19 Replacement	70	2700	12,000	\$2
CFL (Dimmable) A19 Replacement	70	2700	12,000	\$10
Halogen A19	20	2750	8,400	\$2.50
Incandescent A19	15	2760	1,000	\$0.63



Sandia National Laboratories

What brought us together in the past?

Epitaxy, Characterization, Modeling, and Device Physics



What brings us together in this TIR project?

LED lighting system evolution – System Integration

Phase 1

Socket replacement



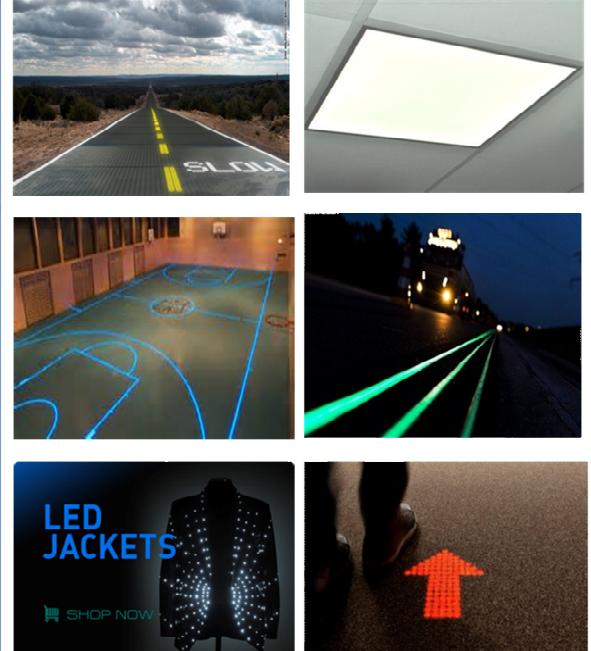
Phase 2

Form factor innovation and connectivity



Phase 3

Infrastructure integration



Collapse of system hardware levels

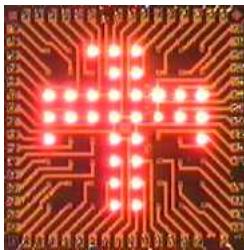
Integration S&T Capabilities at Sandia

Microsystems and Engineering Science Applications (MESA)



- 60+ years as DOE/NNSA mission lead in electronics
- Silicon and III-V Materials
- Sensors, Optoelectronics, Electronics, MEMS, 2.5-D integration

<http://www.sandia.gov/mstc/>

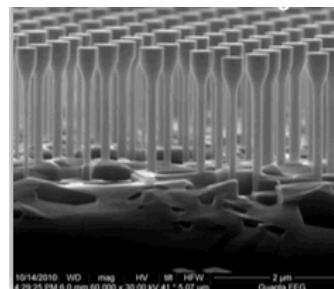


Center for Integrated Nanotechnologies (CINT)



- DOE BES-SUF NSRC
- Celebrating 10th Anniversary
- Focus on Integration of Nanoscience and Technology

www.cint.lanl.gov



Where are we at after two months?

Execute NDA-	5/31/2017
Initial Kick-Off Meeting at Lumileds-	6/2/2017
Develop CRADA Documents-	June-July, 2017
Follow-Up Technical Exchange (teleconference) -	7/17/2017
CRADA Approved (anticipated)-	8/16/2017
Technical Workshop at Sandia -	8/18/2017

Important Ingredients for Success (no magic here):

- Assembly core teams to drive progress
- Work towards goals and deliverables
- Get NDA/CRADA in place to make everyone comfortable with detailed technical and market discussions
- Provide/promote continual opportunities for one-on-one and broader engagement of technical staff and management

Thank You

Lumileds

- Wouter Soer
- Ron Bonne
- Oleg Shchekin
- Ananth Tamma

Sandia

- Jeff Nelson
- Jeff Tsao
- Igal Brener
- Bob Kaplar