LED ROADWAY LIGHTING

leading the LED technology wave

‘LED Lighting – Products and Developments’

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Presentation

- LED's & how they work?
- How to manufacture an LED Streetlight.
- MTBF & Reliability.
- Cost Benefits.
- Q&A's

LED's Old or New Technology ?

LED Wristwatch circa 1974

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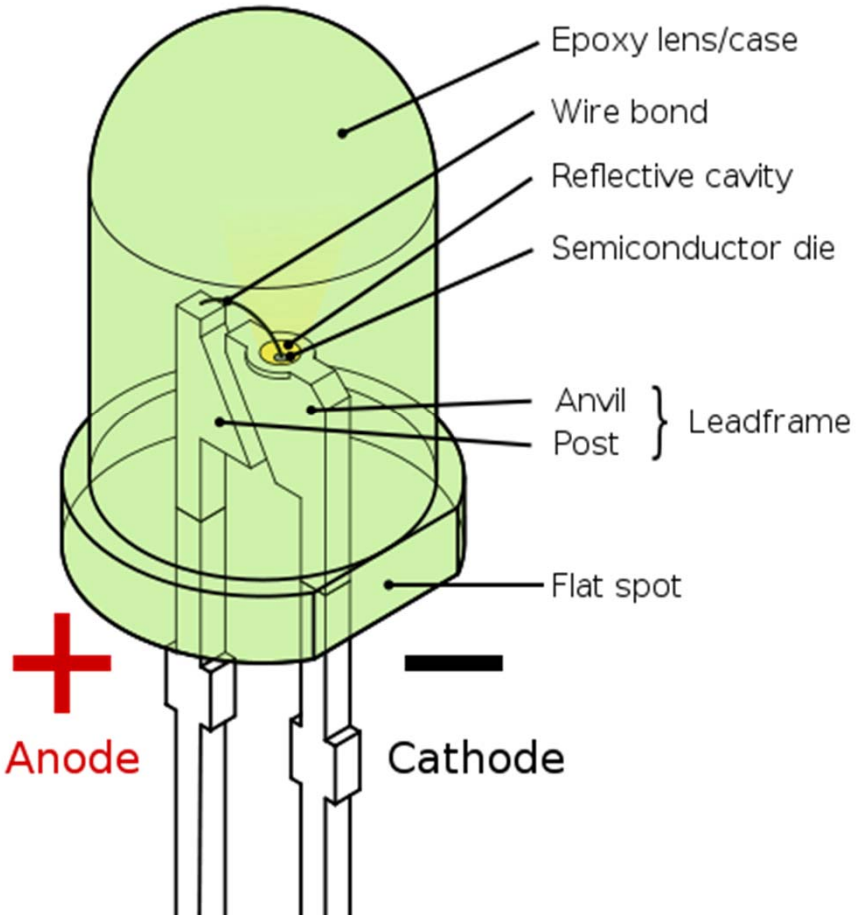
40+ Year Design Life



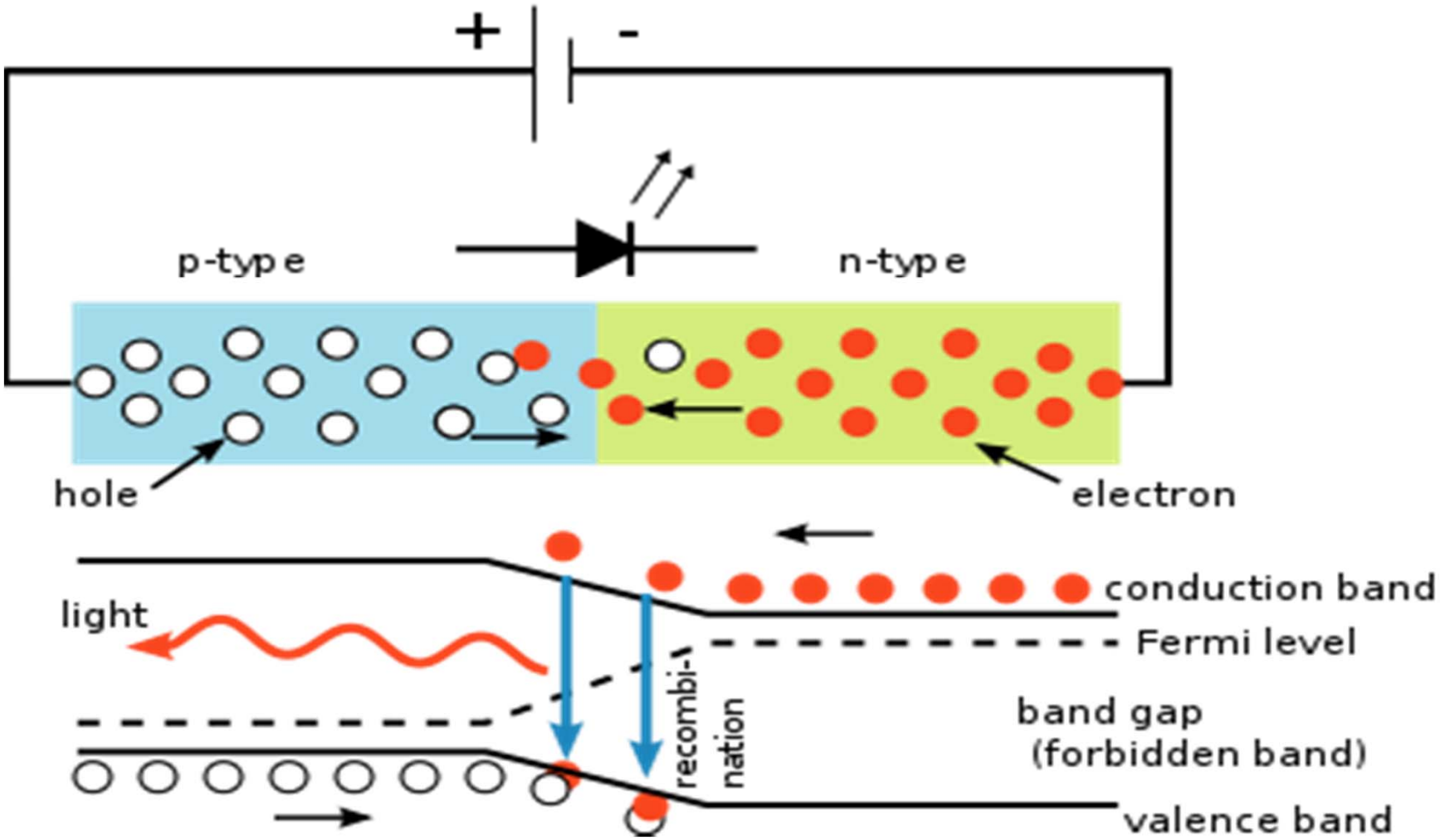
Red, pure green and blue LEDs of the 5mm diffused type

Type	Passive, optoelectronic
Working principle	Electroluminescence
Invented	Nick Holonyak Jr. (1962)
First production	1968

Electronic symbol

Pin configuration

How do they work ?



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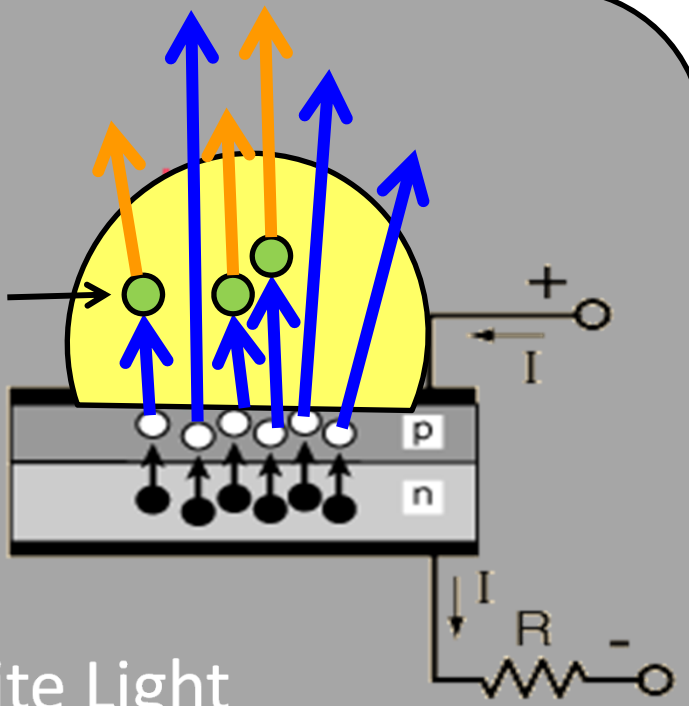
White Light

White Light Emitting Diode (LED) Structure

NICHIA Brand LEDs

- Largest Supplier of LEDs in the world
- Inventor of the Blue LED
- Inventor of the White LED

Phosphor



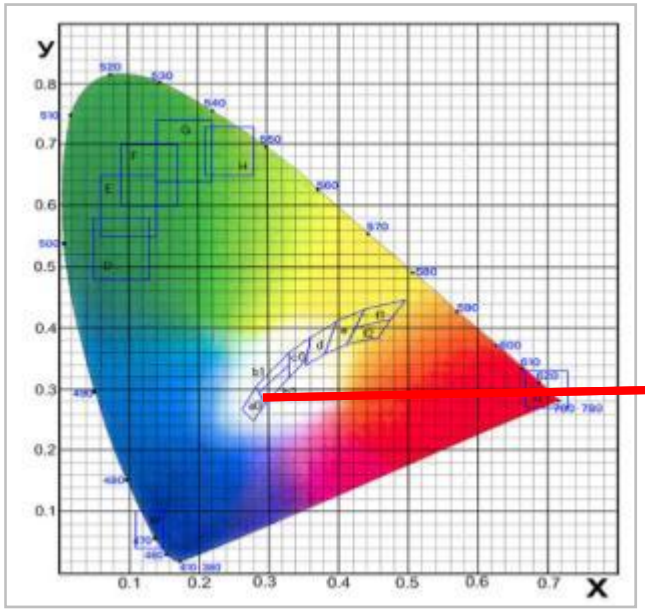
Human Eye: Chromaticity: Blue + Green = White Light

White Light = coating a Blue LED with yellow/green phosphor

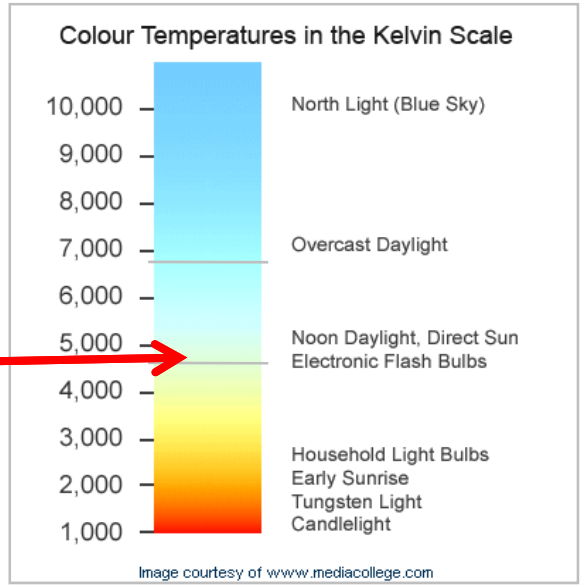
LED Binning

Not all LEDs are created equal

- LEDs are manufactured in large batches, normally with very little consistency in color and efficacy.
- LEDs are then sorted into groups, or 'bins', according to color, efficacy and forward voltage (Vf).
- LRL is supplied by Nichia from its two highest quality bins and the highest percentage from its top bin.
- LRL regularly tests its products in its integrating sphere to verify efficacy.



Universal Chromaticity Chart



LED Roadway Lighting fixtures ~ 5,000K

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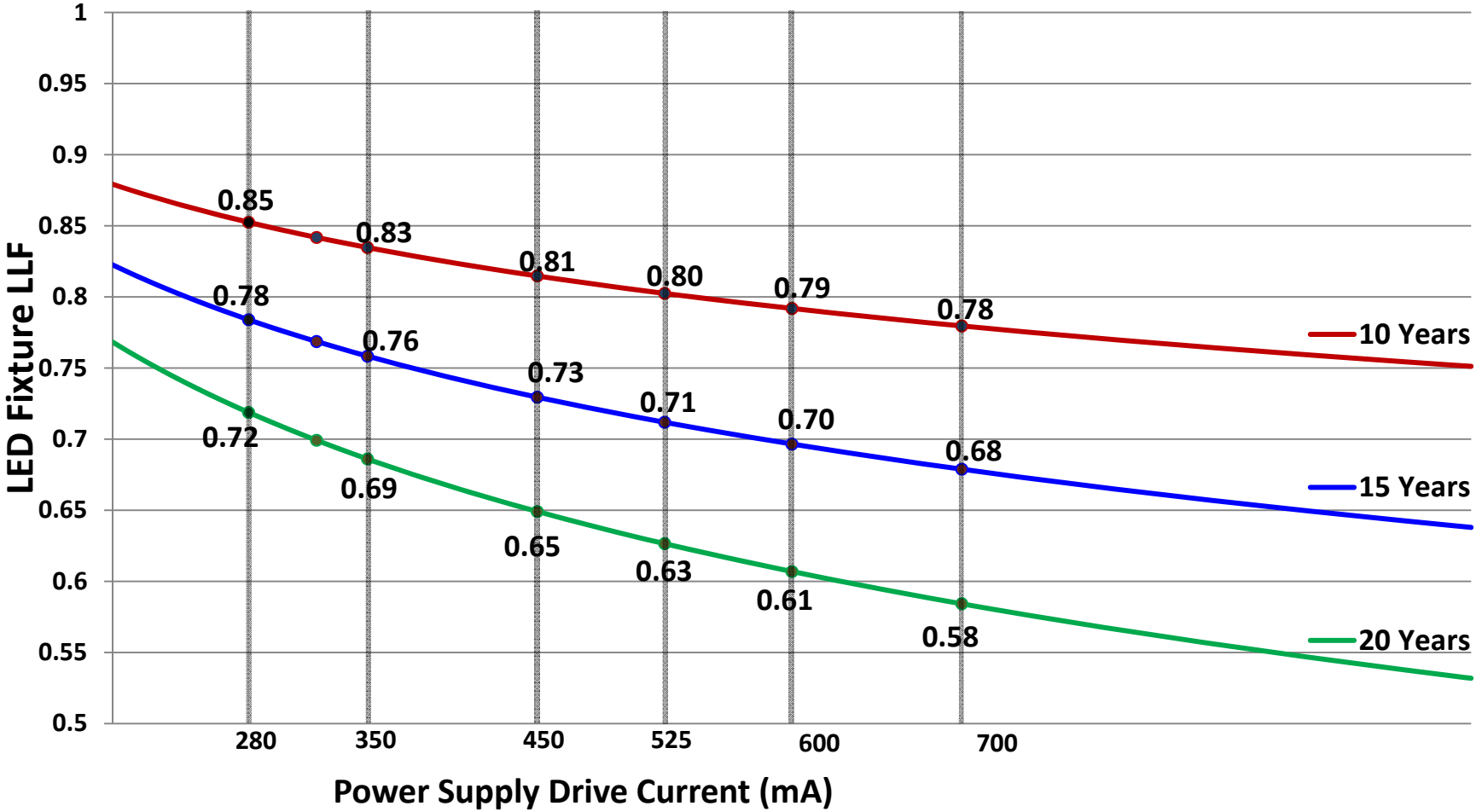
LRL Total Fixture LLF vs. Driver Current (ambient T=20°C/68°F)



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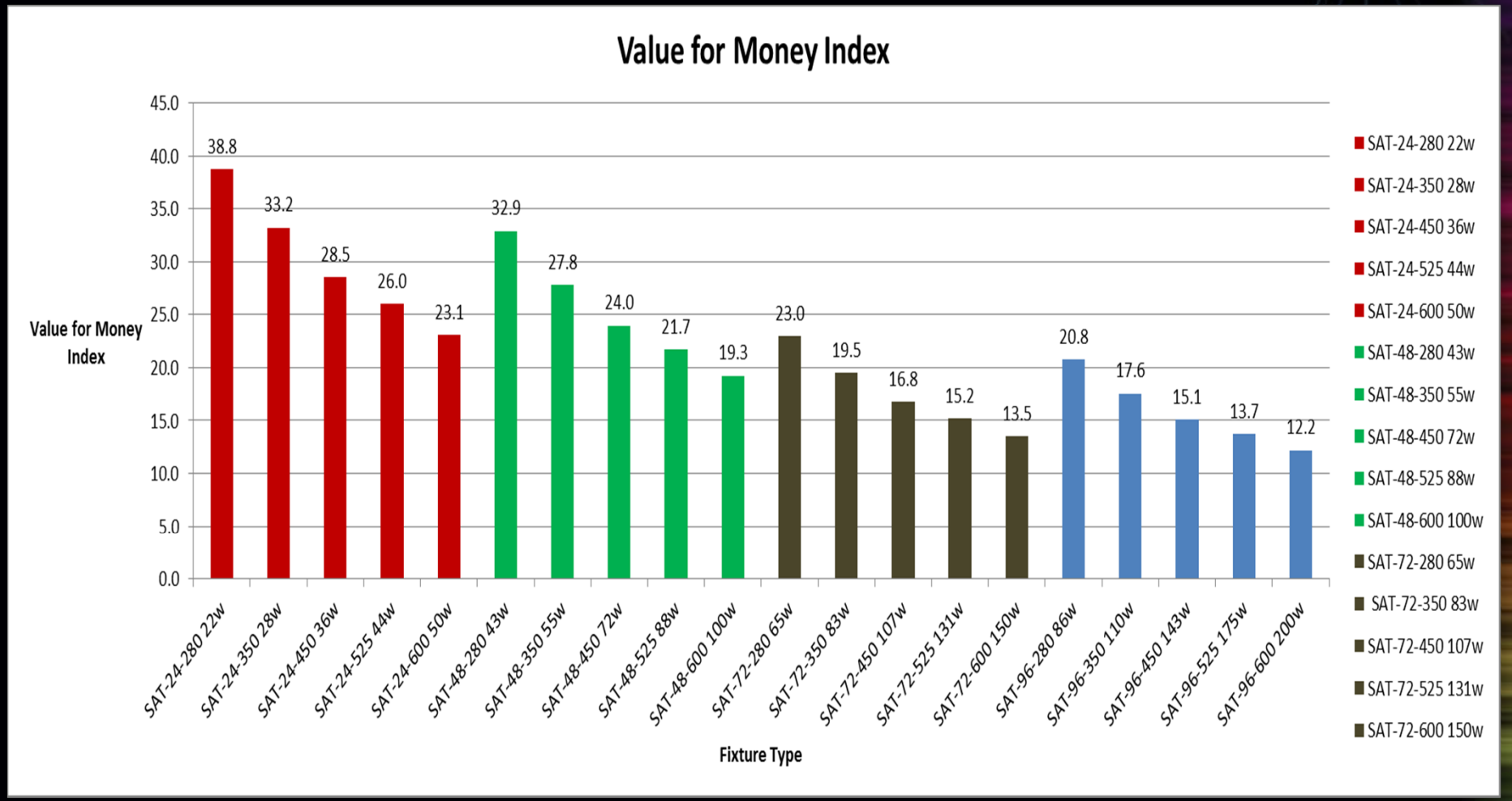

LED Development Facts

The development of LED technology has caused their efficiency and light output to rise exponentially, with a doubling occurring about every 36 months since the 1960s.

The advances are in general attributed to the parallel development of other semiconductor technologies and advances in optics and material science.

In February 2008, a luminous efficacy of 300 lumens of visible light per watt of radiation (not per electrical watt) and warm-light emission was achieved by using nanocrystals.

In 2009, a process for growing gallium nitride (GaN) LEDs on silicon has been reported. Epitaxy costs could be reduced by up to 90% using six-inch silicon wafers instead of two-inch sapphire wafers

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How to Build an LED Street Light with a 20 year Design Life ?

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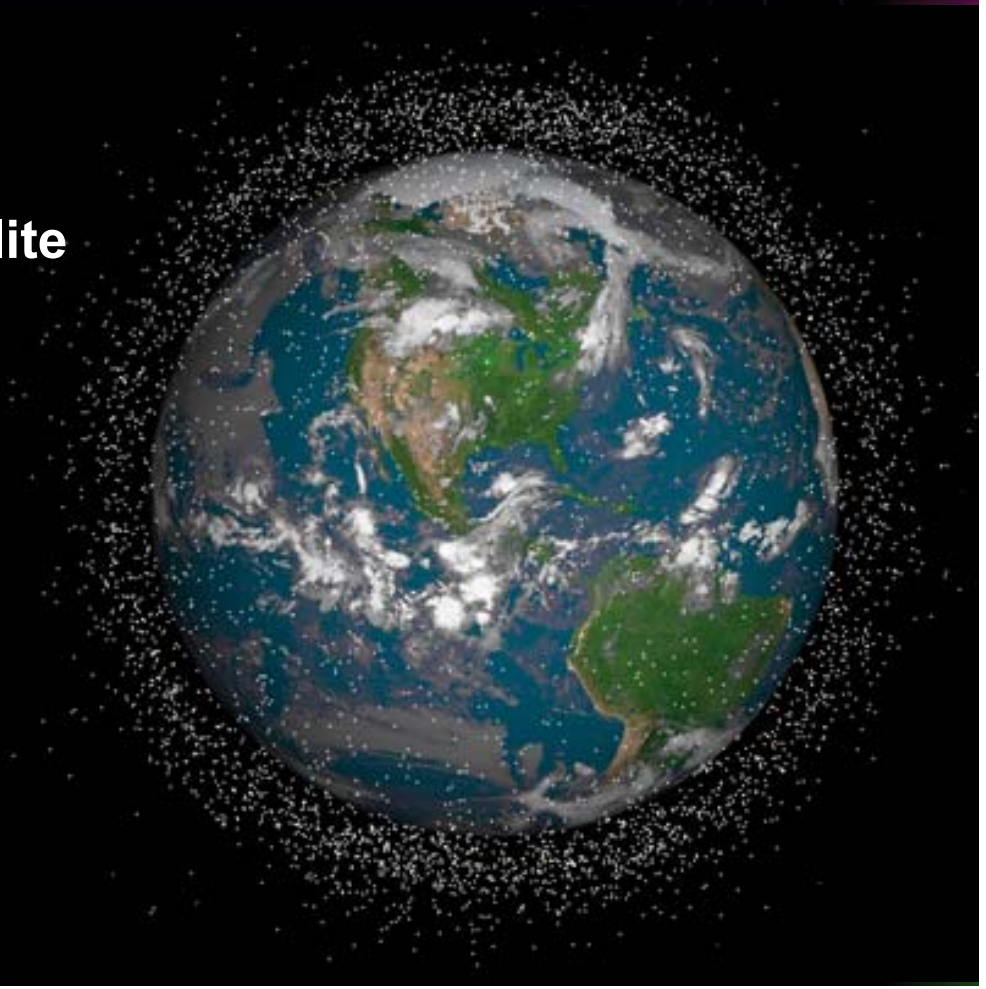
~ 1,000s of Satellites in Earth Orbit: >25 yr Power Supplies

MILSTAR: A communication satellite



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Leadership

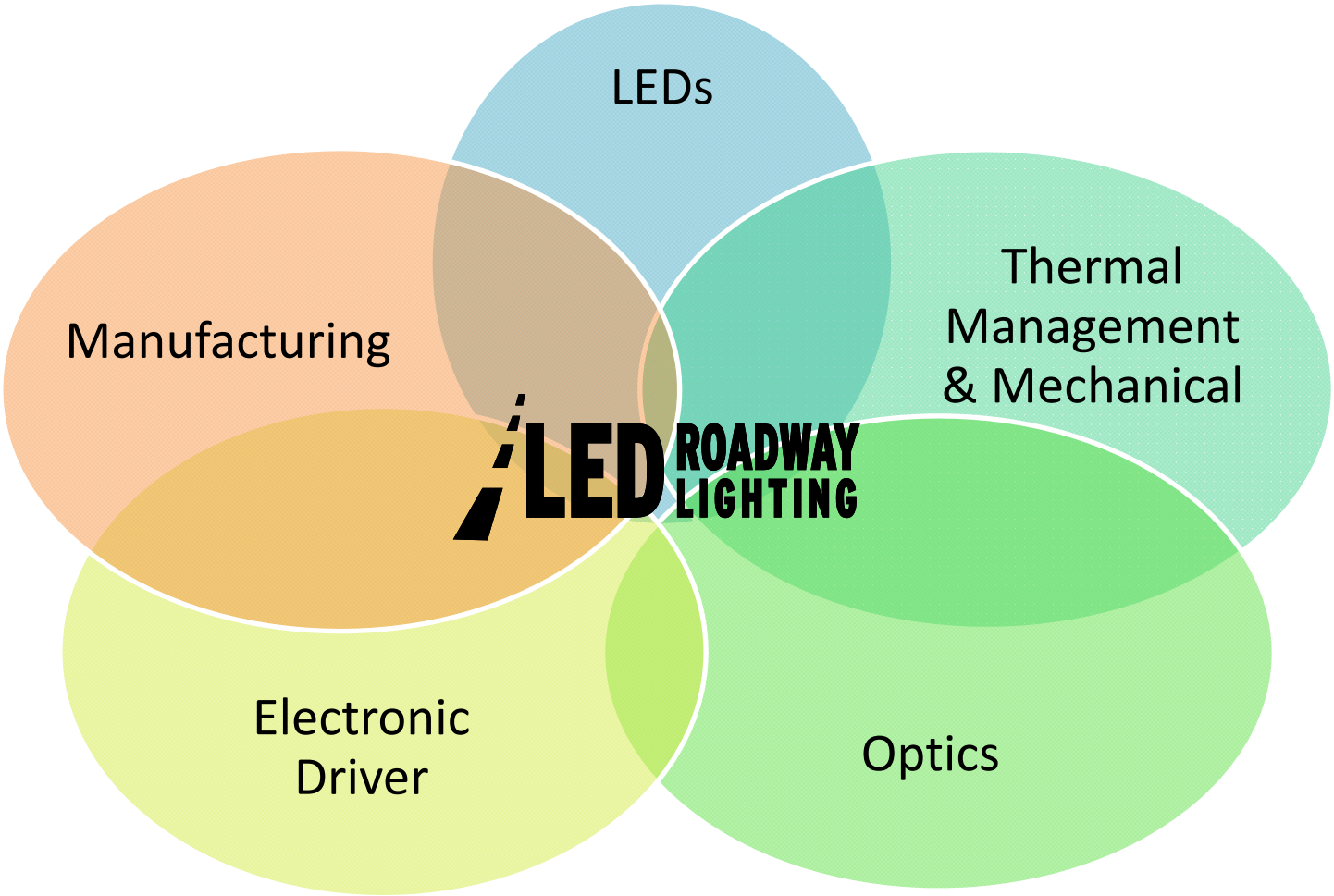
Chuck Cartmill C.E.T - CEO & Founder (Cartmill Group Of Companies)

- Lighting industry experience starting in 1974-CSA Enterprises (Manufacturers Rep)
- LED lighting manufacturing since 2003 (C-Vision Electronics Manufacturing)
- 2006 Ernst & Young Manufacturing Entrepreneur of the Year and overall Entrepreneur of the Year for Atlantic Canada - Top 50 CEO Hall of Fame

Dr. Jack Josefowicz – CTO & Director of R&D

- 16+ Patents
- PhD in Physics from the University of Waterloo
- Killam Memorial Scholar at Harvard University
- Hughes Research Laboratories in Malibu, CA
  - o Senior Scientist and Program Manager
- Tyco Electronics ($1 Billion business unit), LA, CA
  - o Director of Technology and R&D

5 Major LED Fixture Design Challenges



~ All Vertical Integration at LED Roadway Lighting Ltd. ~

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Manufacturing

About Us

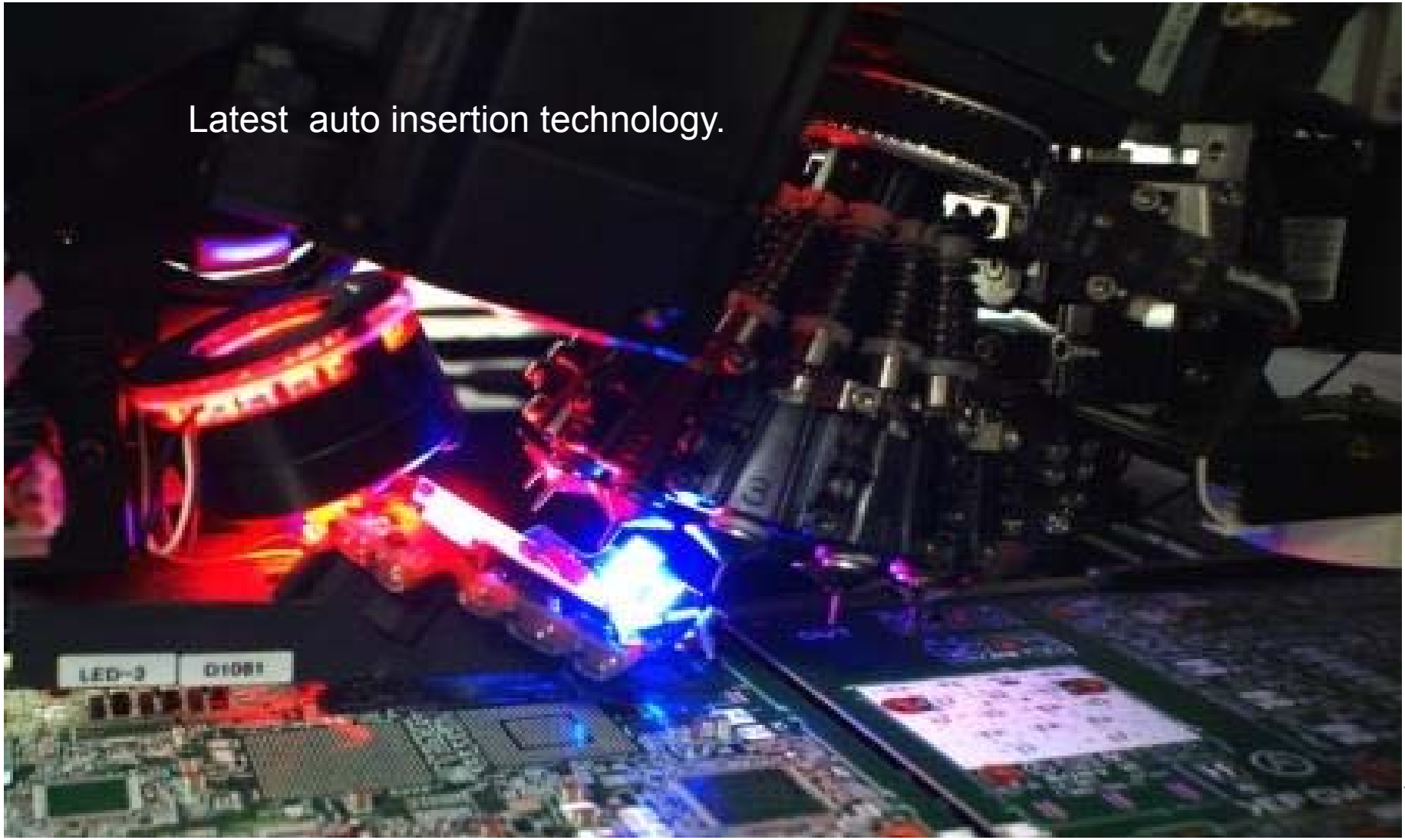
- Electronics manufacturer since 1993.
- 20,000 m^2 world class electronics production facility in Nova Scotia.
- Manufacturing LED products since 2003
- Over 200 employees
- Manufacturing with SONY UK Tech since August 2011

Manufacturing Facility

- 5,100 m^2 facility
- Production Capacity: 5,000 fixtures per week
- ISO 9001 Certified by British Standards Institute (BSI)
- RoHS Compliant & Lead-Free Assembly Certified (IPC)
- LEDs are stored in Moisture-proof cabinets to prevent moisture ingress, dust free environment.

Nova Scotia, Canada

Manufacturing Facility



Manufacturing RoHS Capabilities

Nitrogen Tank

(improves quality when building lead-free)

XRF Analyzer

(tests solder and components to verify lead-free)

LED Electronics Assembly Lines

(grounded electronics working stations complete with hydraulic lifts, etc)

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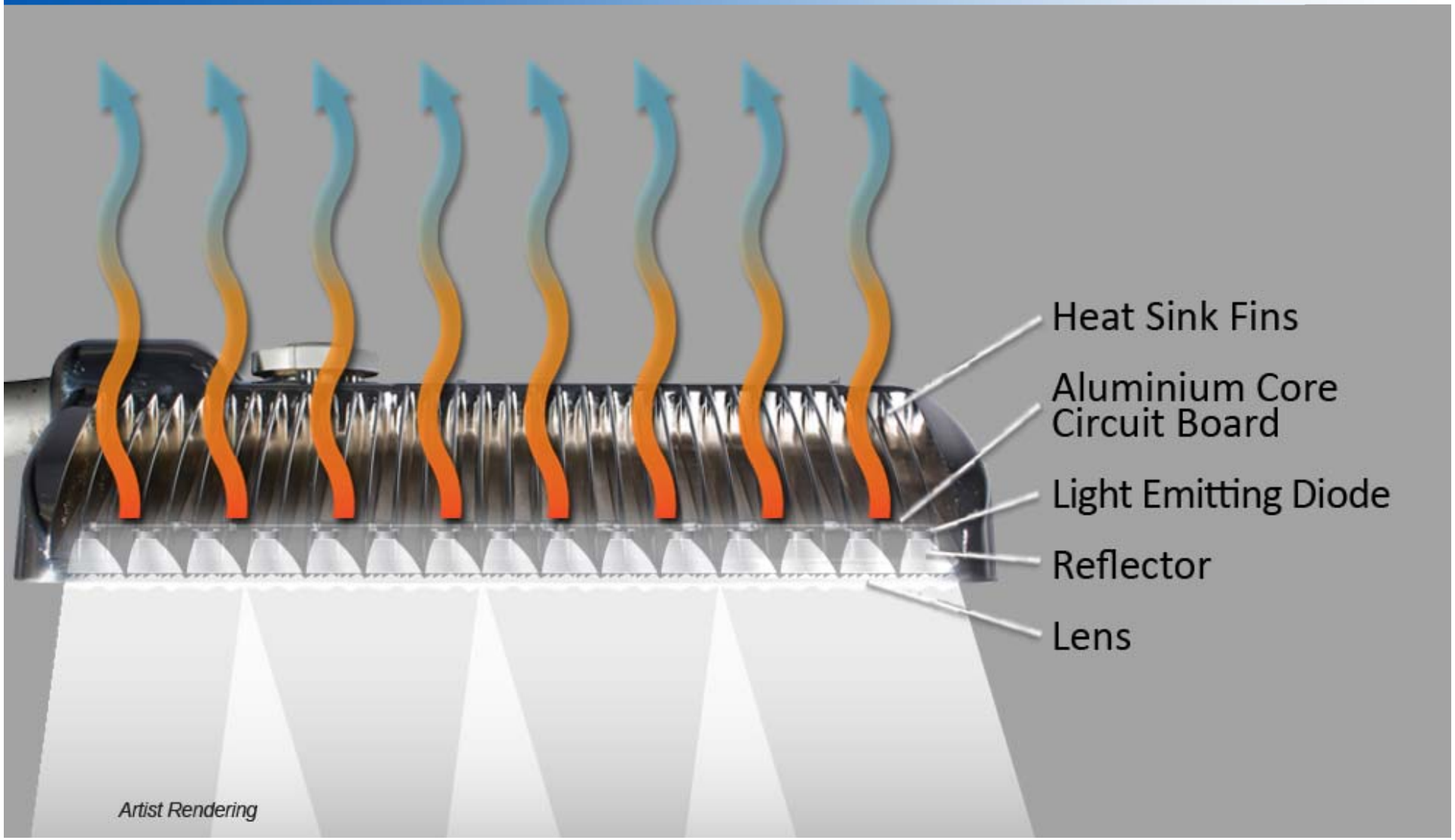
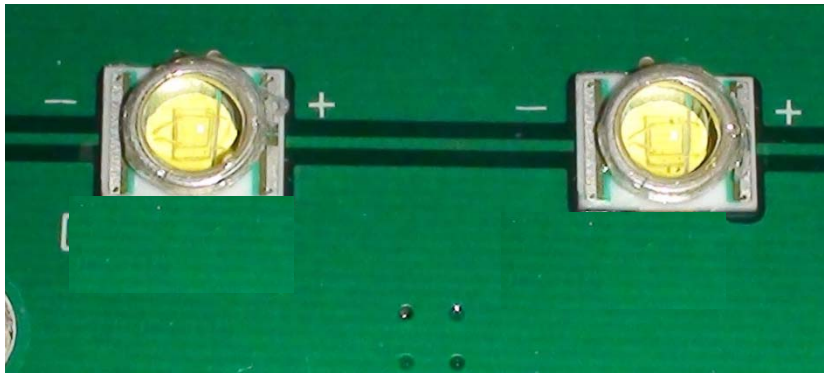
Thermal Management



Industry Standard FR-4 (Fiberglass) Light Engine Circuit Board

- Non-conductive
- Heat builds in LEDs

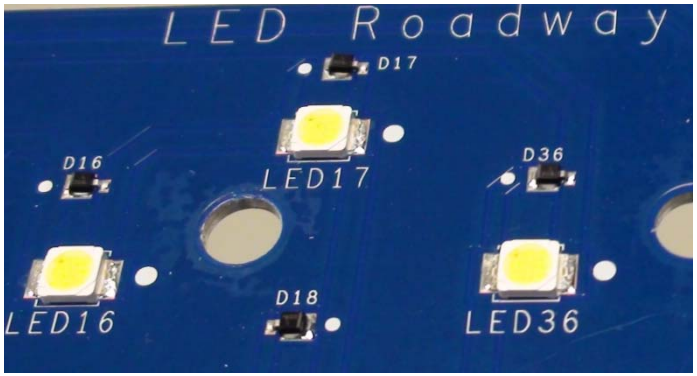
Commercial Grade Printed Circuit Board (PCB)



LRL – Aluminum Metal Core Light Engine Circuit Board

- Conducts heat from LEDs
- Clad to heat sink fins
- Efficacy and life expectancy improves

Satellite™ Standard Metal Core Printed Circuit Board (PCB)



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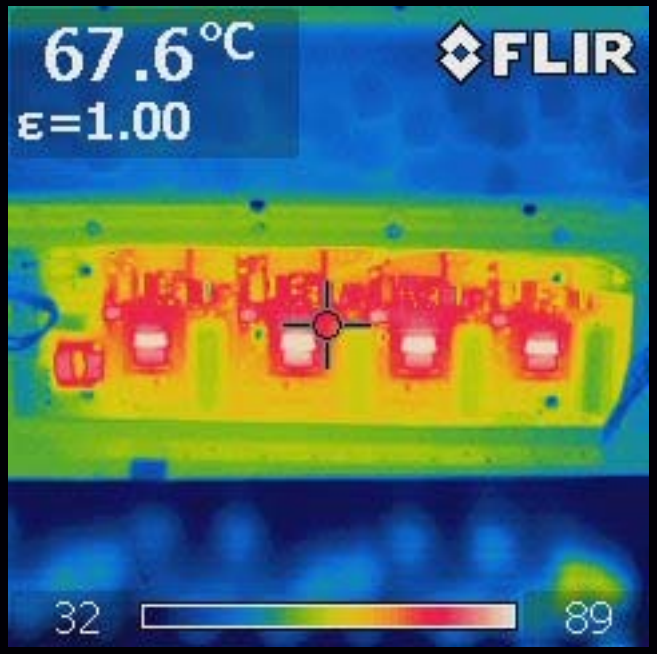
LRL SAT-96M Custom Power Supply at Thermal Equilibrium



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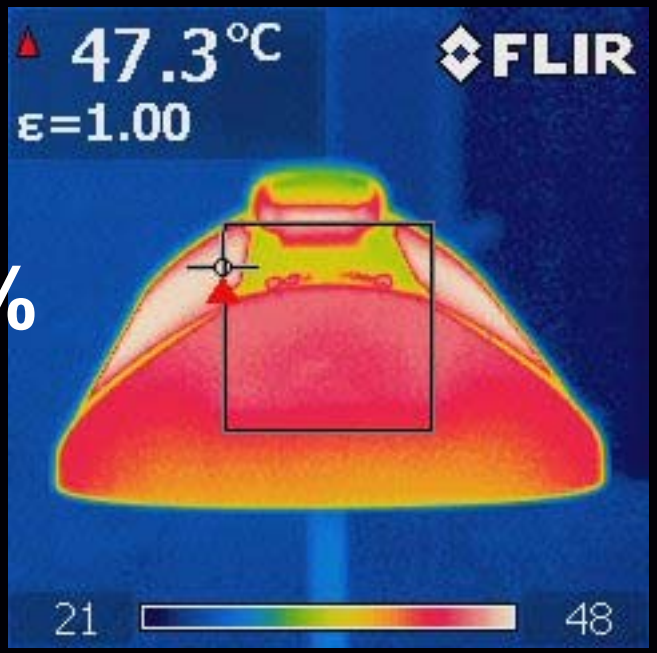
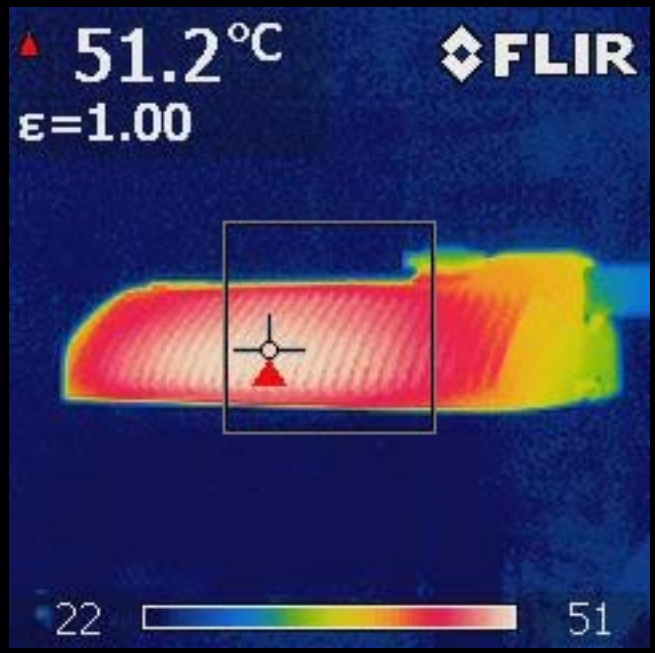
LRL SAT-96M LED Roadway Light

65%





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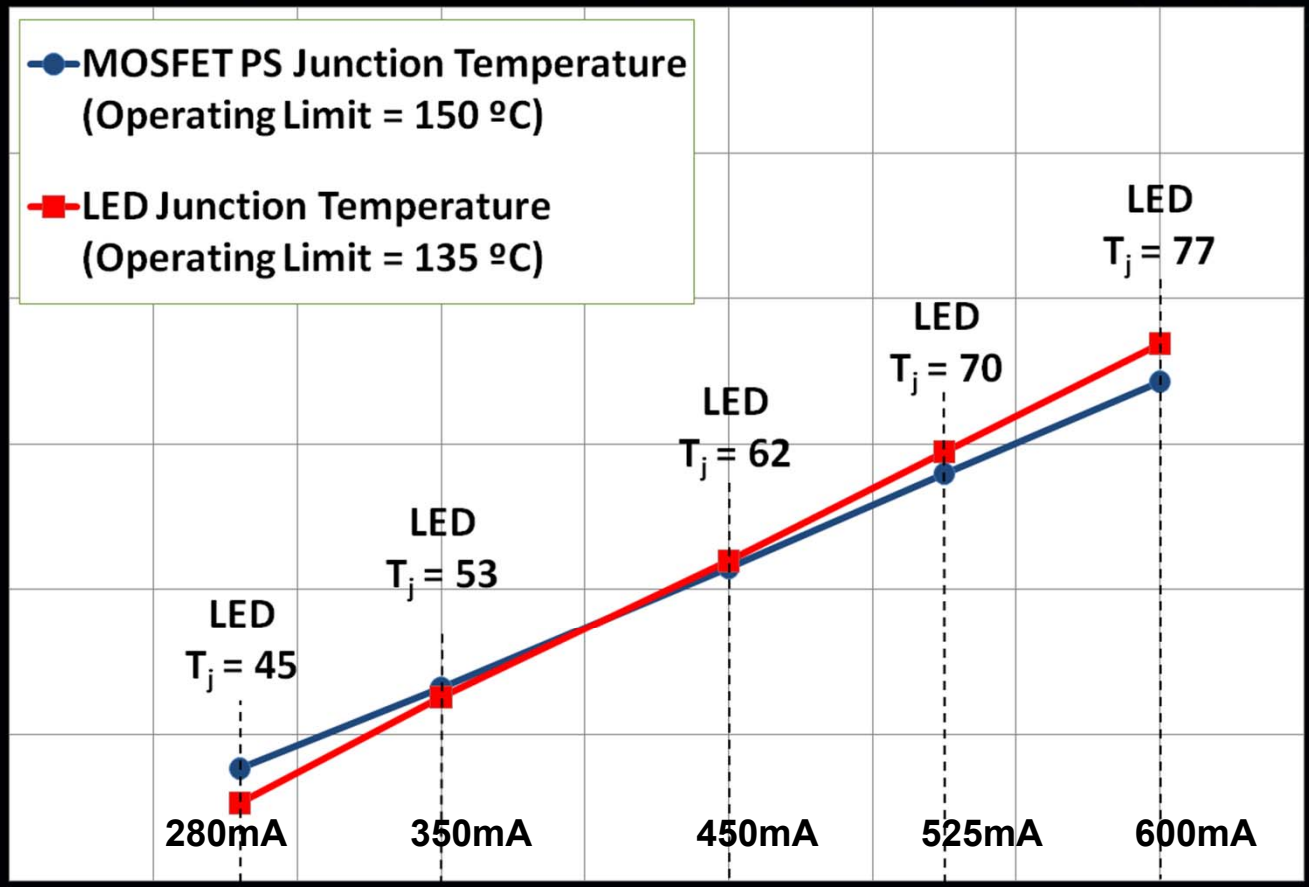

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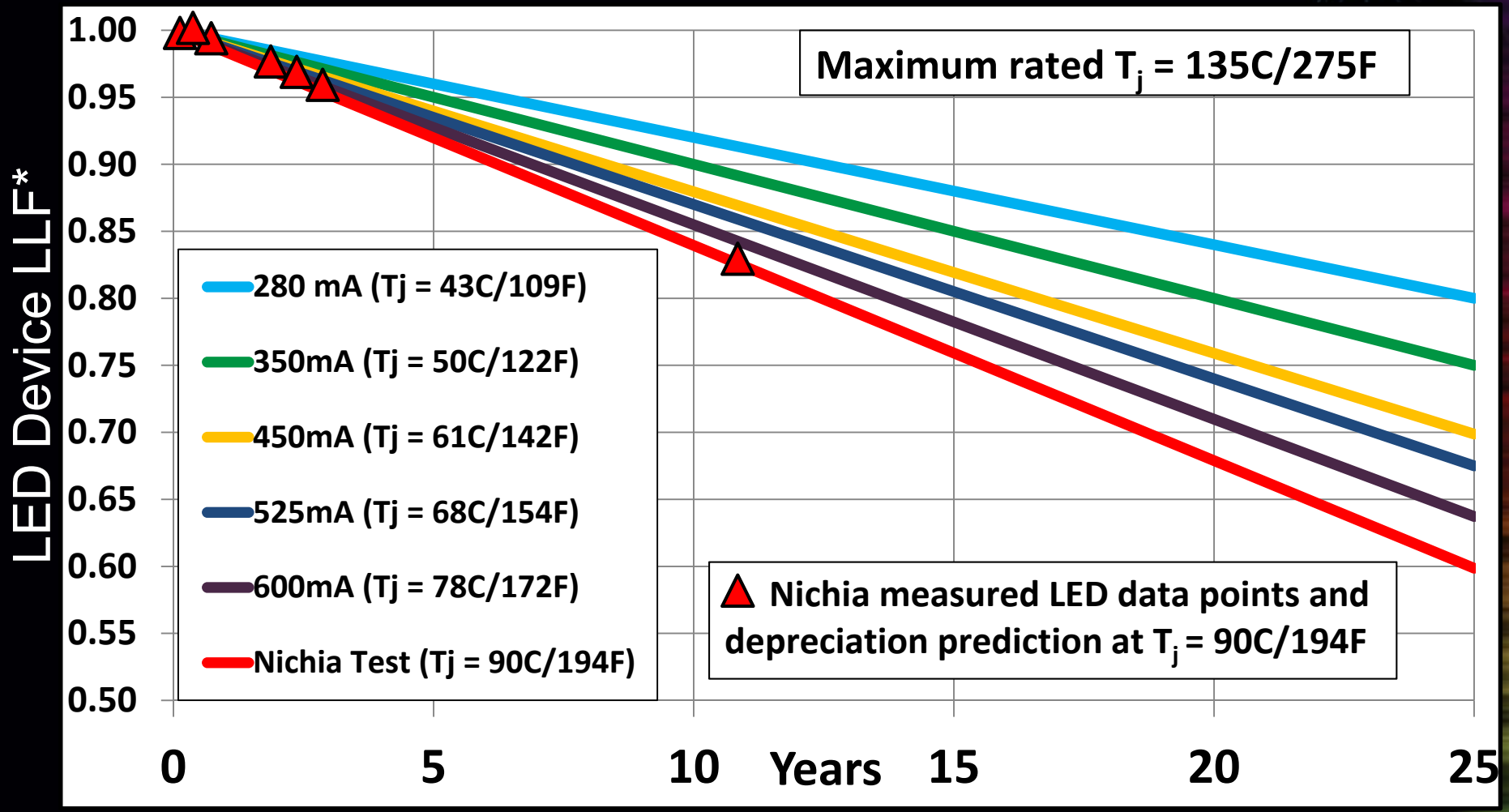
Chart #1: LED Device LLF* over Time (at Ta = 20C)



*LLF = Light Loss Factor

Photometrics & Optical Systems

Two Lighting Engines Mounted at 30° Angles

- **Maximum distribution with high optical efficiency**
- **Higher performance than flat, LED light engine designs**
- **Reduces need to bend light: bending light wastes energy**
- **Dark sky approved**

Optics System

Reflectors

- Each LED has a reflector “cup” mounted on top of it that collects and directs 100% of LED light
- Maximizes light delivery to the optical system

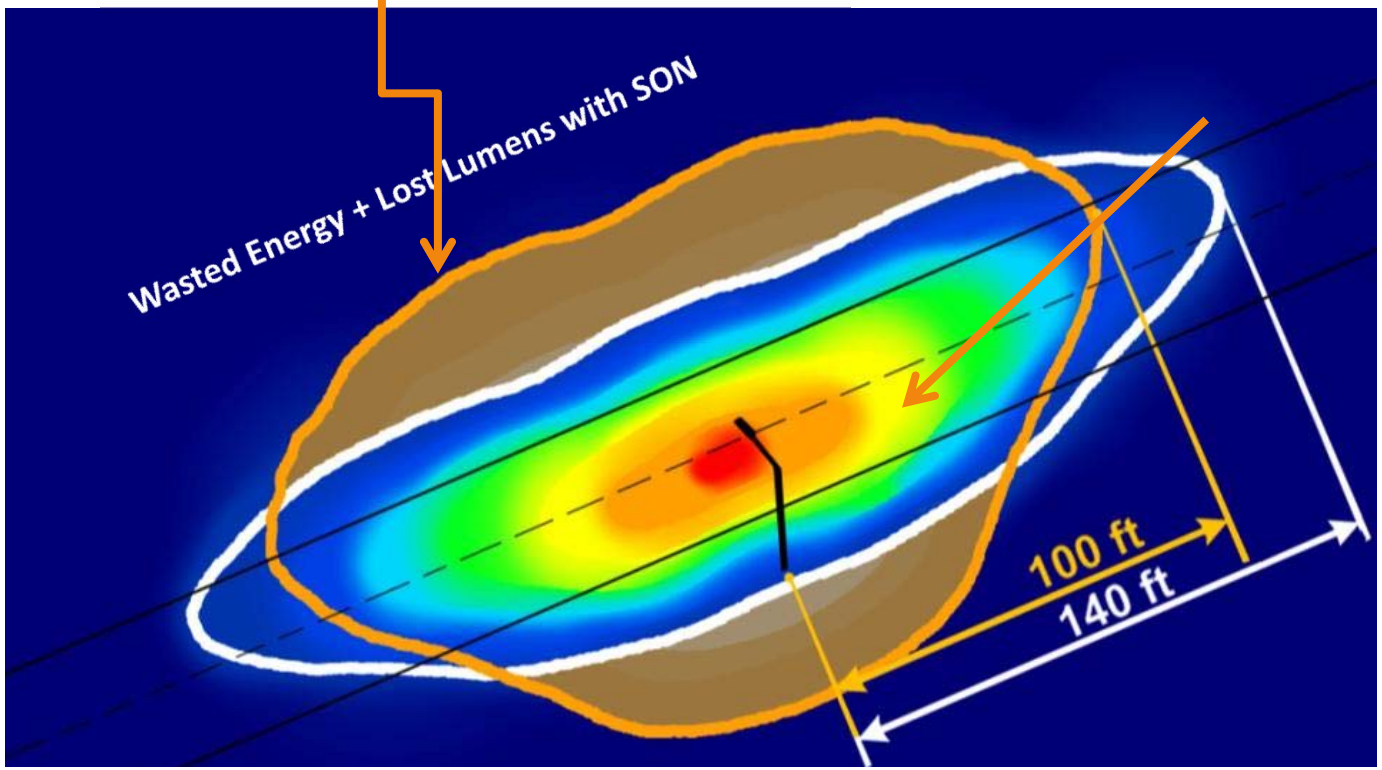
Optics/Lenses

- Unique individual refractor optics fine tunes light distribution
- Repeating sets of 12 producing identical pattern
- Durable acrylic is UV resistant with high transmission

More "Target Lumens" versus SON

100W SON
49% of 6.2klm lands on the road

Sat-48-350mA (55W)
72% of 4.5klm land on the road



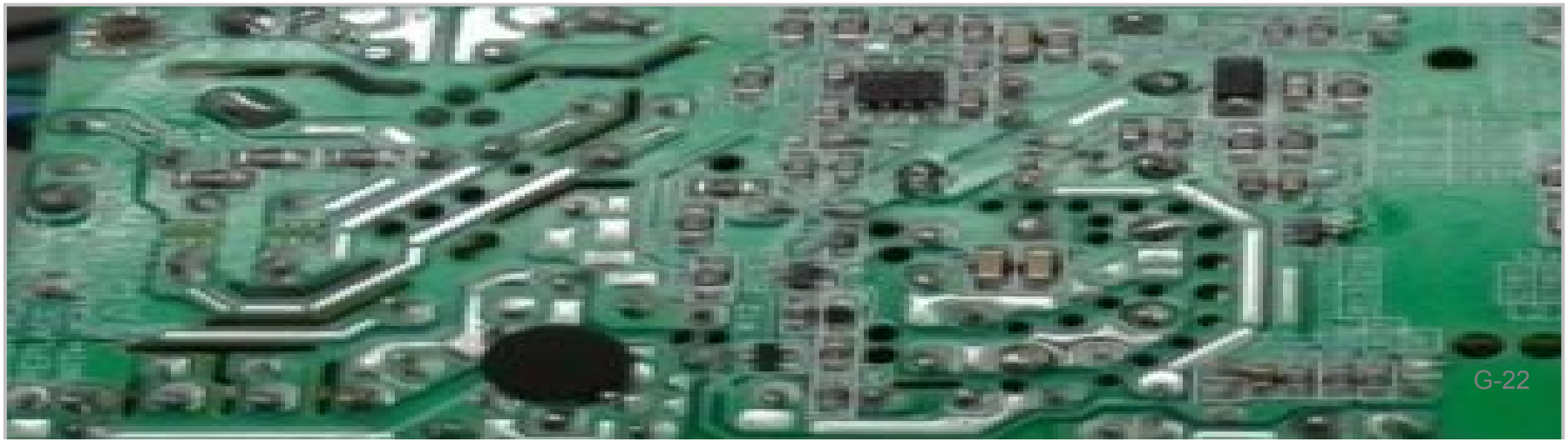
60% Energy Savings

Electronics

20-Year Design Life Power Supply

Exclusive use of Automotive & Aircraft grade components

- All components rated for extreme temperatures (hot and cold)
- Brown out, thermal cut-out, surge protection built in
- High Reliability Design Rules/ military-aerospace
- LRL “Exclusive” long life supply designed and built in house
- £8 to £15 is a range of cost to send a crew to service a light in the UK.



Power Supply Design for 20 Year Life Reliability

Component	LED Roadway Driver	Typical Competitor Driver
Electrolytic Capacitor	110,000hrs (22 years) @ 85°C/185°F £3.00 per piece	28,000hours (6.5 years) @ 85°C/185°F £0.18 per component
Opto-couplers	Eliminated through design	Degrades by 50% over 5 years.
Potentiometers	Eliminated through design	1000 hour life at 0.5W, 70°C/158°F
Potting Compounds	Not Required: IP66 Rated	Stress during thermal cycling can cause parts to lift from the driver, causing failure

Fixture Efficacy

Measure of Efficacy

100W High Pressure Sodium (SON) Fixture
≈ 55 Lumens per Watt

Satellite™ LED Fixture
up to 80 Lumens per Watt

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Measurement & Testing

WHAT is Mean Time Between Failure (MTBF) and WHY does it matter?

Commercial Power Supplies are generally the weakest link of any LED fixture and is the most common cause of a fixture failure.

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Definition of MTBF

- ‘Mean time between failure (MTBF) is the measure of hardware reliability expressed in hours. This indicates in statistical terms the working lifetime of a given component: The higher the figure, the more reliable the product’

Calculating MTBF. The total time measured divided by the total number of failures observed.

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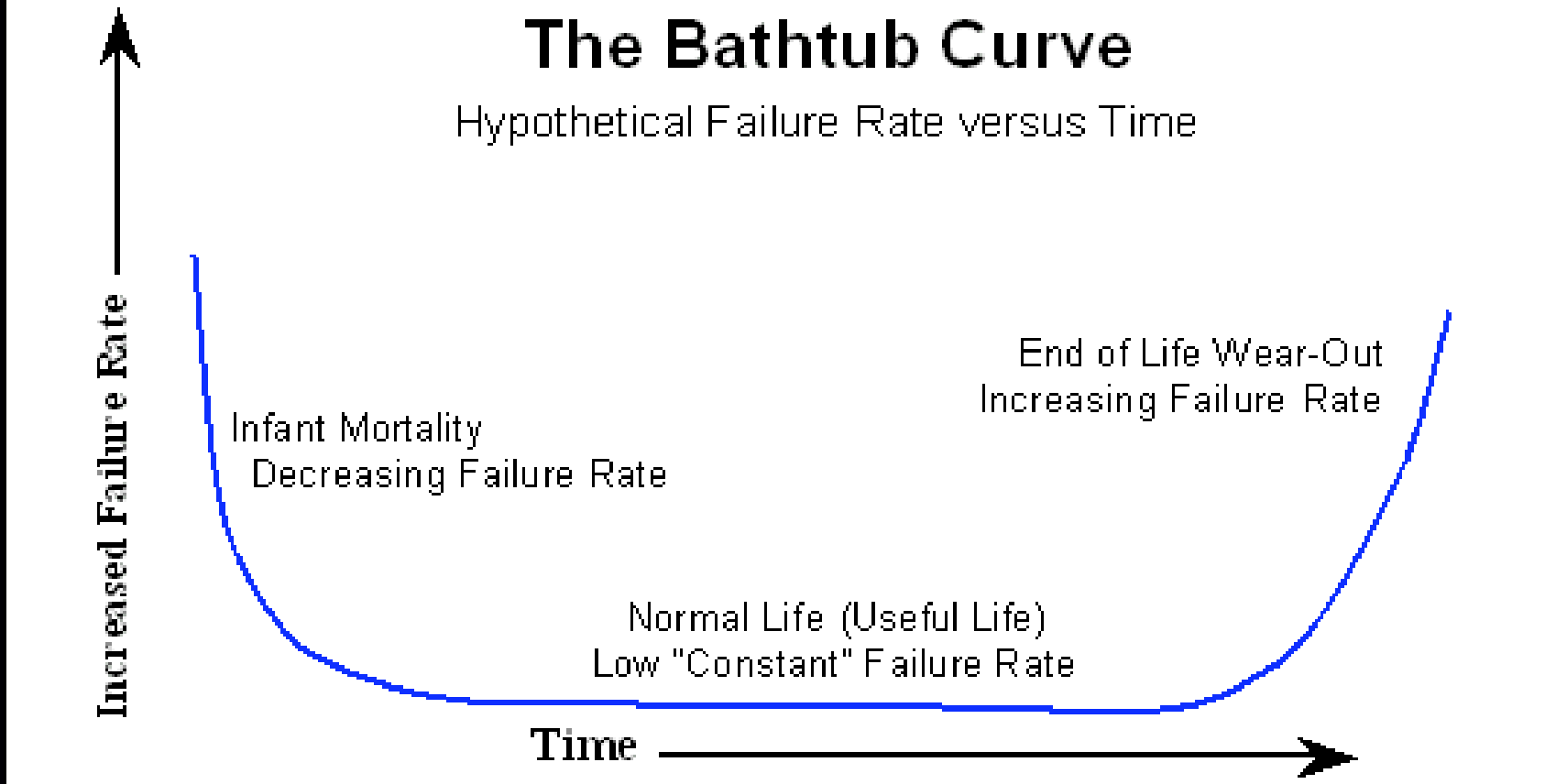

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Reliability: Power Supply Driver

Mean time between failures (MTBF) is the predicted elapsed time between failures of a system during operation.

Telcordia: SR-332

Standard for determination of Mean Time Between Failures (MTBF)

T-Cubed Systems Inc., Westlake Village, CA

Is the independent company that calculated the MTBF for LRL Satellite Series Power Supply. Some of the companies using Telcordia SR-332 include: Boeing Aerospace, Caterpillar, Dupont Electronics, Hewlett-Packard, IBM, Lockheed Martin, Tyco Electronics, and many more.

- **MTBF LRL SAT-48-280mA = 4,646,797 hours (T=25°C)**
- **MTBF LRL SAT-48-450mA = 2,511,934 hours (T=25°C)**
- **MTBF LRL SAT-96-280mA = 3,323,722 hours (T=25°C)**

Typical Commercial/Competitor LED Drivers MTBF = (T=25°C) ≈ 100,000 *to* ≈ 200,000 hours

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BS4200 Definition of Reliability

- ‘The ability of a product to perform a required function (without failure) under stated conditions for a stated period of time’

How do we determine the **DRIVER failure rate over a 20 year period (87,600 hours)?** Using the MTBF number of **2,251,536 hours** (calculated by T-Cubed Systems for a **SAT-24S 525mA**):

$$\text{Reliability} = e^{-(20\ \text{Years}/2{,}251{,}536)}$$

87,600 hours / 2,251,536 hours

$$96.20\% = e^{-(20\ \text{Years}/2{,}251{,}536)}$$

87,600 hours / 2,251,536 hours

96.20% are reliable = 3.8% are unreliable

3.8% X 20,000 fixtures = 763 Total Driver Failures over 20 Years

Why does MTBF Matter?

Comparative Analysis:
SON, LED Competitor & LRL's Satellite

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Life Cycle Costing over 20 years

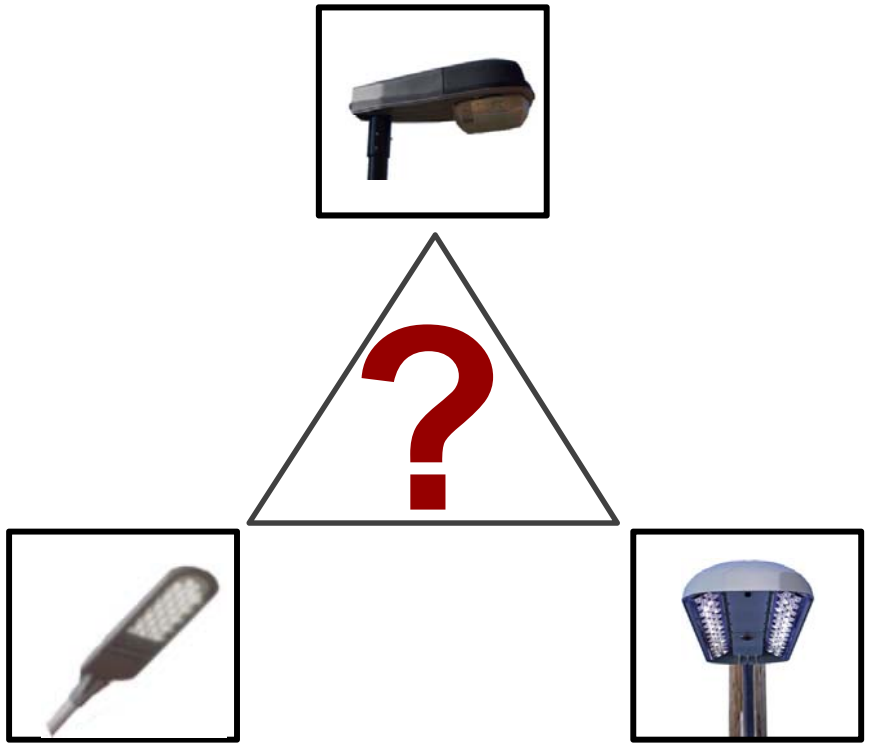
There are 3 Primary Costs in Street Lighting

1. Energy Costs

2. Maintenance Costs

3. Fixture Costs

4. CRC Costs



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Energy Costs

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Energy Costs over 20 Years

SON

LED Competitor

	70W SON	52 LEDs (70W)	Sat-24S 525mA-TII
	Energy Cost for 20,000 Fixtures		
Fixture W	85 W	70W	44 W
Annual kWh	7,446,000kWh	6,132,000kWh	3,854,400kWh
20 Year Energy Cost	£19,706,078	£16,228,535	£10,200,793

£9,505,285 in Energy Savings over ***SON***

£6,027,742 in Energy Savings over **LED Competitor**

for equal lighting over 20 Years

Cost is based on £0.08/kWh at 12 hours per day with a 5% inflation

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Reliability *depends on* MTBF (Mean Time Between Failure)

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Maintenance & MTBF

Mean time between failures (MTBF) is the predicted elapsed time between failures of a system during operation.

SON

Lamp replacement every 3 years

20,000 fixtures @ £15

Cost on average includes:
2 men in a bucket truck plus the cost of replacing the bulb.

LED Competitor

100,000 Hours

52 LEDs (70W)

20,000 fixtures@ £25

Cost Includes:
2 men and a bucket truck and the power supply driver

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2,251,536 Hours

SAT-24S 525mA TII

763 fixtures@ £36.52

Cost Includes:
2 men and a bucket truck and the power supply driver

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MTBF & 20 Year Maintenance Costs

SON

LED Competitor

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Fixture	70W SON	52 LEDs (70W)	Sat-24S 525mA-TII
Re-Lamp/MTBF	3 years	100,000 Hours	2,251,536 Hours
Total Re-Lamps	133,333	11,672	763
20 Year Cost	£ 3,308,165	£582,460	£ 39,439
	133,333 failures x **£**15 per defective parts (lamp/ photocell/ballast failure) and labor costs.	**11,672** failures x **£**25 per failure based on MTBF (labor and power supply costs)	**763** failures x **£**36.5per failure based on MTBF (labor and power supply costs)

£3,268,726 in Maintenance Cost Savings over ***SON***

£543,021 in Maintenance Cost Savings over ***LED Competitor***

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Initial Fixture Cost

SON

£ 2,800,000

70W SON

20,000 fixtures @ £140

LED Competitor

£ 11,600,000

52 LEDs (70W)

20,000 fixtures @ £580

£5,300,000

SAT-24S 525 TII

20,000 fixtures @ £265

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Total Lifecycle Costing

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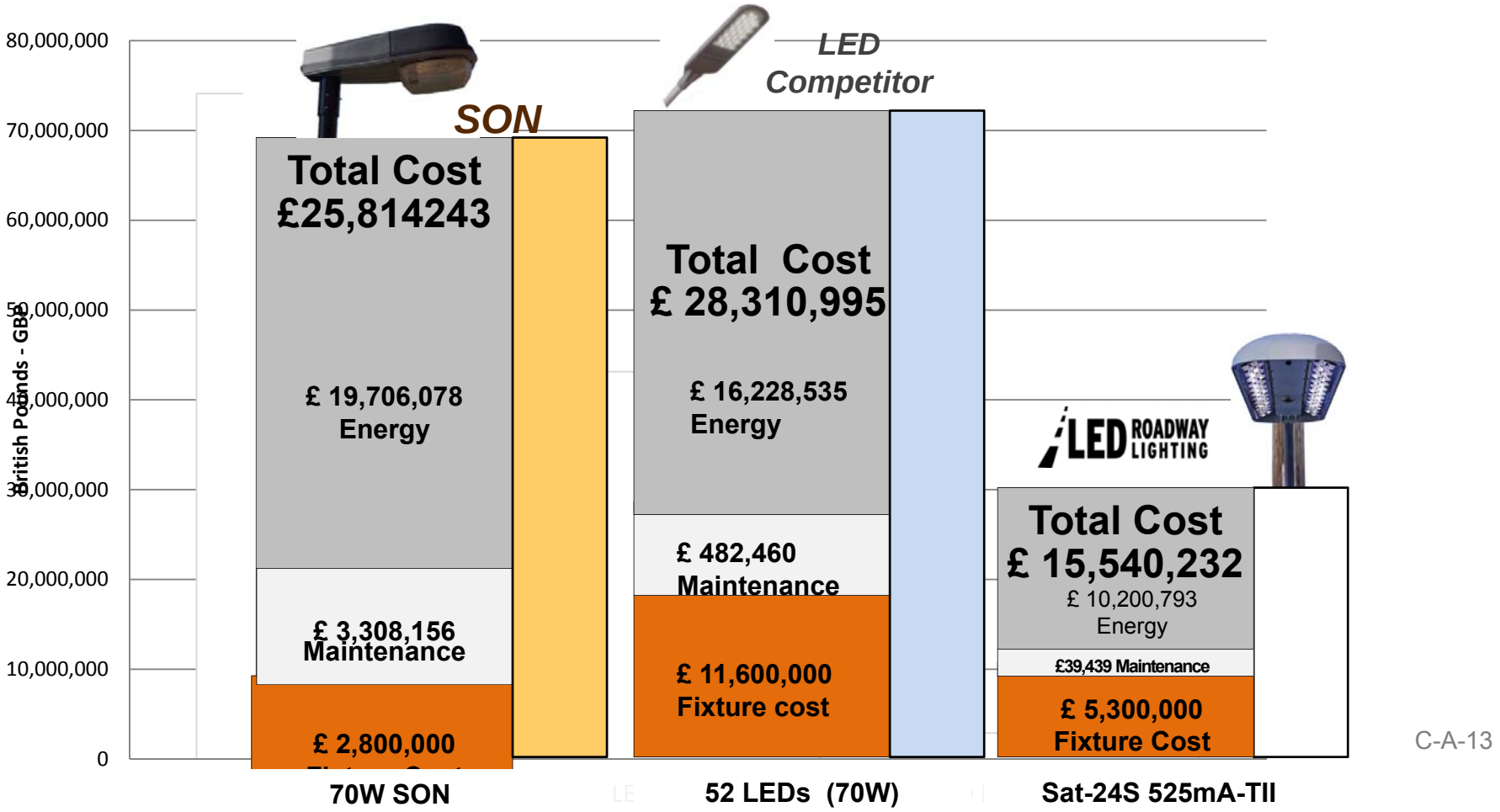
Lifecycle Cost Savings for 20,000 Fixtures - **20 Years**



C-A-13

£9,474,011 in Life Cycle Cost Savings over ***SON***

£12,770,763 in Life Cycle Cost Savings over ***LED Competitor***

How to specify LED luminaires, Standards.

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LED Luminaire Standards

IES - L M 79 Standard for luminaire testing, fully evaluates the assembled luminaire for total flux, electrical power, efficacy (lm/watt), chromaticity, and angular distribution of light.

IES LM-80 Standard for measuring populations of LEDs over their early lifetime, includes luminous flux, color, dominant wavelength, chromaticity and correlated color temperature (CCT) controlled to a variety of currents and LED case temperatures.

Telcordia SR332 test of reliability for an electronic system, MTBF indicator measured in hours.

Installations

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Salford City Council - 50%Energy Savings

Before

85 Circuit Watts
SON - 70W

After

43 Circuit Watts
Satellite™ 48 LED-280mA

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Salford City Council - 40%Energy Savings

Before

65 Circuit Watts
SOX - 35W

After

43 Circuit Watts
Satellite™ 48 LED-280mA

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Salford City Council Stats

There are 28,094 columns in Salford, of these we are replacing 2000 in 2010/11 and 24,111 in the main retrofit (subject to final council sign-off).

Total Lighting Units to change is 26,111 of the 28,094 columns.

Current maintenance is £855,000 and the future maintenance budget will be circa £275k.

For the 24,111 columns there is an energy saving of 55.9% £545k from £1.05m to £460k.

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SWTRA Britton Ferry Bridge, 37% Energy Savings

276 Watts
ZX3-250W SON

175Watts
Satellite™ 96 LED-525mA

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Cardiff, Wales (Lansdowne Road) - 43% Energy Savings

185 Watts
SON – 150W Lamp

110 Watts
SAT-96M (96 LEDs)-350mA

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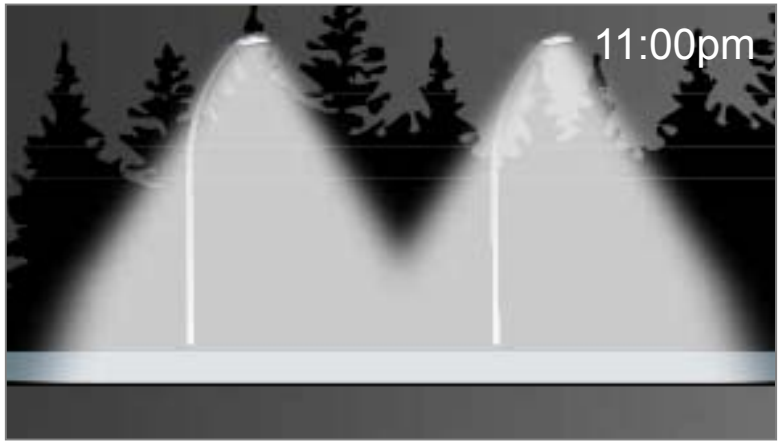
CMS & Monitoring

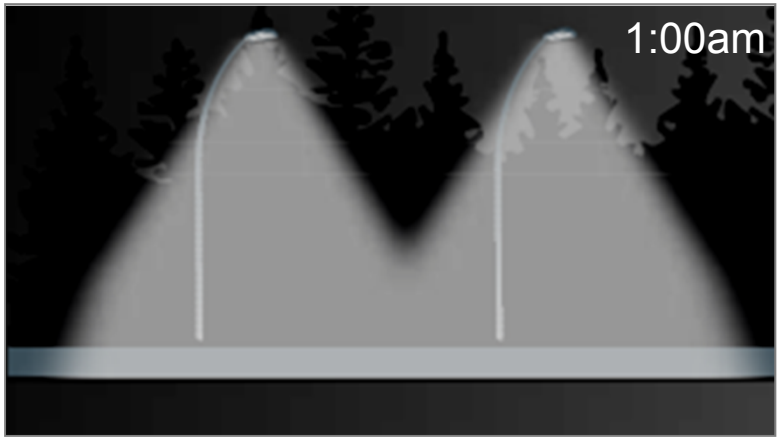
Monitoring and Control Systems

Our fixture integrates within any type of monitoring and control system.

Alternative Low Cost Energy Savings with Pre-Programmed Time-of-night Dimming

- Maximizes energy savings during times of night with lower activity levels
- Cost effective and easy to deploy alternative to wireless and power line carrier systems





The End

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