THE NEXT BIG SHIFT IN THE EVOLUTION OF LIGHTING

Mark Hand

VP Engineering, Indoor

AcuityBrands.

The Evolution of Digital Lighting

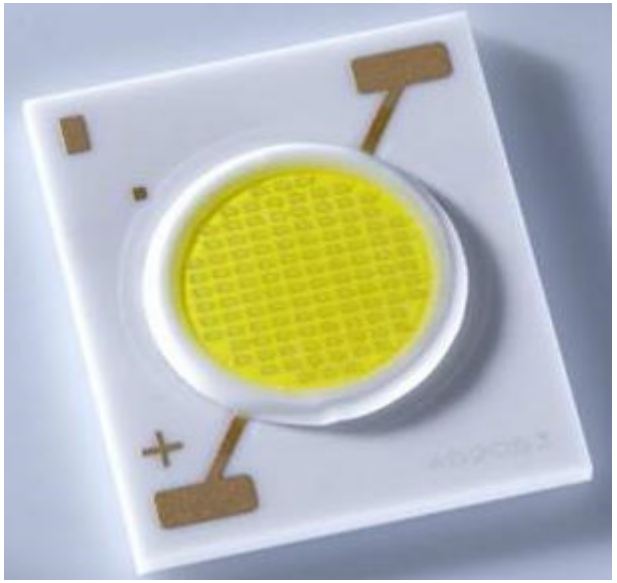
- LED Basics
- The Way it Was
- The Way it Is
- The Way it will be (AKA The Next Big Shift)

AcuityBrands.

LED Basics

AcuityBrands.

LED Basics

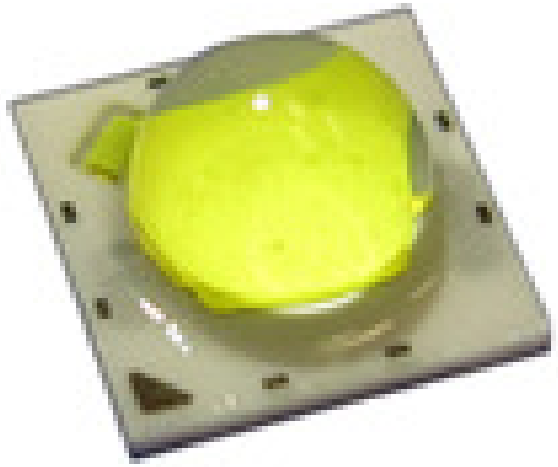


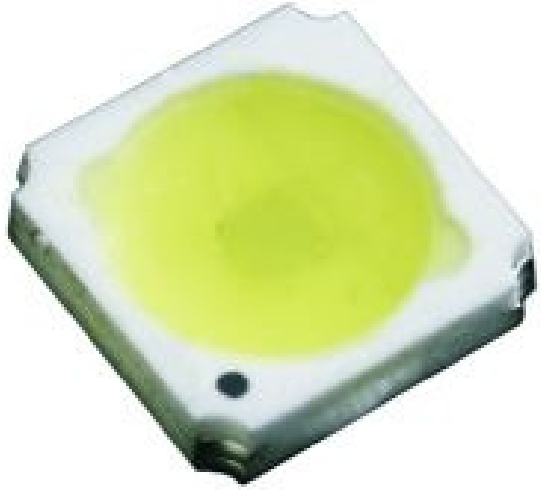
Phosphor Converted (PC)

Types

3 Main types

- COBs
- High Power
- Medium/Low Power

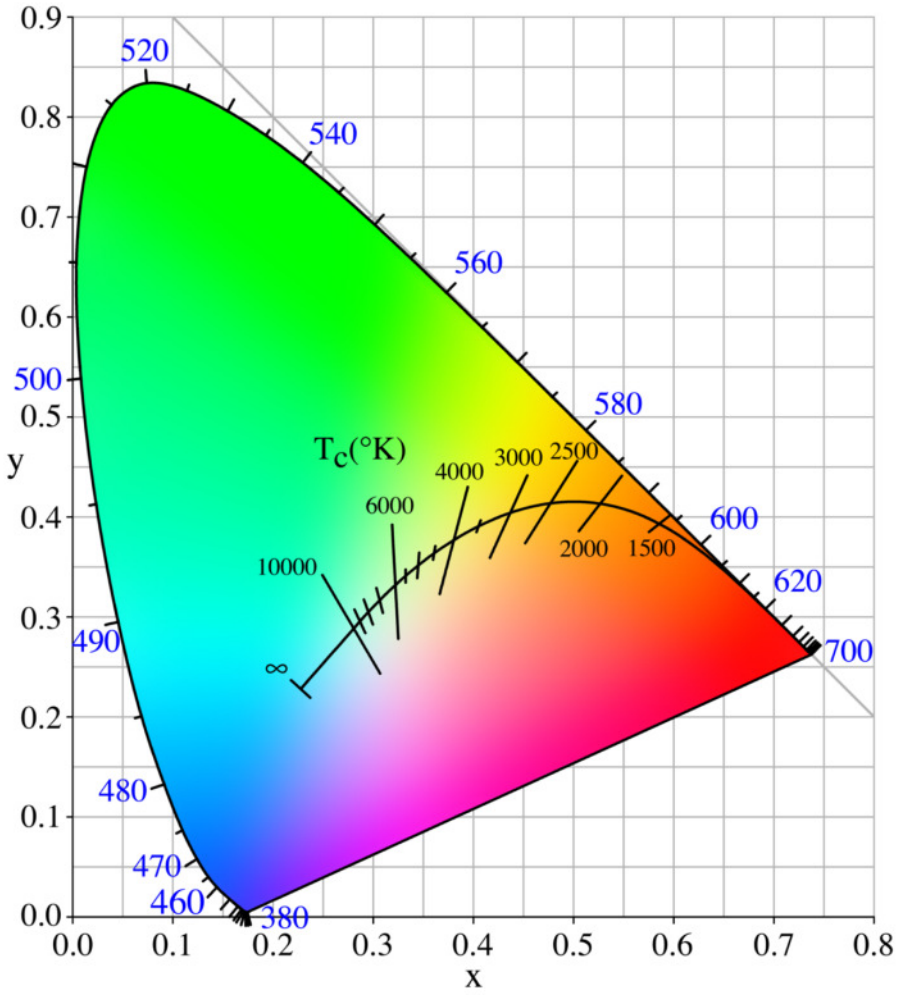


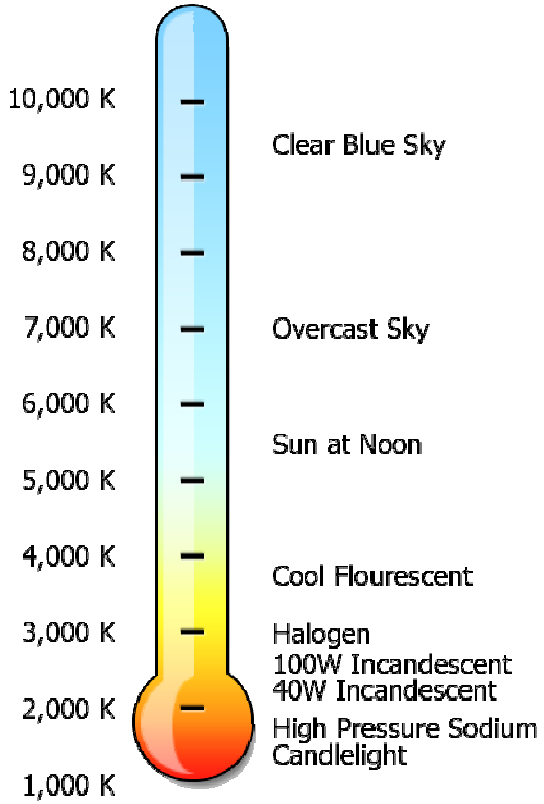


AcuityBrands.

LED Basics

Correlated Color Temperature (CCT)





AcuityBrands.

LED Basics

Color Rendering Index

CRI

CRI Ra

- R1-R8
- No Saturated Colors
- Color Quality Scale

$$R_a = \frac{1}{8}\sum_{i=1}^{8} R_i$$

http://www.nist.gov/pml/div685/grp03/vision_color.cfm

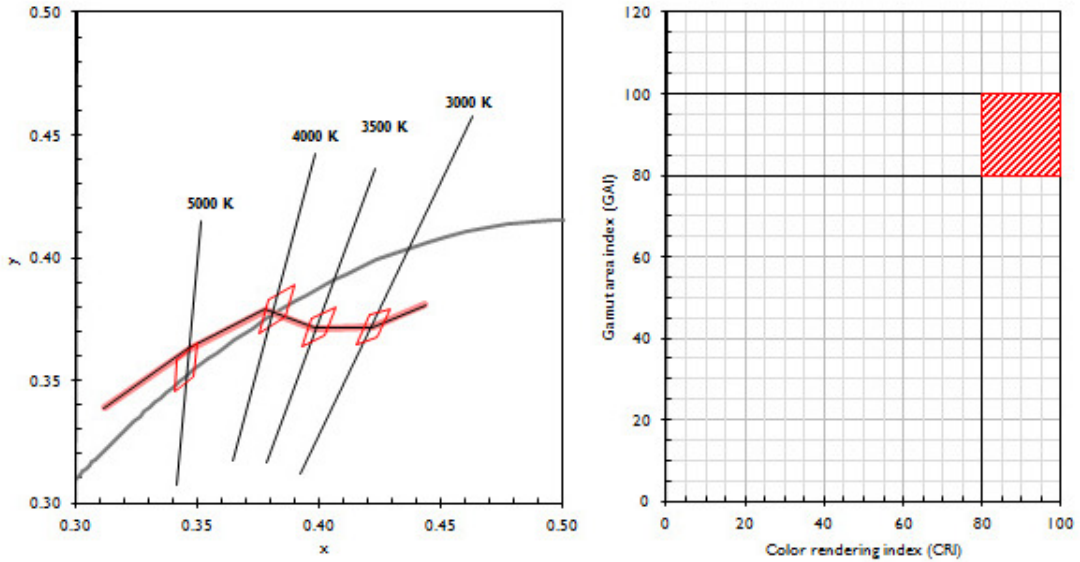
AcuityBrands.

LED Basics

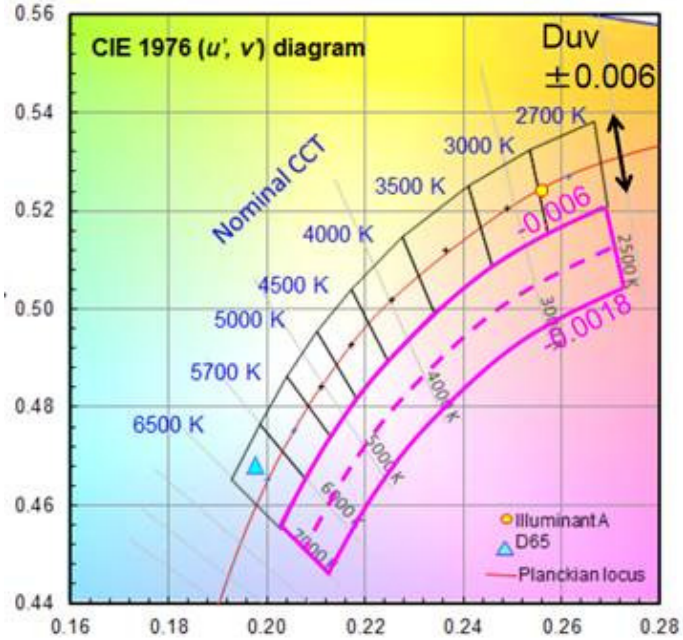
Color Rendering Inde

What's Being Done

- ASSIST Research
  - White Light Line
  - CRI GAI
- NIST Research



Class A Color lighting recommendations for chromaticity tolerance (left) and CRI/GAI combination (right) for retail applications



http://www.lrc.rpi.edu/programs/solidstate/colorResearch.asp

http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/freyssinier_designation_longbeach2013.pdf

http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/ohno_color-quality_tampa2014.pdf

AcuityBrands.

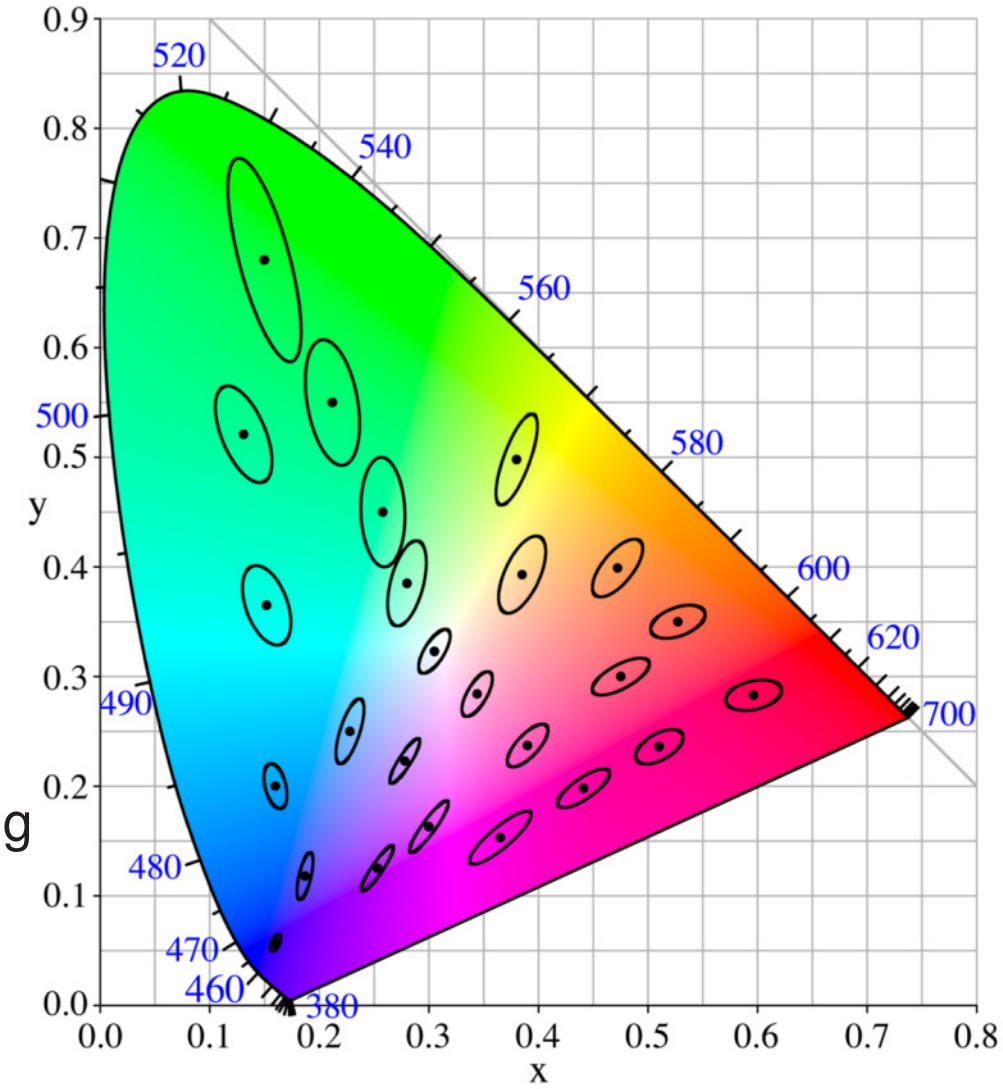
LED Basics

David Lewis MacAdam

American Physicist

Technological Color Control

- Kodak
- MacAdams Ellipse
- Standard Deviation Color Matching
- SDCM



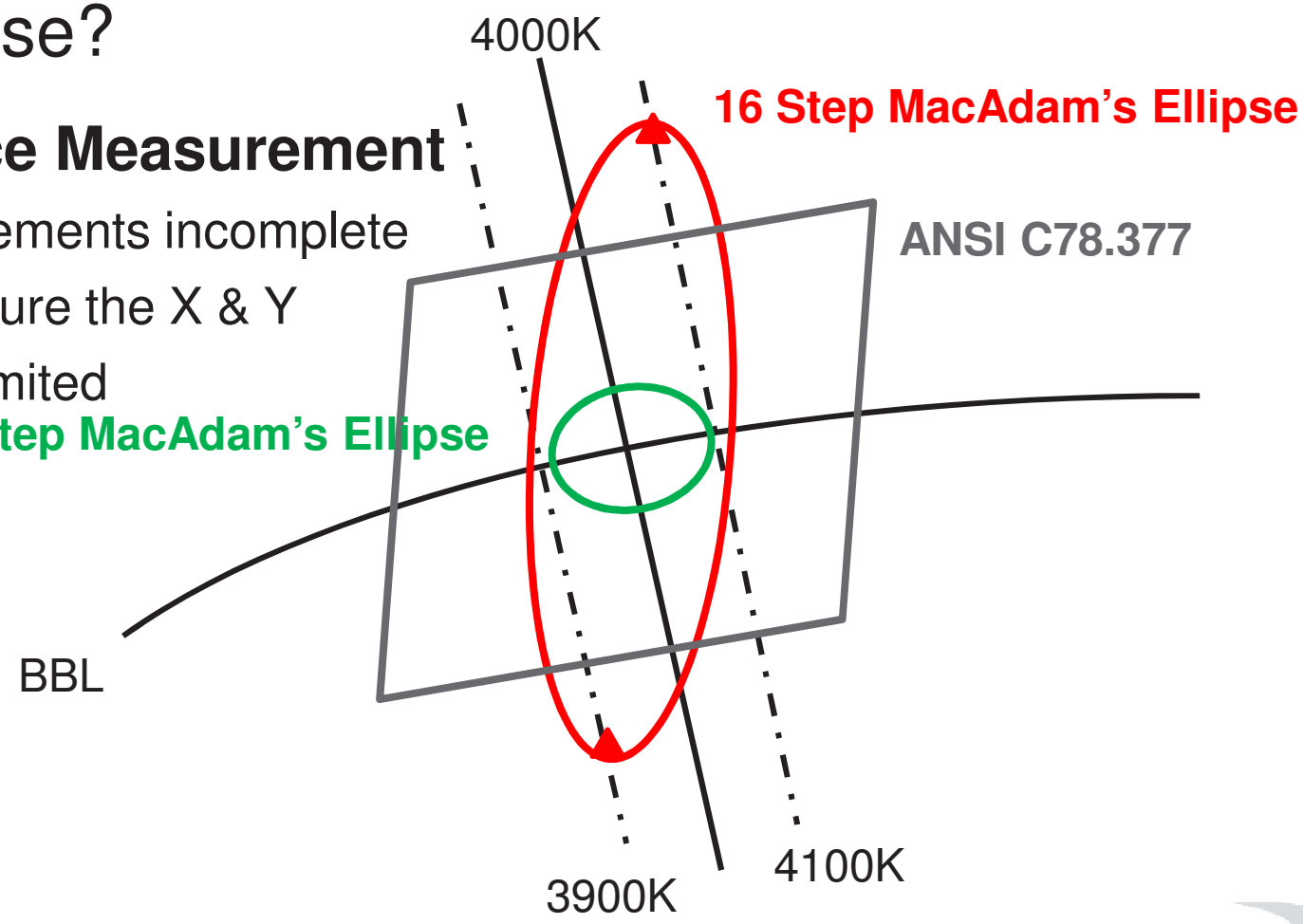
AcuityBrands.

LED Basics

Why an Ellipse?

Best Tolerance Measurement

- +/- CCT measurements incomplete
- Only way to capture the X & Y
- ANSI C78.377 limited



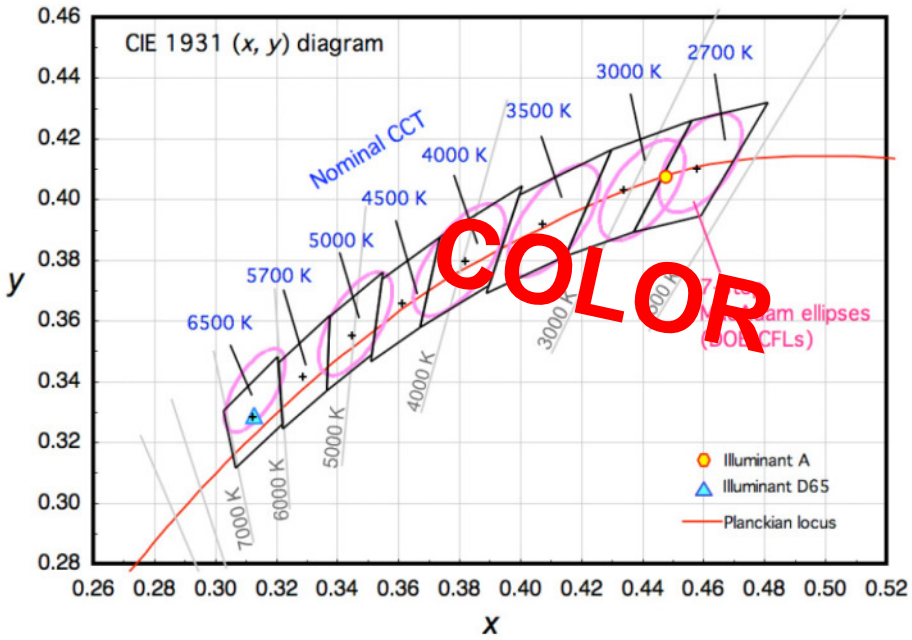
AcuityBrands.

LED Basics

Binning

Flux Bins	
Bin Code	Minimum Photometric Flux (lm)
P	120
Q	140
R	160*
S	180
T	200
U	220
V	240
W	260
X	280

FLUX



COLOR

Table 10.

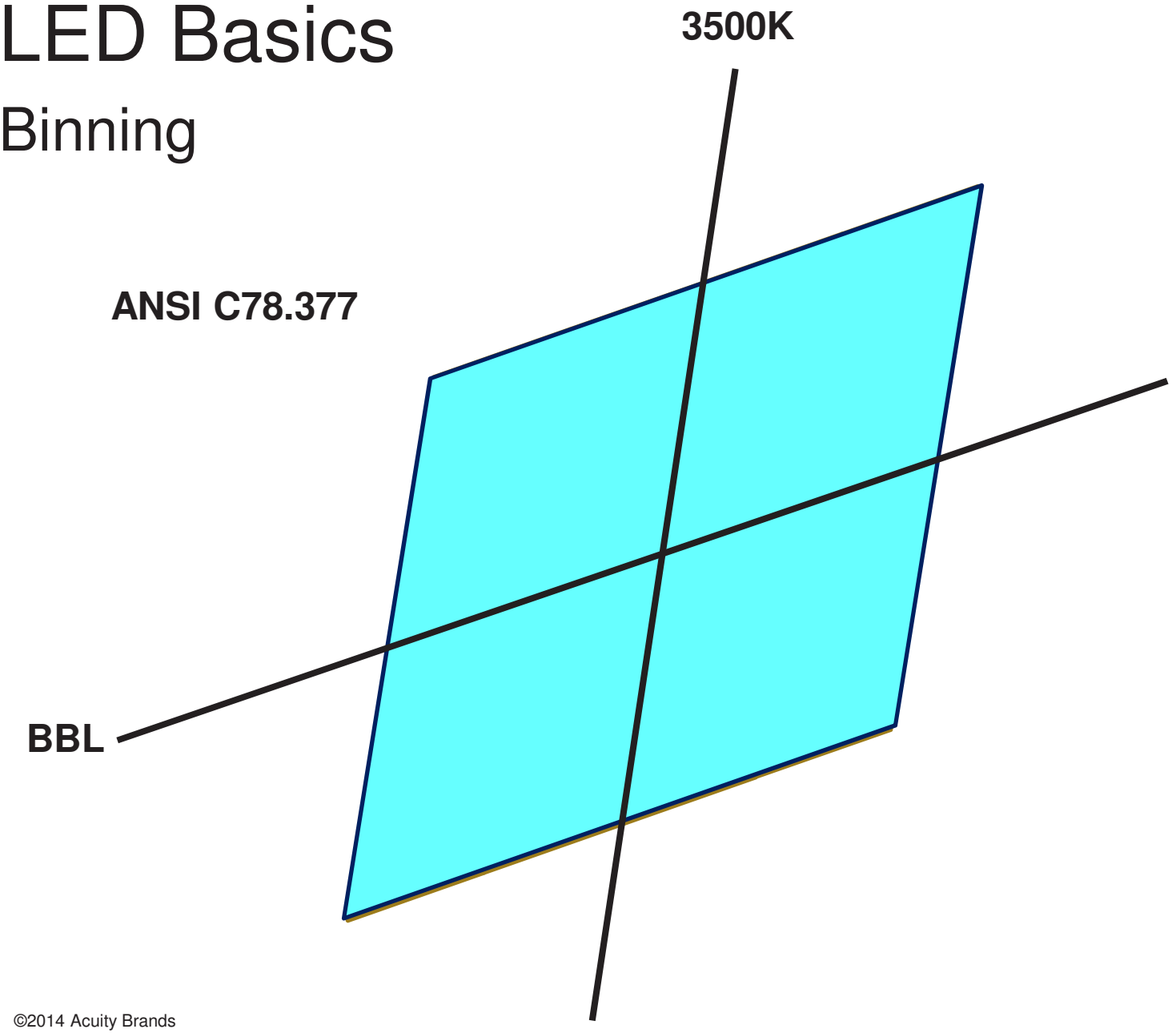
	V_f Bins	
Bin Code	Minimum Forward Voltage (V)	Maximum Forward Voltage (V)
B	2.55	2.79
C	2.79	3.03
D	3.03	3.27
E	3.27	3.51
F	3.51	3.75
G	3.75	3.99

VOLTAGE

AcuityBrands.

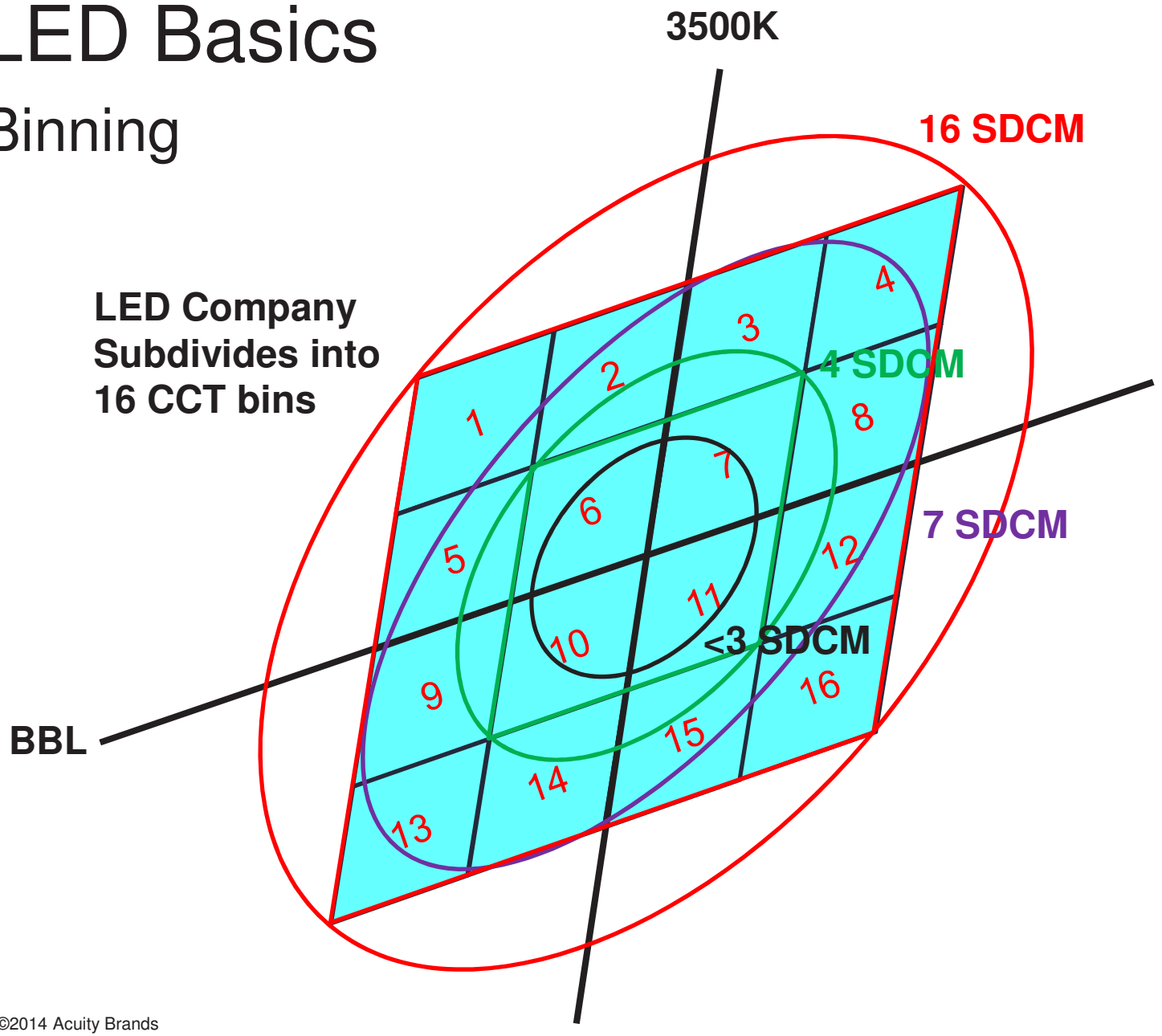
LED Basics

Binning



LED Basics

Binning



AcuityBrands.

LED Basics

Binning

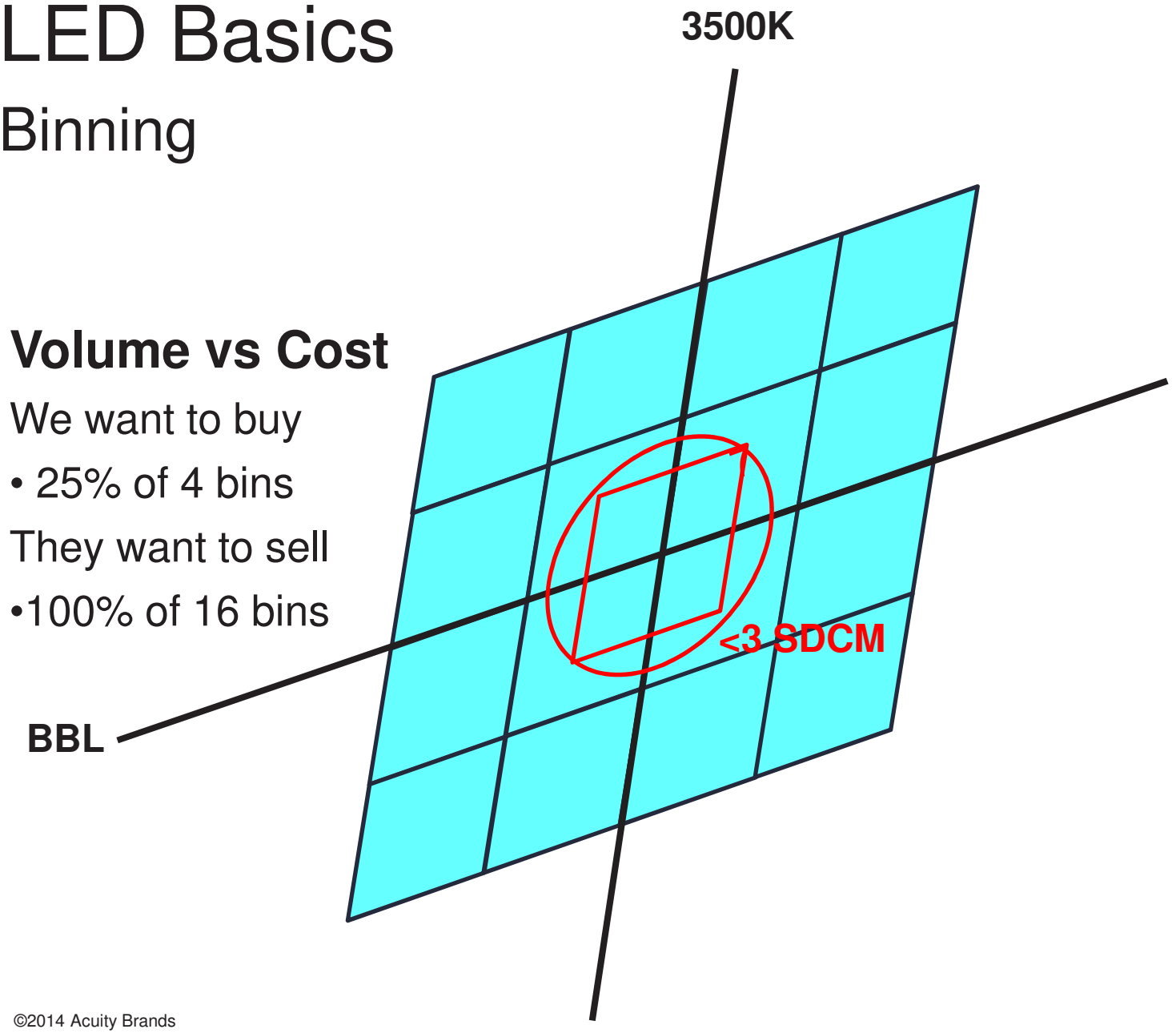
Volume vs Cost

We want to buy

- 25% of 4 bins

They want to sell

- 100% of 16 bins



AcuityBrands.

LED Basics

Binning

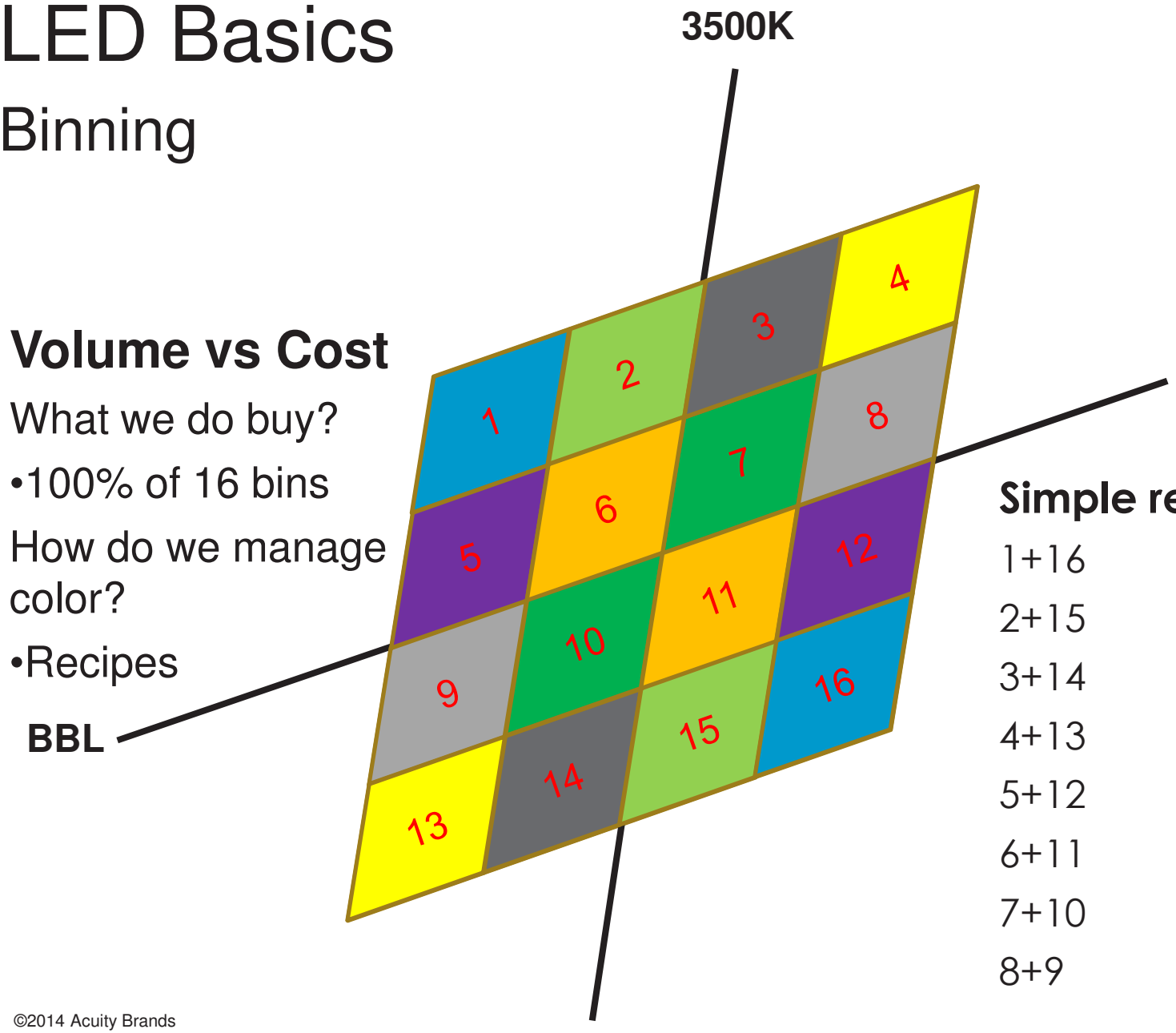
Volume vs Cost

What we do buy?

•100% of 16 bins

How do we manage color?

•Recipes



Simple recipes

1+16

2+15

3+14

4+13

5+12

6+11

7+10

8+9

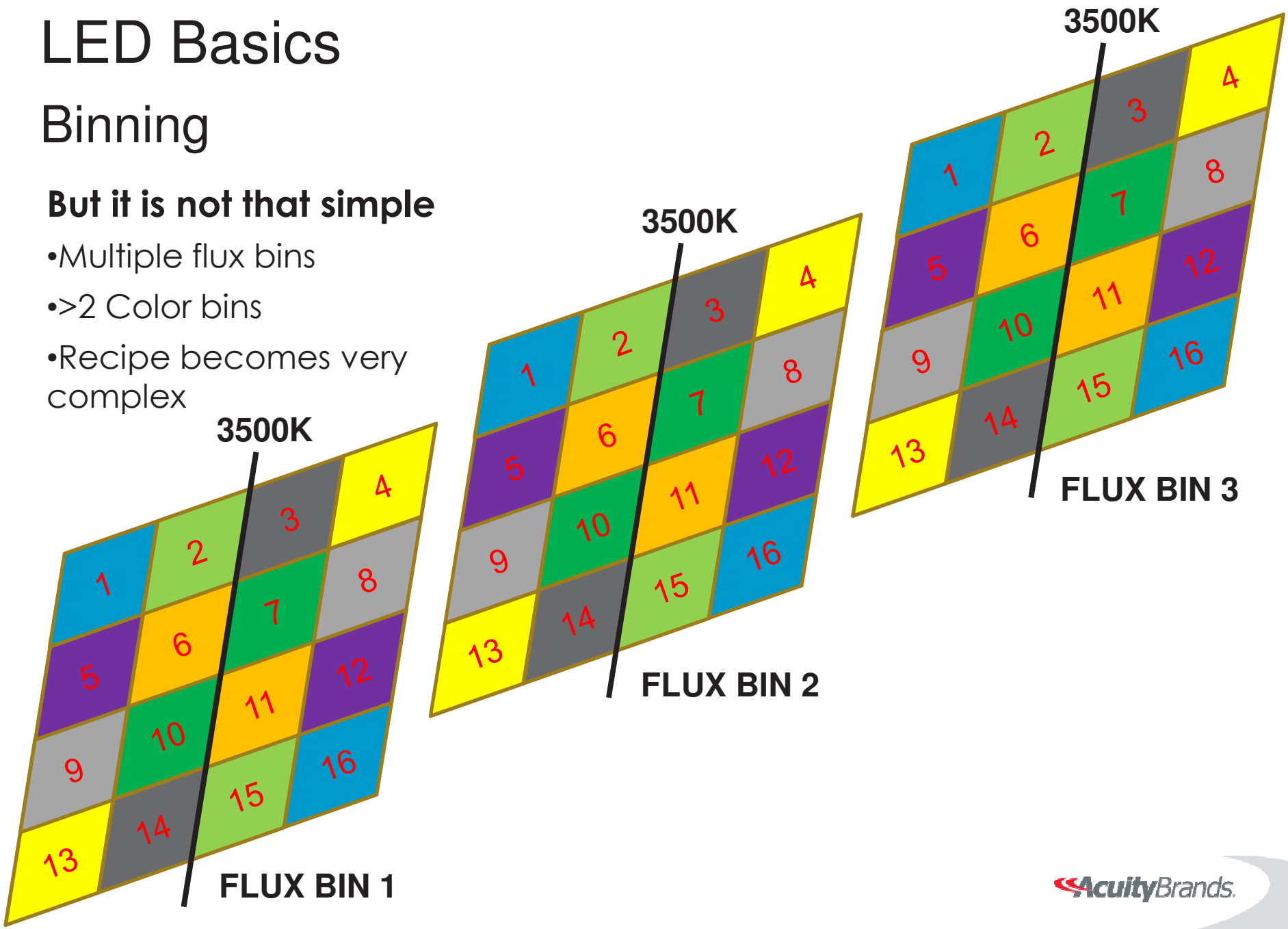
AcuityBrands.

LED Basics

Binning

But it is not that simple

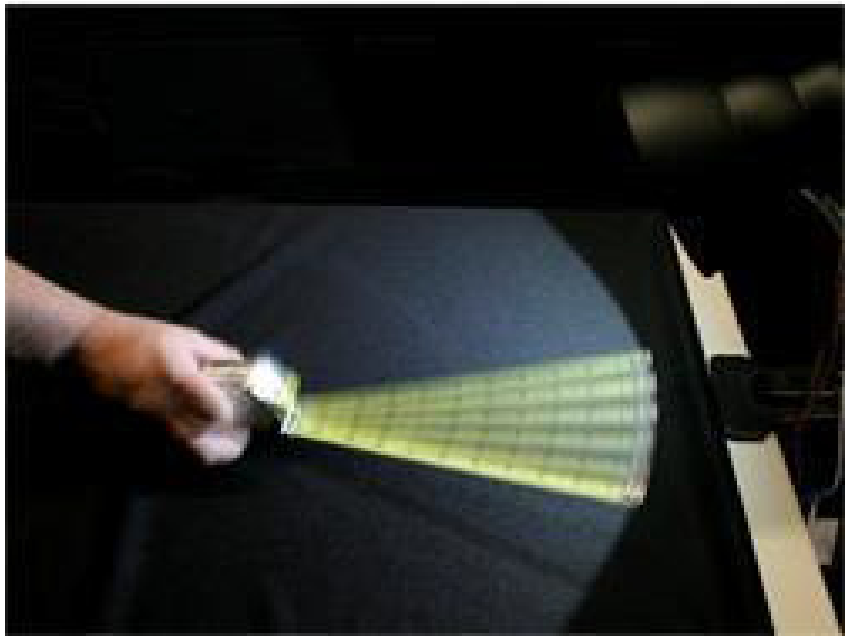
- Multiple flux bins
- >2 Color bins
- Recipe becomes very complex



AcuityBrands.

LED Basics

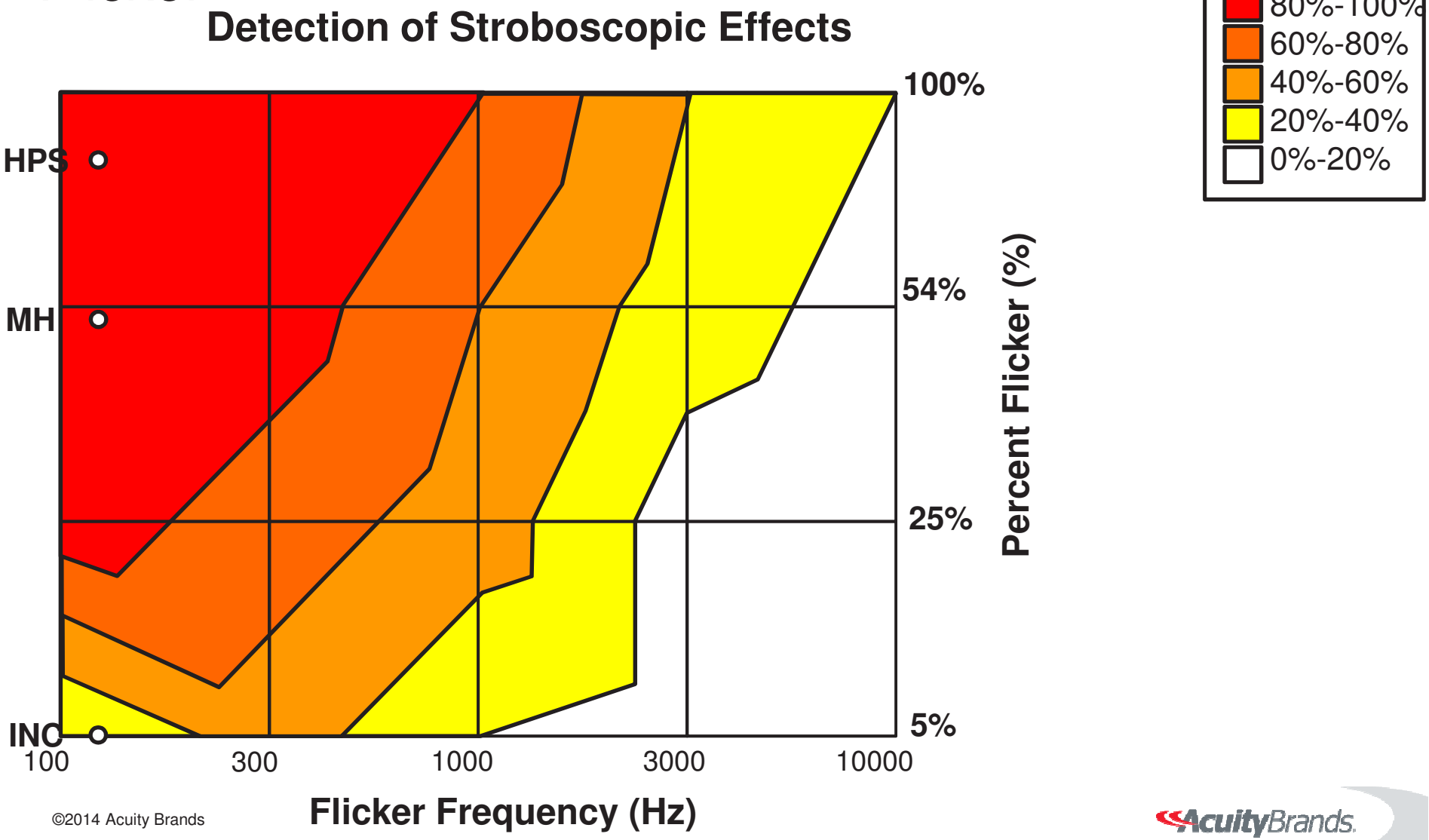
Flicker



http://www.lrc.rpi.edu/programs/solidstate/assist/flicker.asp

LED Basics

Flicker

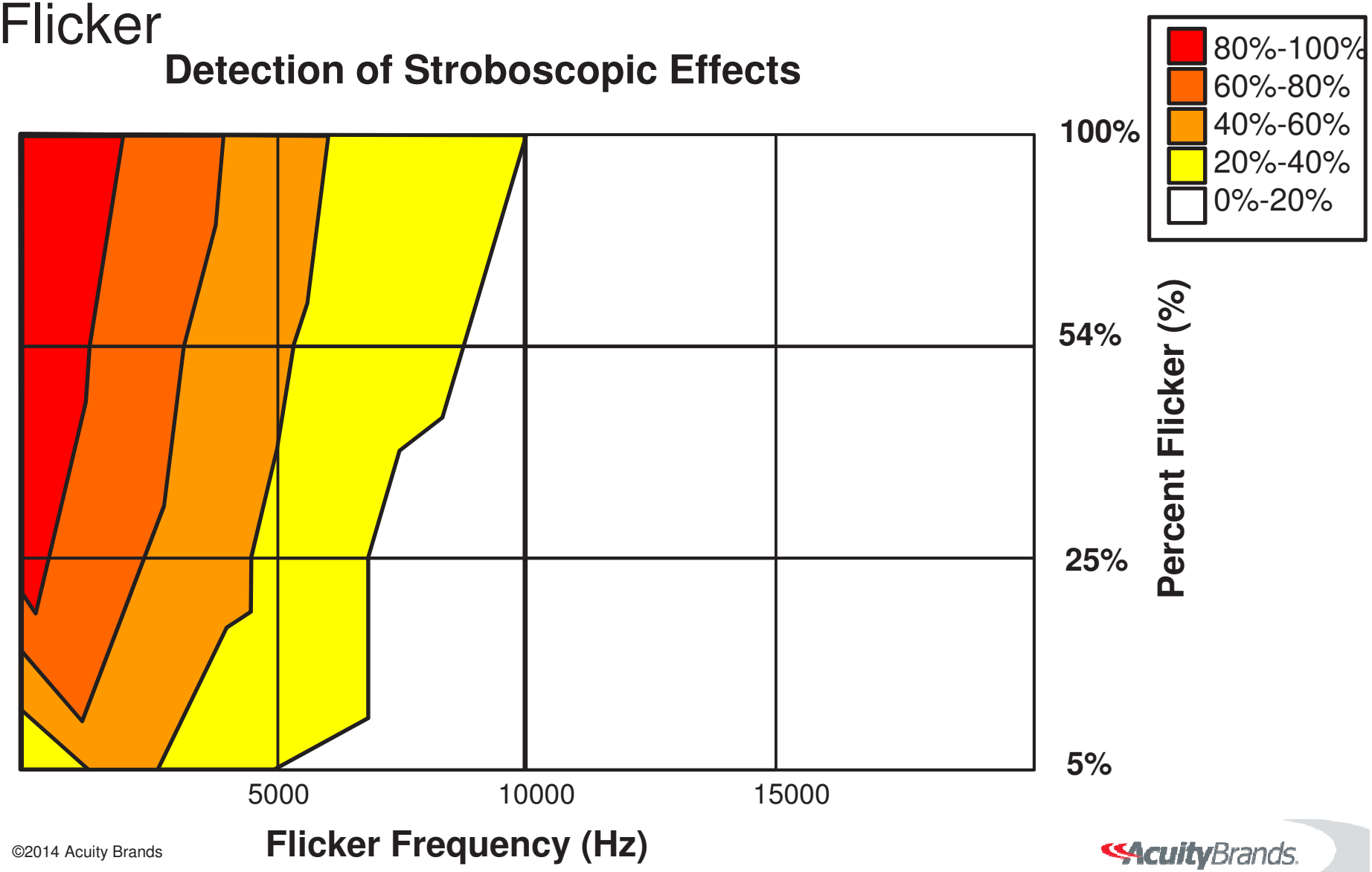


http://www.lrc.rpi.edu/programs/solidstate/assist/flicker.asp

AcuityBrands.

LED Basics

Flicker

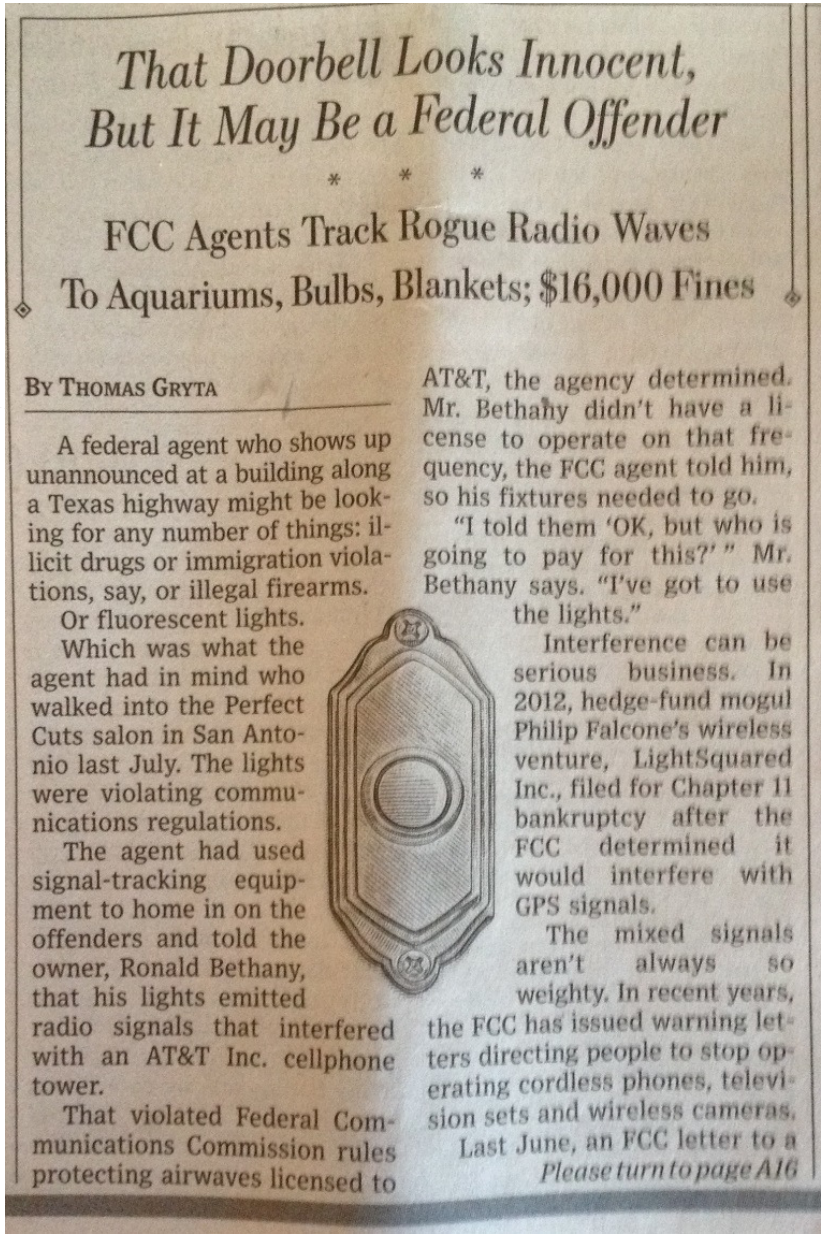


http://www.lrc.rpi.edu/programs/solidstate/assist/flicker.asp

LED Basics

EMI

- AKA EMC
- AKA RFI
- AKA Trouble



That Doorbell Looks Innocent, But It May Be a Federal Offender

* * *

FCC Agents Track Rogue Radio Waves To Aquariums, Bulbs, Blankets; $16,000 Fines

By Thomas Gryta

A federal agent who shows up unannounced at a building along a Texas highway might be looking for any number of things: illicit drugs or immigration violations, say, or illegal firearms.

Or fluorescent lights.

Which was what the agent had in mind who walked into the Perfect Cuts salon in San Antonio last July. The lights were violating communications regulations.

The agent had used signal-tracking equipment to home in on the offenders and told the owner, Ronald Bethany, that his lights emitted radio signals that interfered with an AT&T Inc. cellphone tower.

That violated Federal Communications Commission rules protecting airwaves licensed to AT&T, the agency determined. Mr. Bethany didn't have a license to operate on that frequency, the FCC agent told him, so his fixtures needed to go.

"I told them 'OK, but who is going to pay for this?' " Mr. Bethany says. "I've got to use the lights."

Interference can be serious business. In 2012, hedge-fund mogul Philip Falcone's wireless venture, LightSquared Inc., filed for Chapter 11 bankruptcy after the FCC determined it would interfere with GPS signals.

The mixed signals aren't always so weighty. In recent years, the FCC has issued warning letters directing people to stop operating cordless phones, television sets and wireless cameras.

Last June, an FCC letter to a

Please turn to page A16

Wall Street Journal
March 11th 2014

AcuityBrands.

The Way it Was

LED Basics

Color Consistency

- CFL

LED Basics

Color Consistency

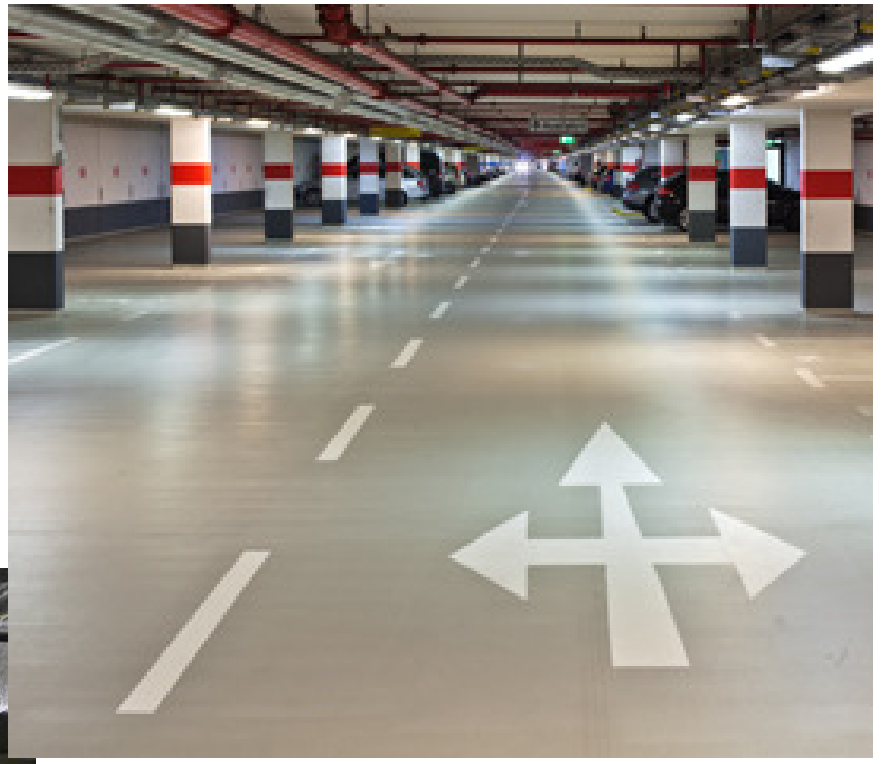
- Linear Fluorescent

AcuityBrands.

LED Basics

Color Consistency

- Metal Halide



LED Basics

Color Consistency

- Early LED

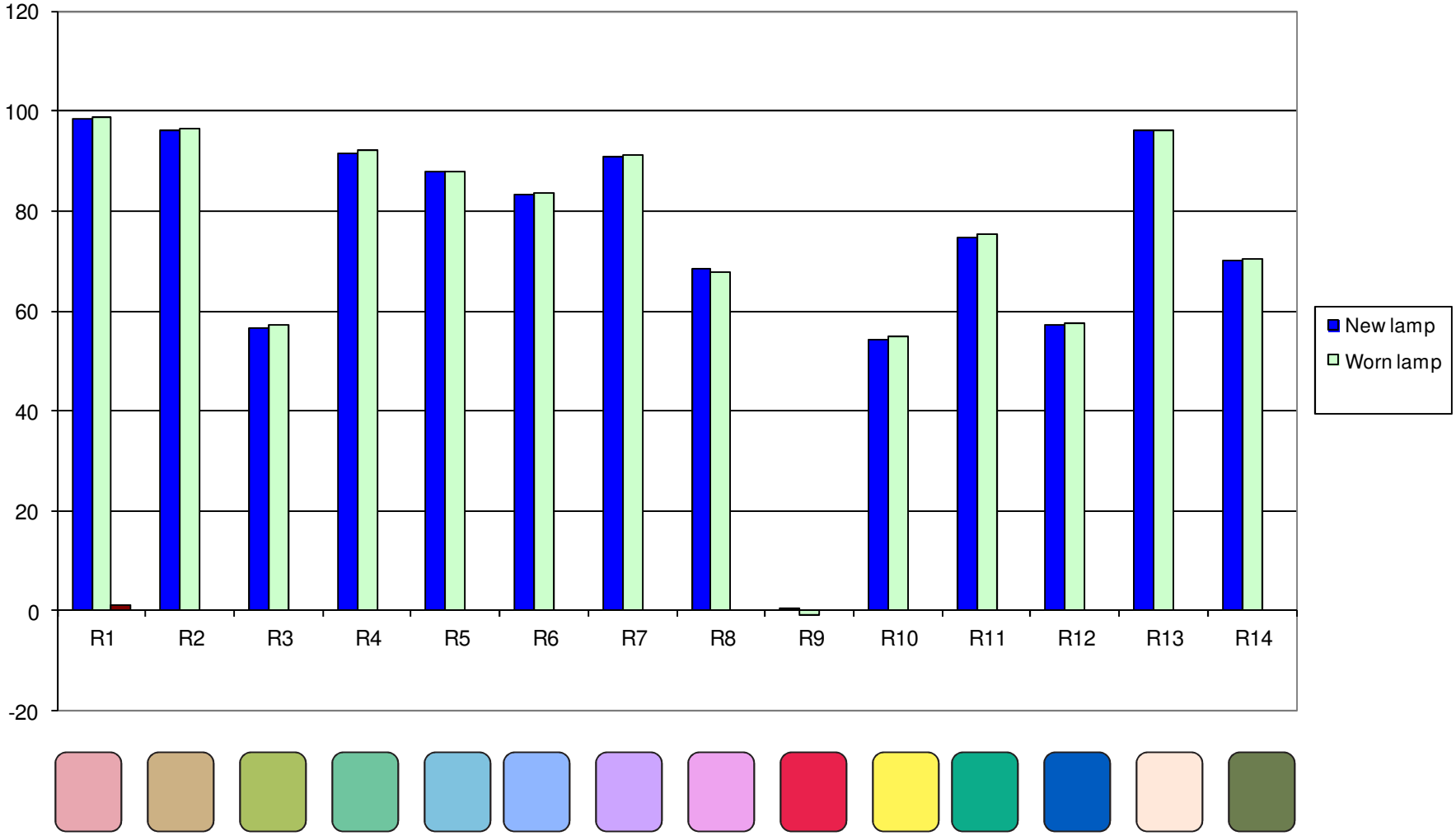
LED Basics

Color Consistency

- HPS

The Way it Was

CRI

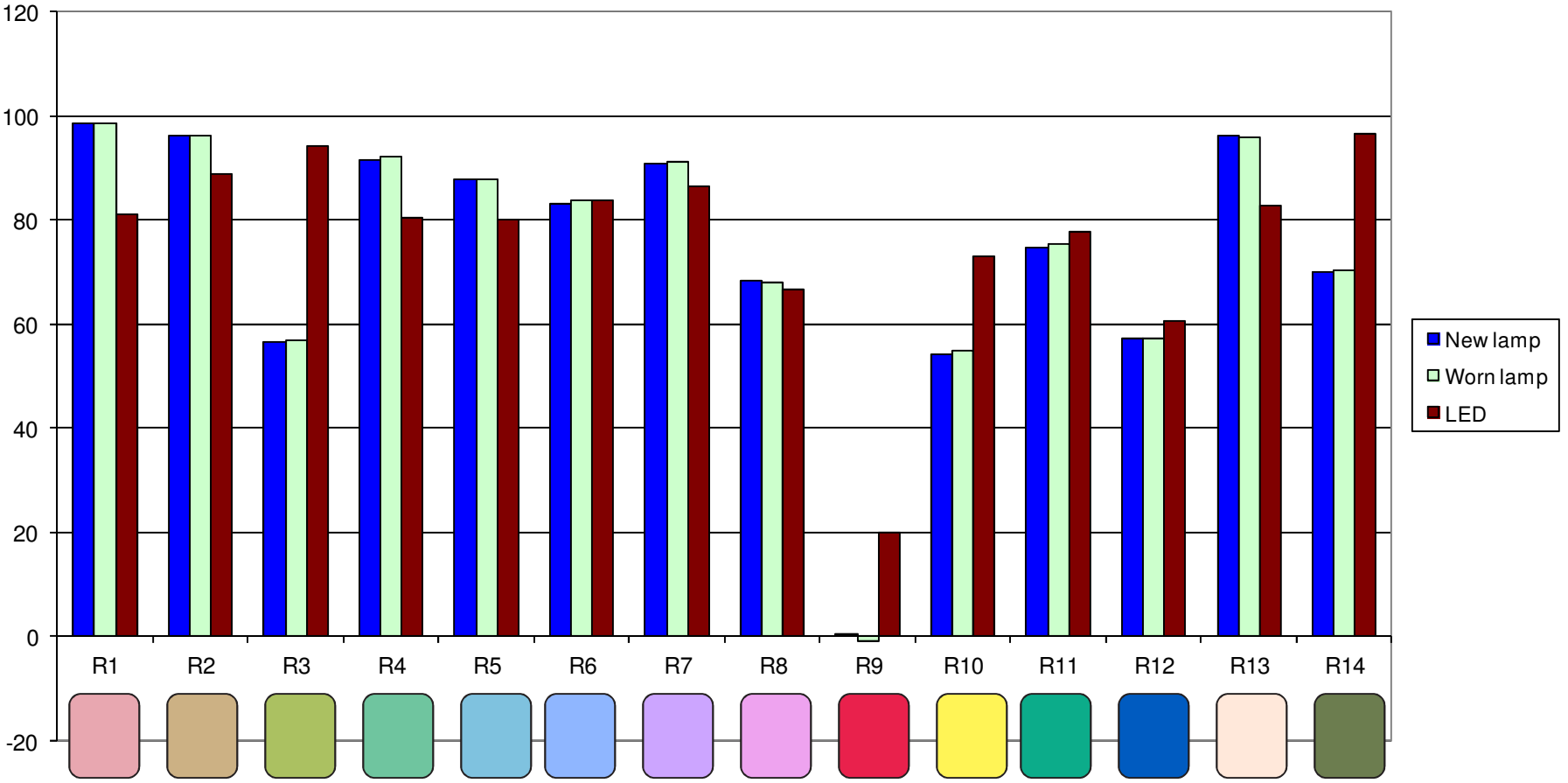


28W GE Fluorescent

AcuityBrands.

The Way it Was

CRI



28W GE Fluorescent VS Acuity LED Luminaire

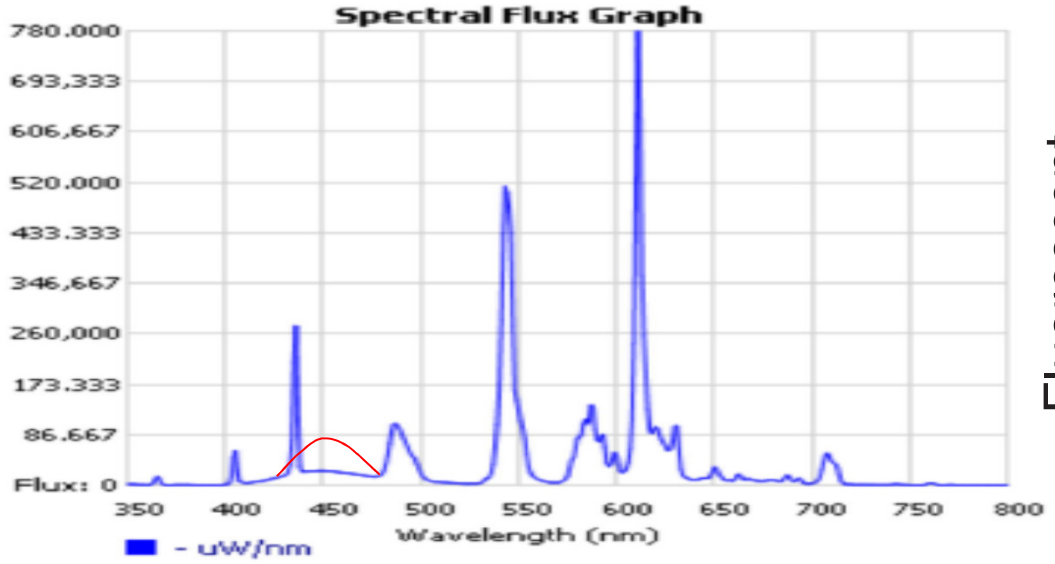
AcuityBrands.

The Way it Was

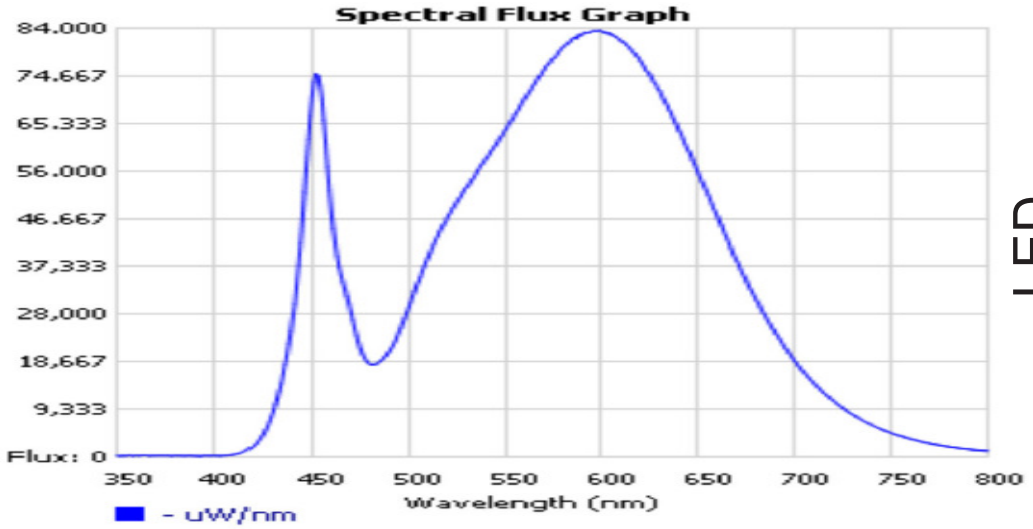
CRI

Note:

Vertical scale is different



Fluorescent



LED

28W GE Fluorescent VS Acuity LED Luminaire

AcuityBrands.

The Way it Was

Dimming

- Fluorescent
- HID
- Incandescent

The Way it Was

Controls

- Occupancy Sensors
- Photocontrols
- Wall switches
- Wired
- $$$$

The Way it Is

The Way it Is

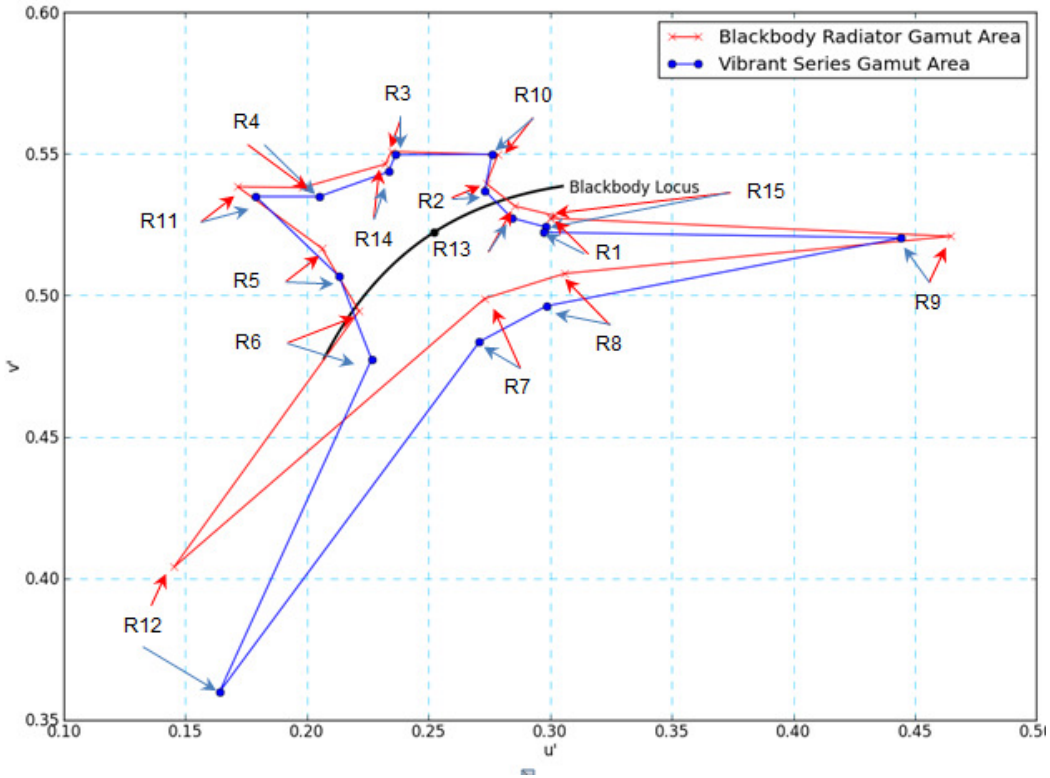
CRI

- 80 vs 90?

1976 CIE u'v' Color space

Calculate area of polygon GA_{BB}

$$GAI_{BB} = \frac{GA_S \times 100}{GA_{BB}}$$



AcuityBrands.

The Way it Is

CRI

- Enhanced Full Color Spectrum

The Way it Is

Enriching Experiences Where it Matters Most

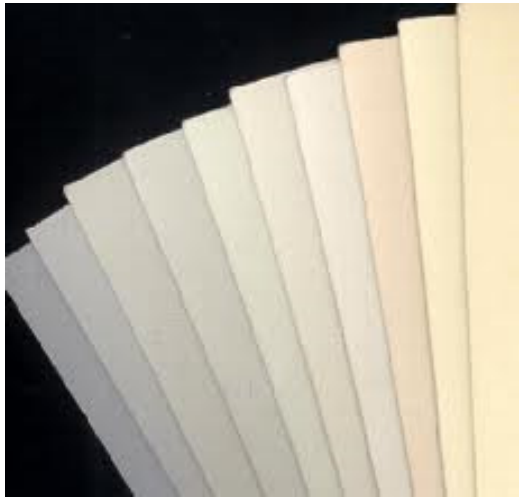
Natural Color	Balanced Color	Vivid Color
		
		

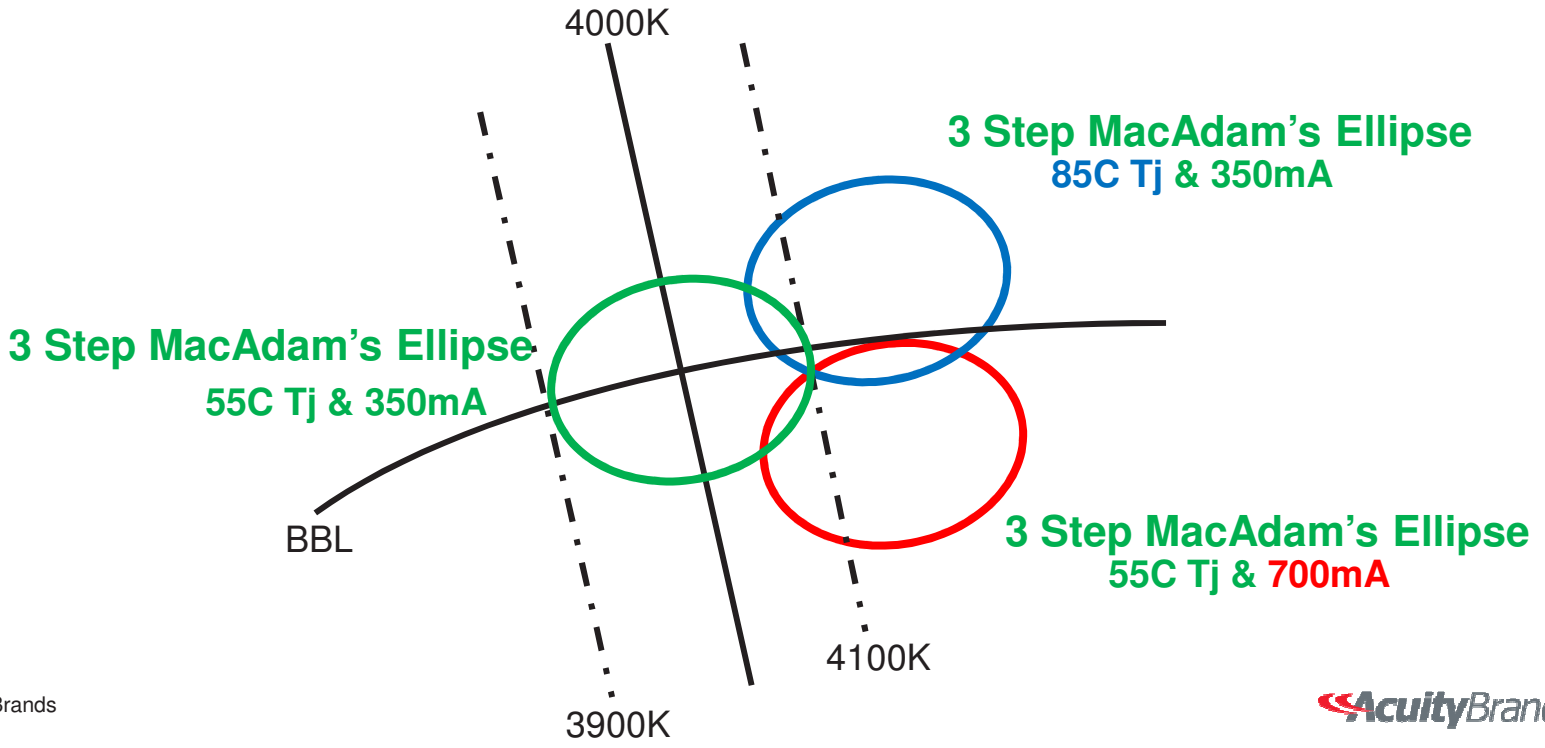
AcuityBrands.

The Way it Is

Color Consistency

- ANSI Bin
- 3 SDCM from the Light Engine
- 3 SDCM from the Luminaire





AcuityBrands.

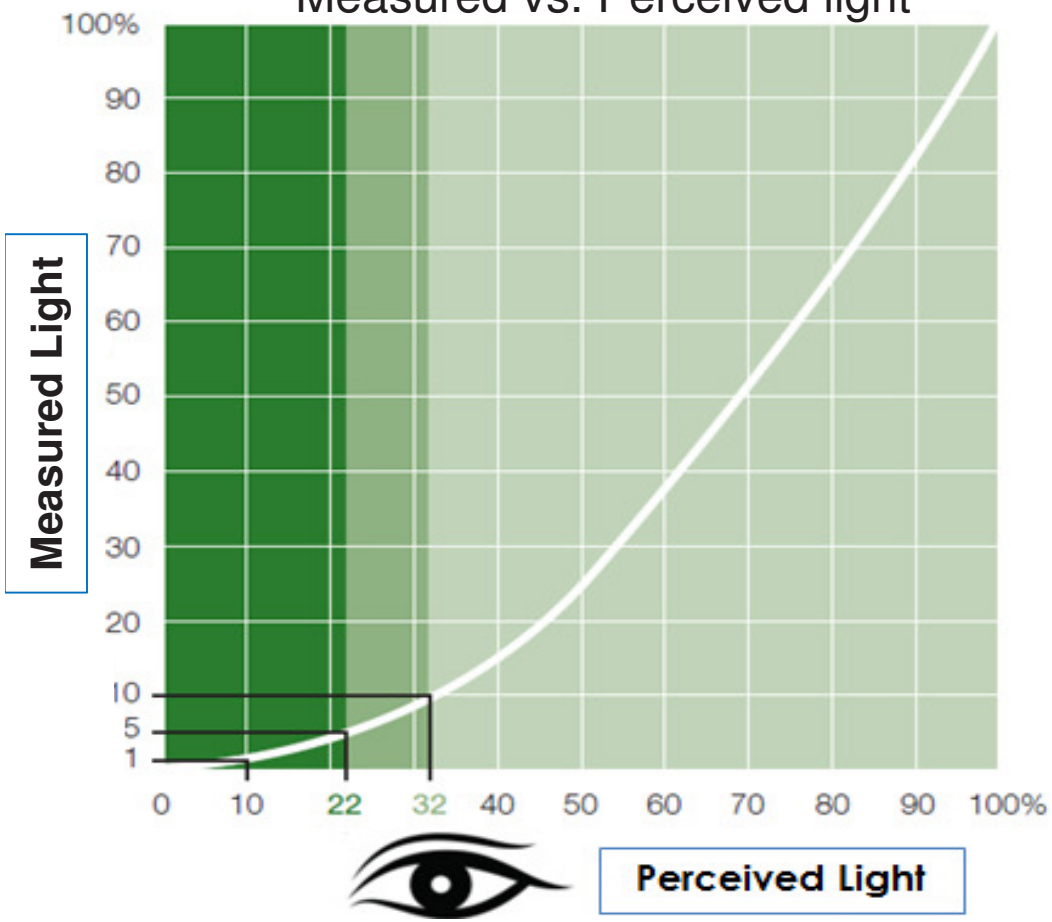
The Way it Is

Dimming

Light level was not a concern of incandescent dimming because it dimmed to off

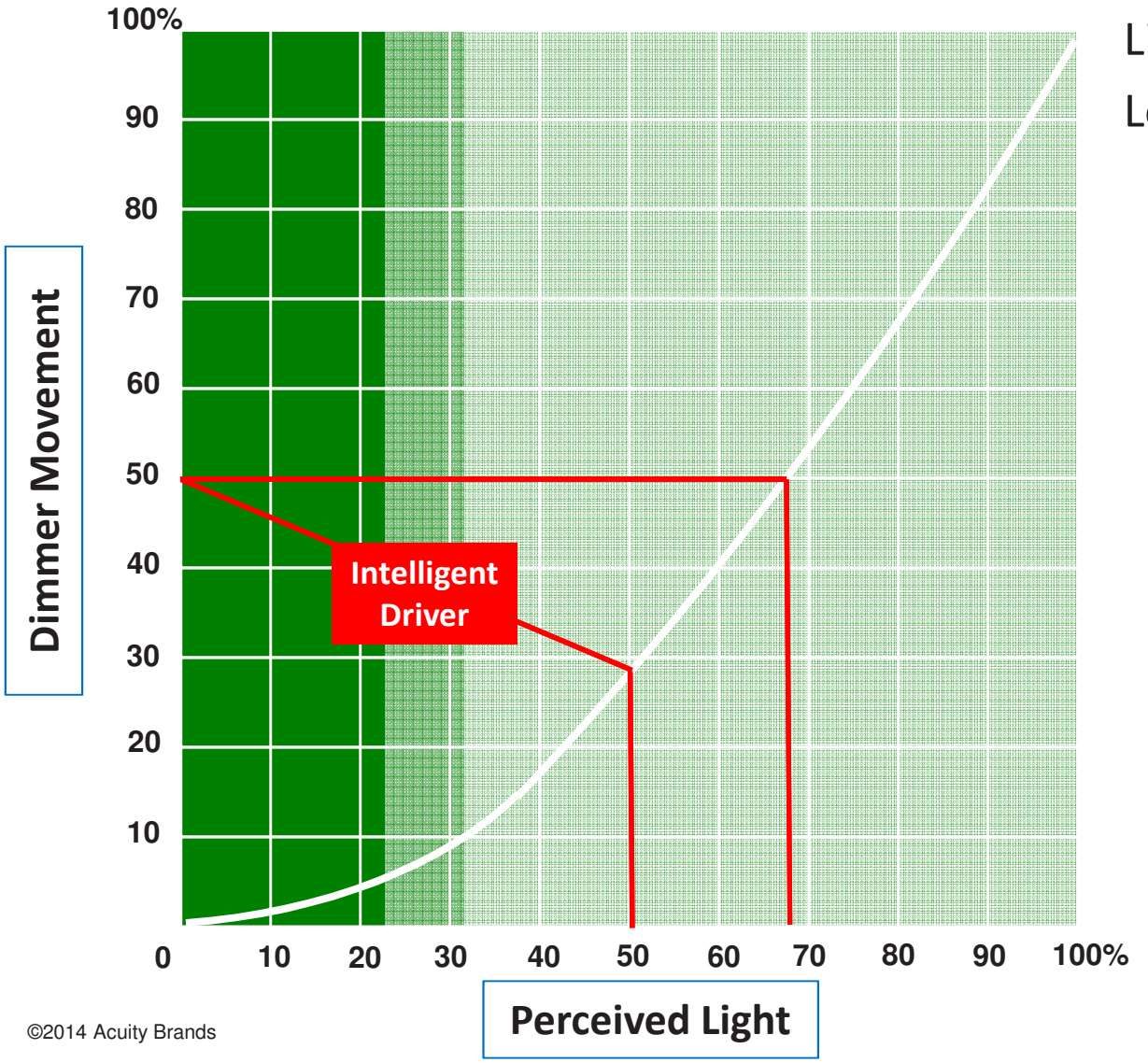
<u>Square law dimming:</u>
10% measured = **32% Perceived**
5% measured = **22% Perceived**
1% measured = **10% Perceived**
0% measured = **0% Perceived**

Source: IESNA Handbook, 9th edition, Measured vs. Perceived light



AcuityBrands.

The Way it Is



Dimming

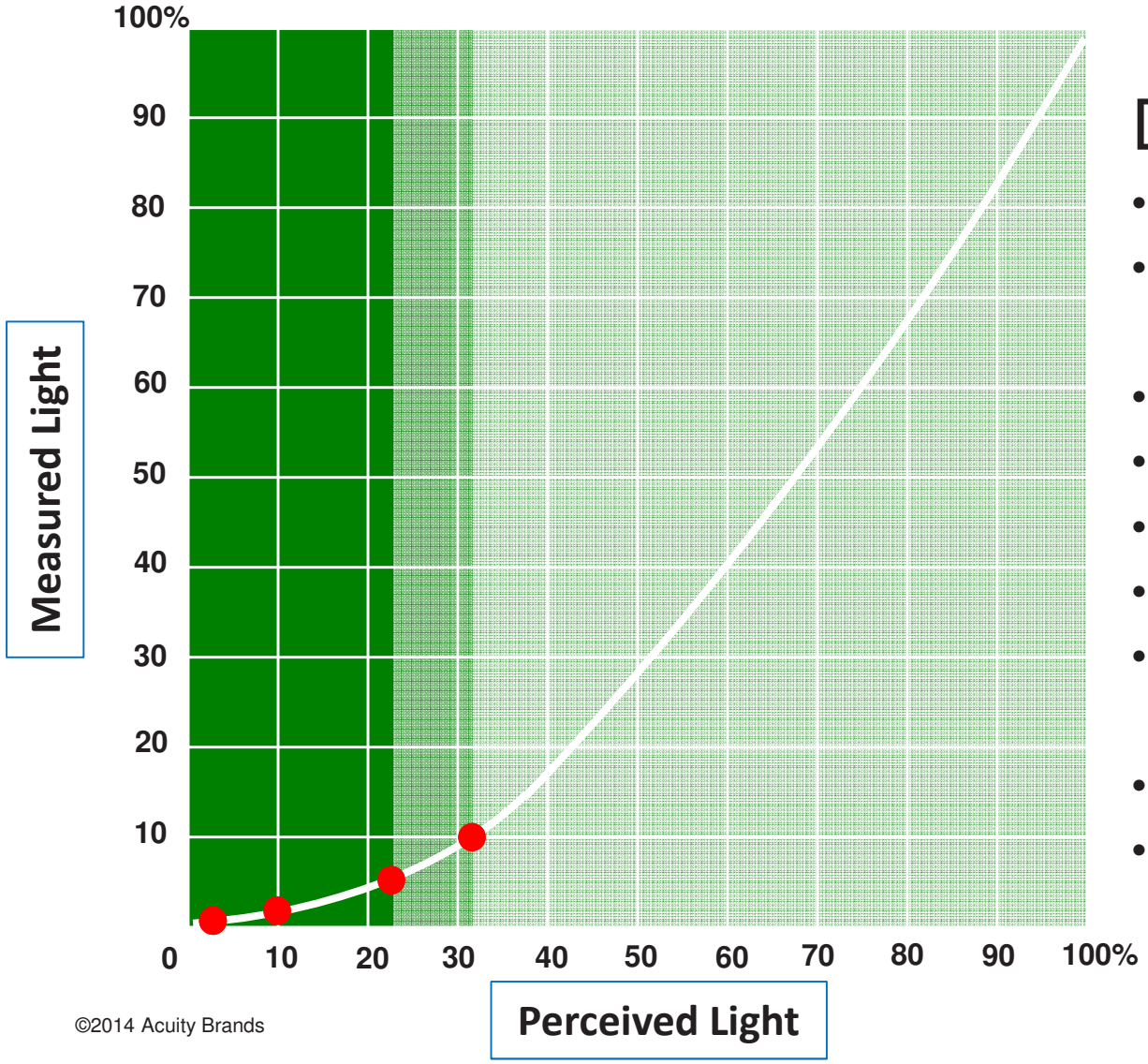
Linear VS Logarithmic

Linear 50% = 67% Light

Logarithmic 50% = 50% Light

AcuityBrands.

The Way it Is



Dimming

- Dim to 10% is 32% Perceived
- Load Shedding – High/Low

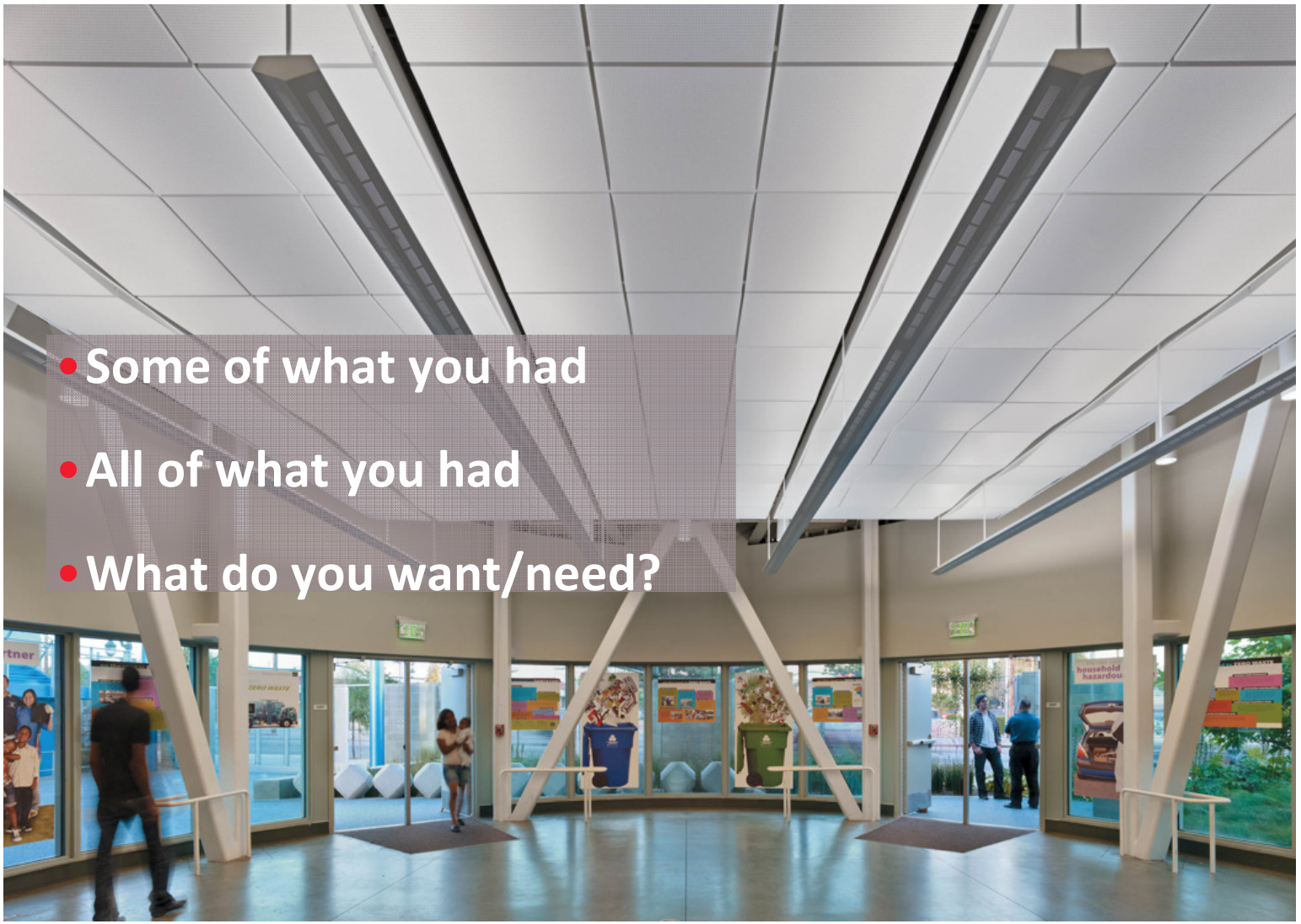
- Dim to 5% is 22% Perceived
- Energy Management Dimming
-
- Dim to 1% is 10% Perceived
- Daylight & Conference Rooms

- Dim to 0.1% is 3% Perceived
- Highest-Performance Spaces

AcuityBrands.

The Way it Is

Lumen Levels

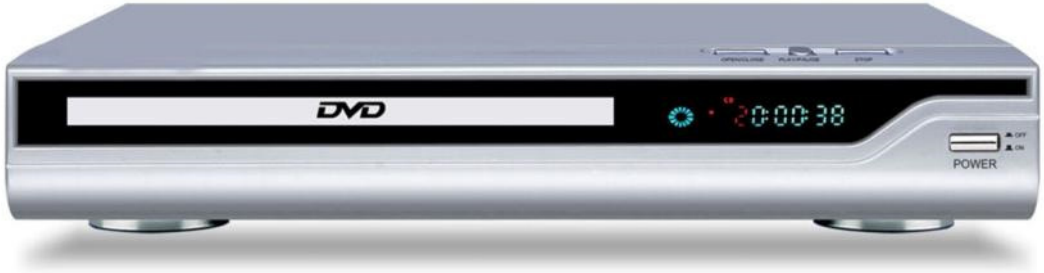


AcuityBrands.

The Way is Is

Construction

- Throw Away
- Modular & Serviceable
- Future Proofed



AcuityBrands.

The Way it Is

Servicing can have risks and unintended consequences

The Way it Is

Servicing can have risks and unintended consequences

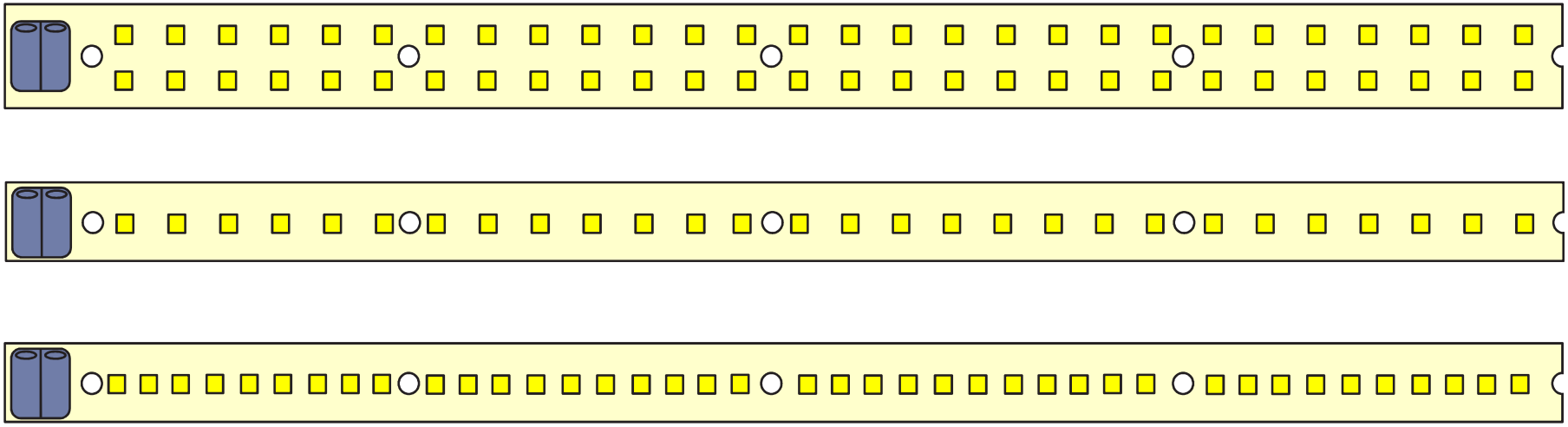
Replacement can be a better option

AcuityBrands.

The Way it Is

Future Proofing

- Simple
- Interchangeable
- Flexible

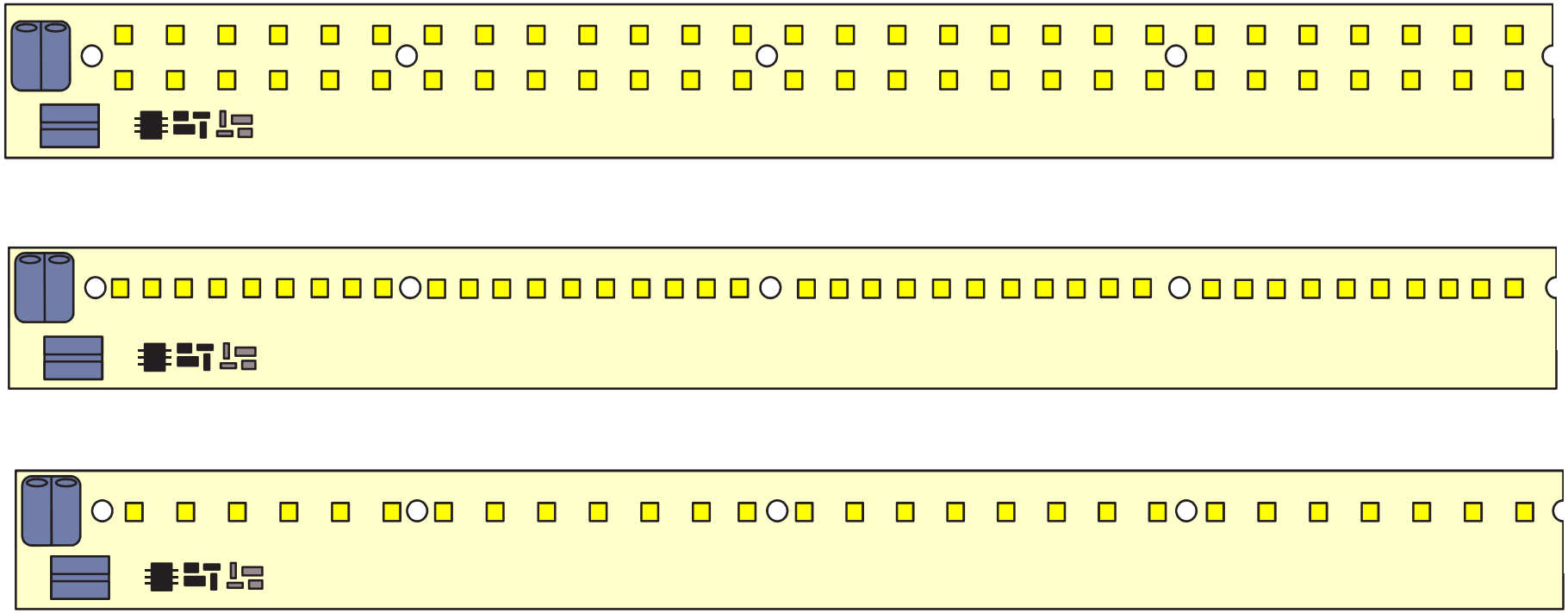


AcuityBrands.

The Way it Is

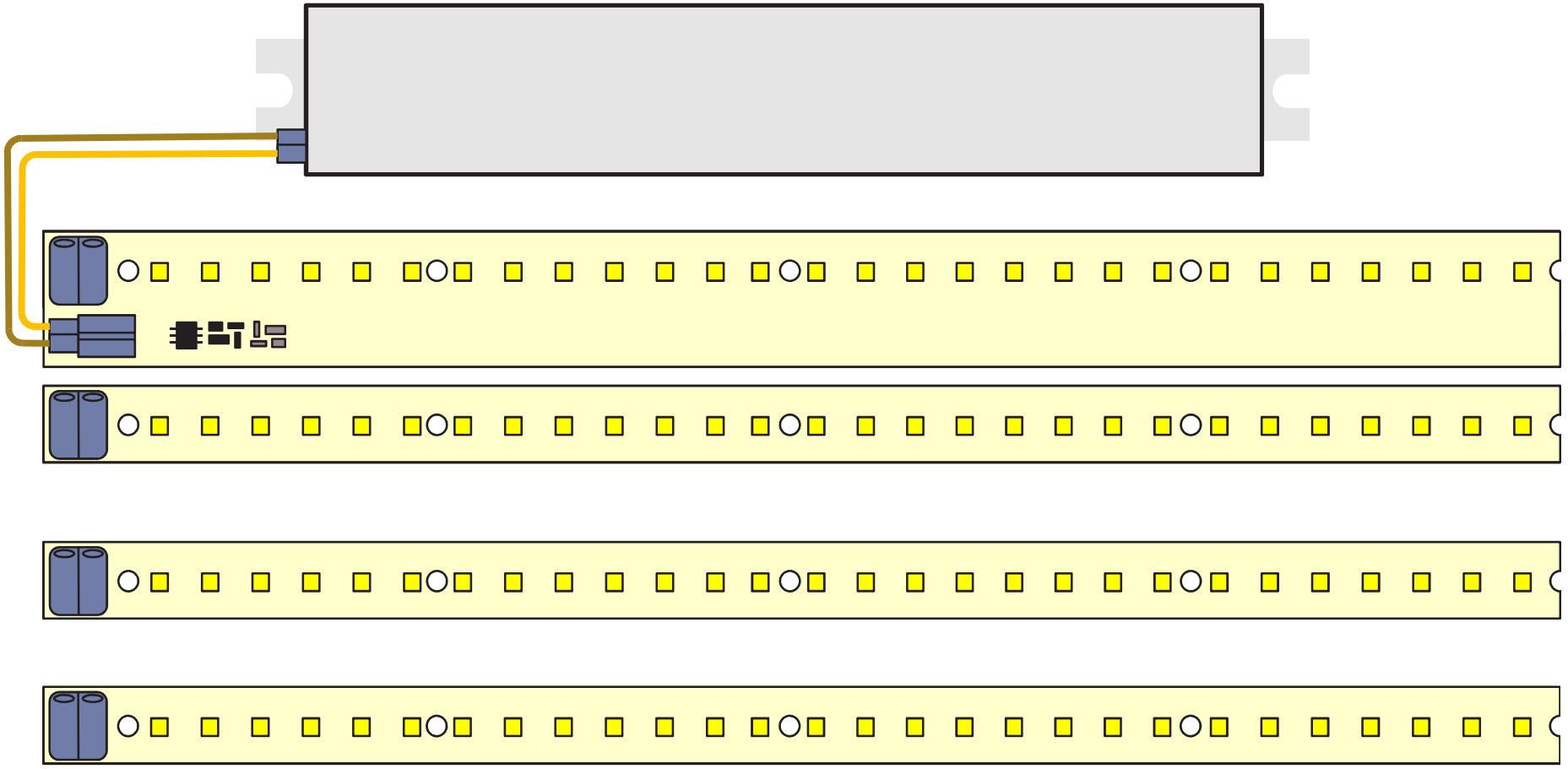
Future Proofing

- Add intelligence



The Way it Is
Future Proofing

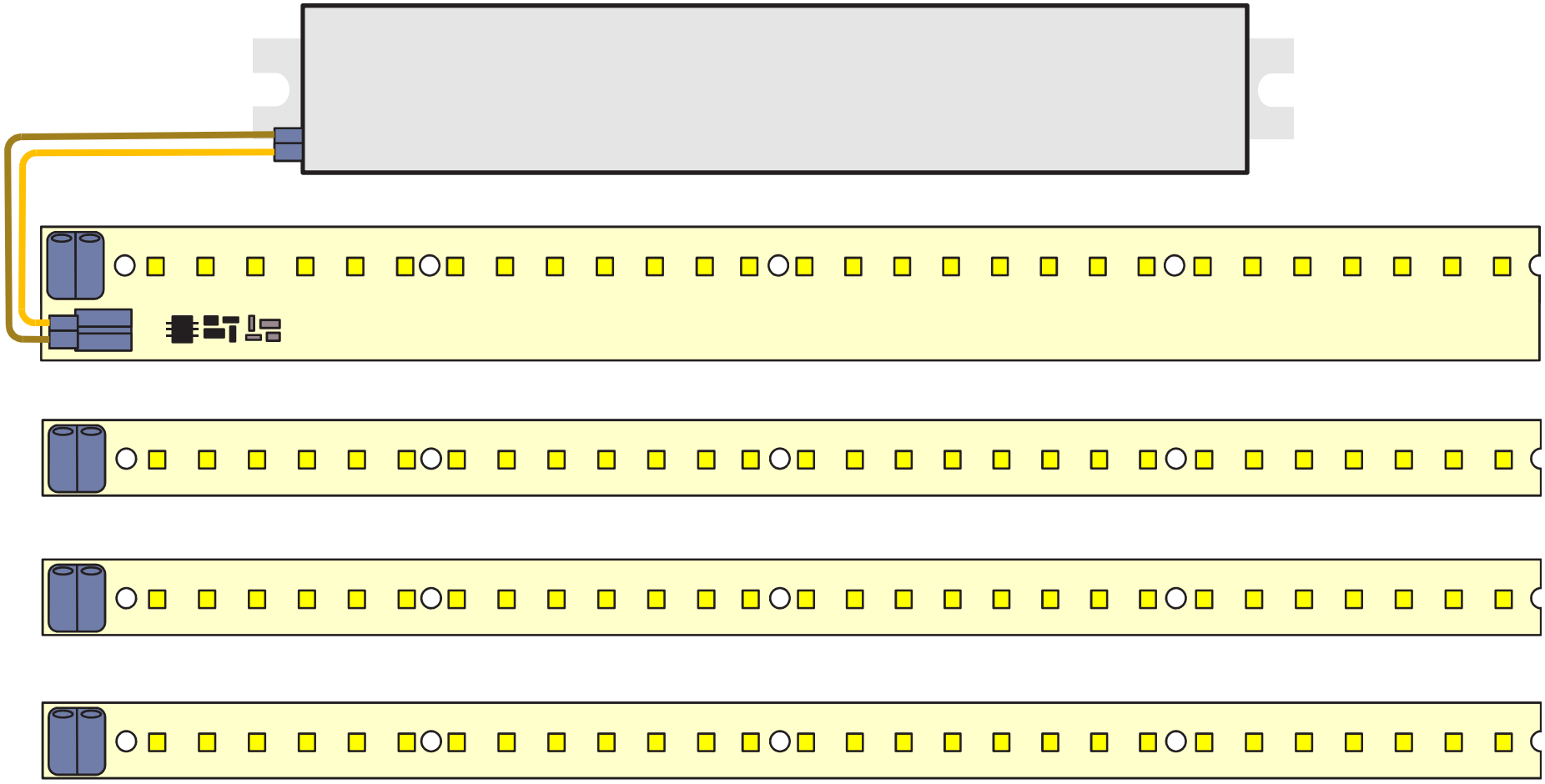
- Current Setting



AcuityBrands.

The Way it Is
Future Proofing

- Current Setting or Constant Lumen Output

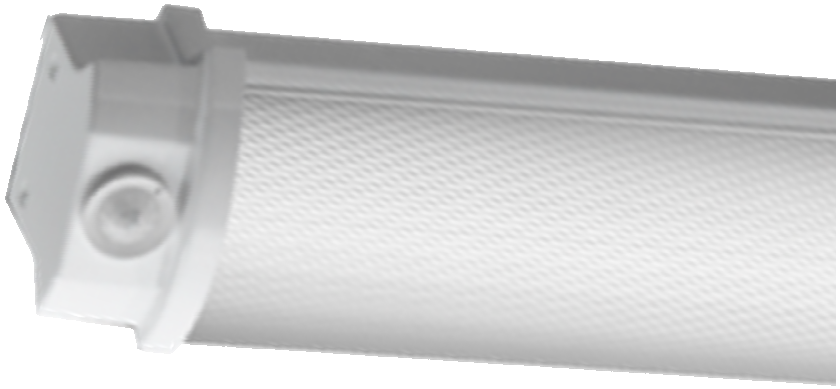


AcuityBrands.

The Way it Is

Controls

- Occupancy Sensors …….Better & Integrated
- Wall switches - Wireless & Battery-less
- ~~Wired~~ Wireless
- ~~$$$$~~ $$



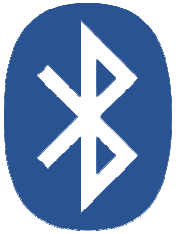
AcuityBrands.

The Way it Is

Controls - Wireless

enocean

ZigBee®



Bluetooth®

AcuityBrands.

The Way it Is

Controls

- Wireless & Zoned
- Responsive integral sensors

The Way it Is

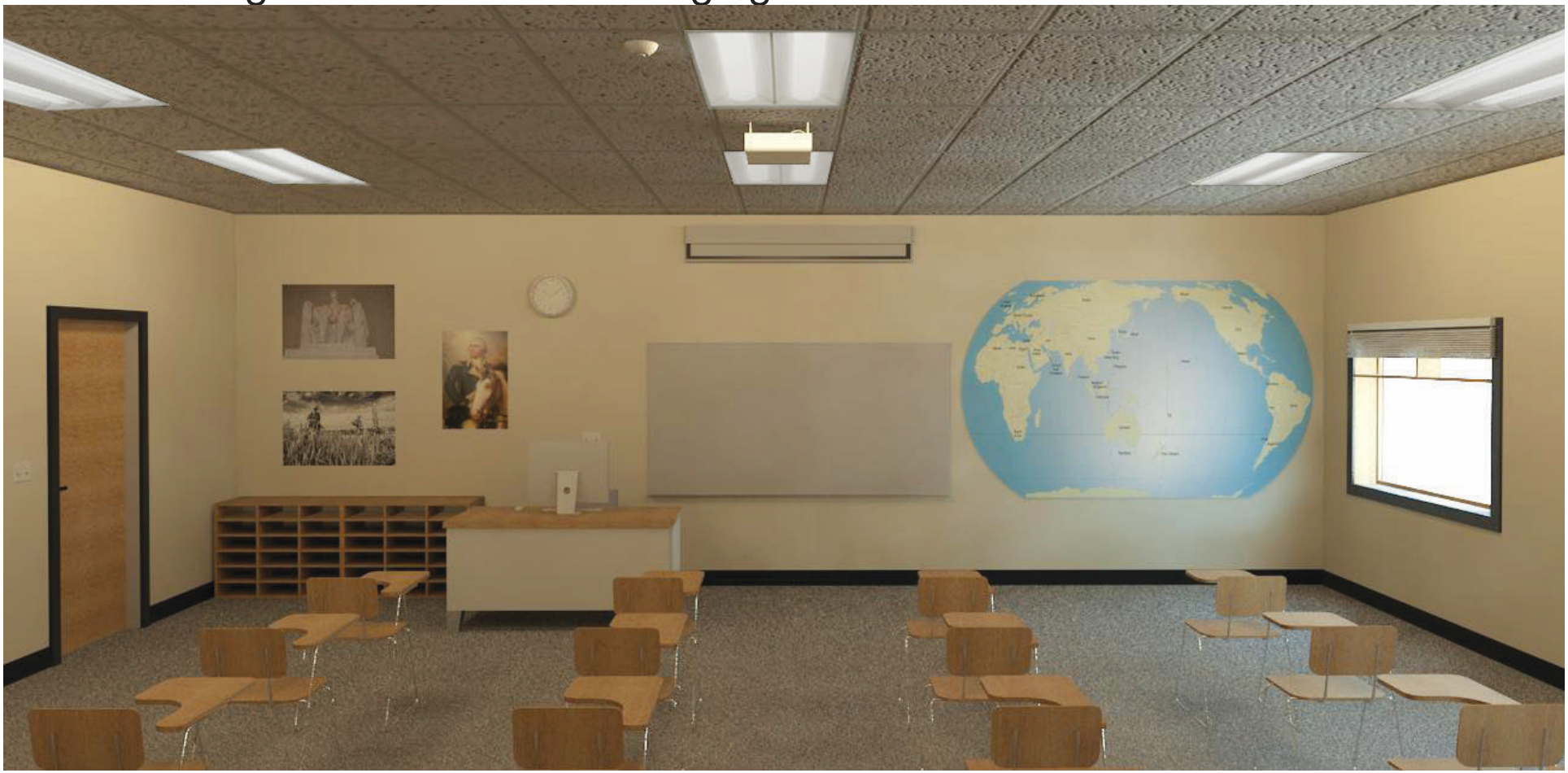
Controls

- Wireless & Zoned
- Responsive integral sensors

The Way it Is

Controls

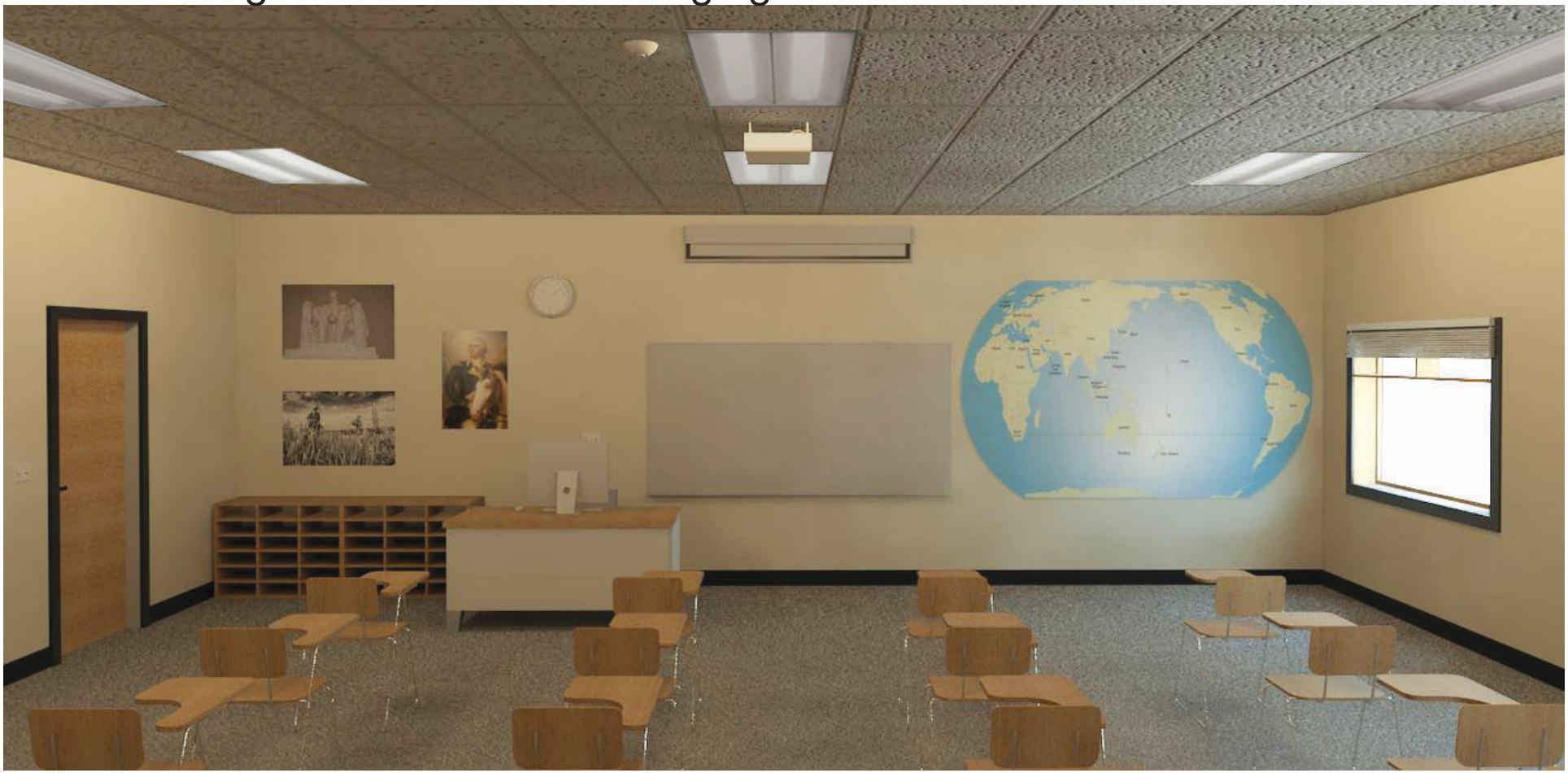
- Multiple zones
- PreSet Scenes
- Light quality optimized to the functions taking place
- Focusing attention…for challenging visual tasks



The Way it Is

Controls

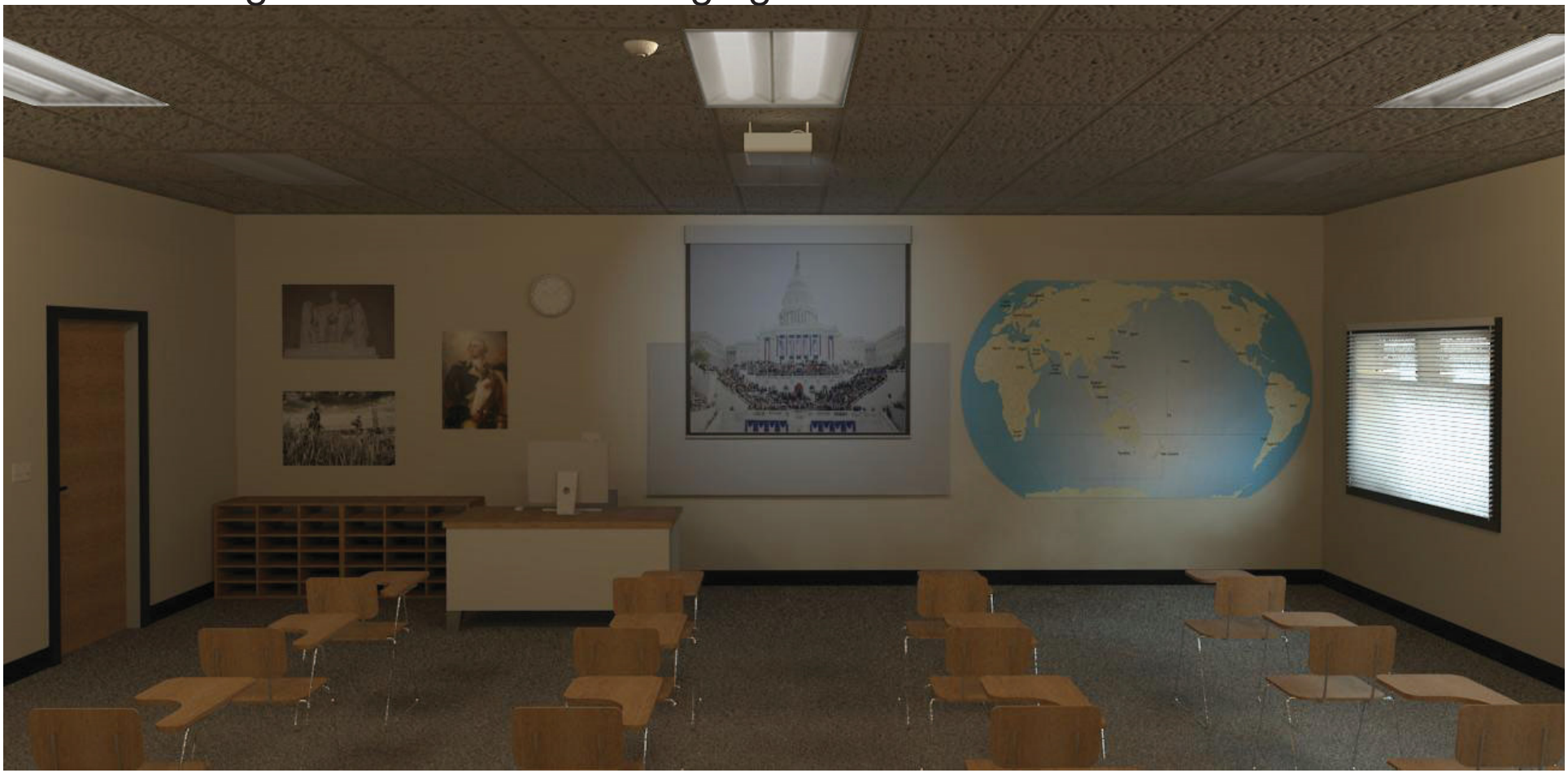
- Multiple zones
- PreSet Scenes
- Light quality optimized to the functions taking place
- Focusing attention…for challenging visual tasks



The Way it Is

Controls

- Multiple zones
- PreSet Scenes
- Light quality optimized to the functions taking place
- Focusing attention…for challenging visual tasks

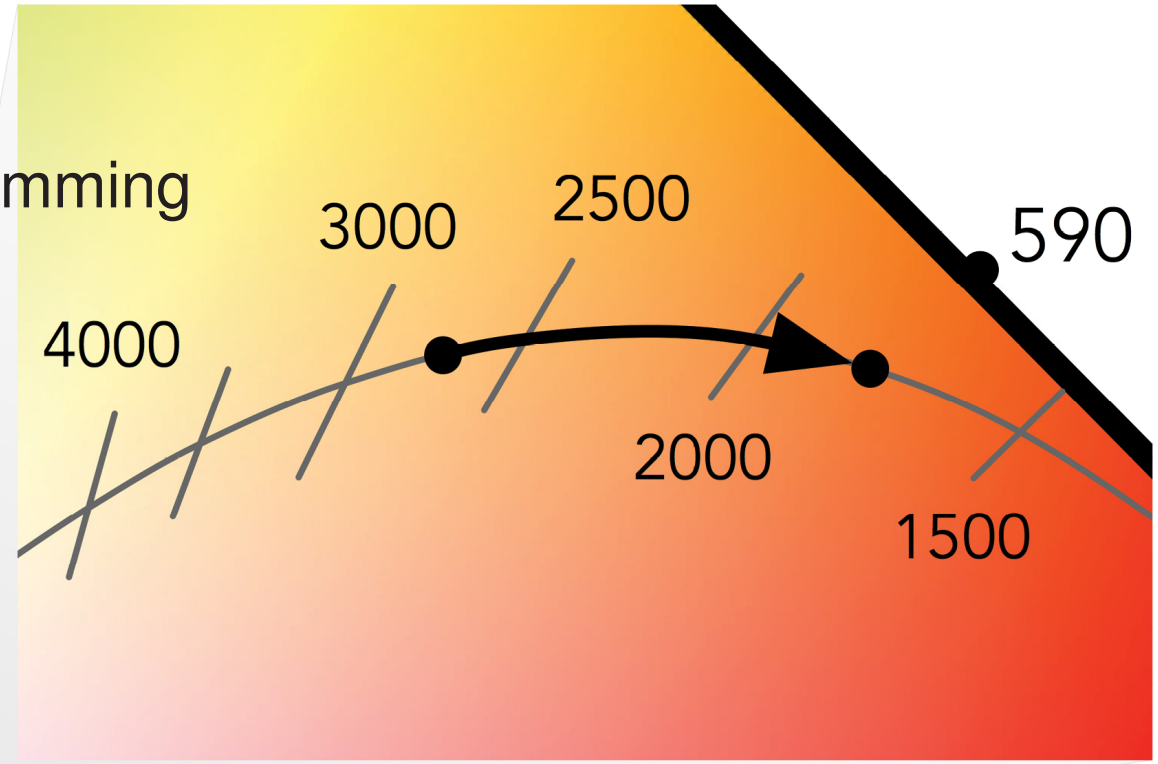


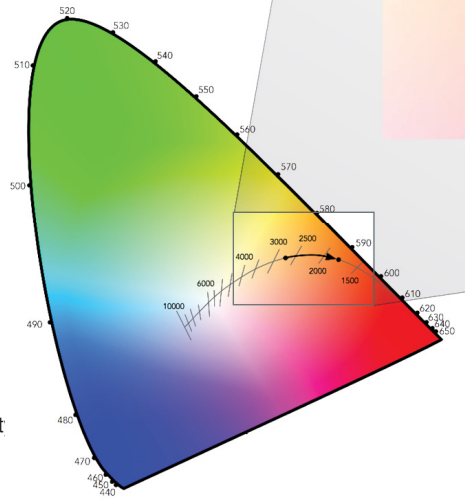
The Way it Will Be

The Way it Will Be

Color Consistency Choices

- Dim to Warm
- AKA Halogen Dimming
- Choices
  - > BBL
  - > Linear

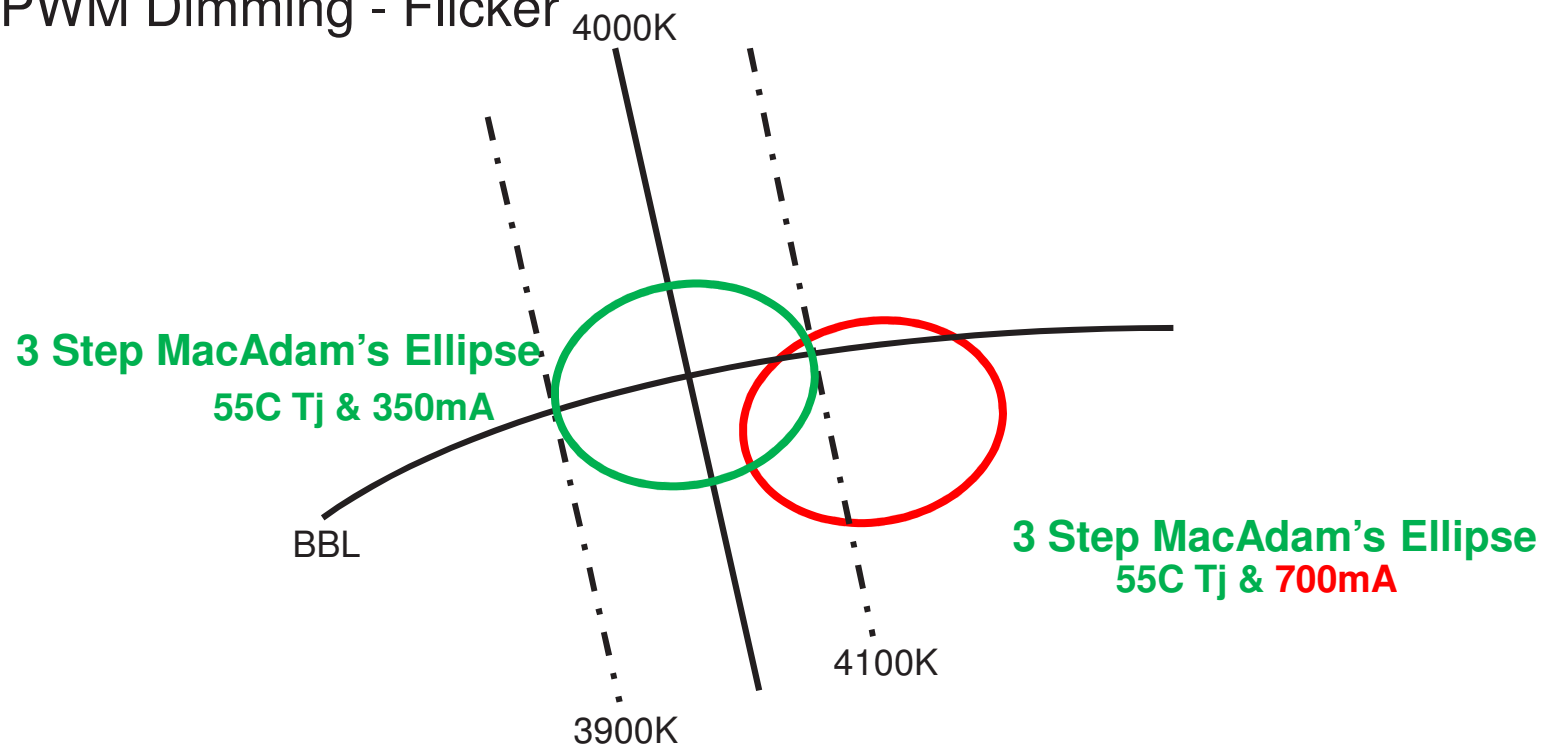




The Way it Will Be

Color Consistency Choices

- Dim at the same color – Desireable?
- Constant Current Dimming – Color Shift
- PWM Dimming - Flicker

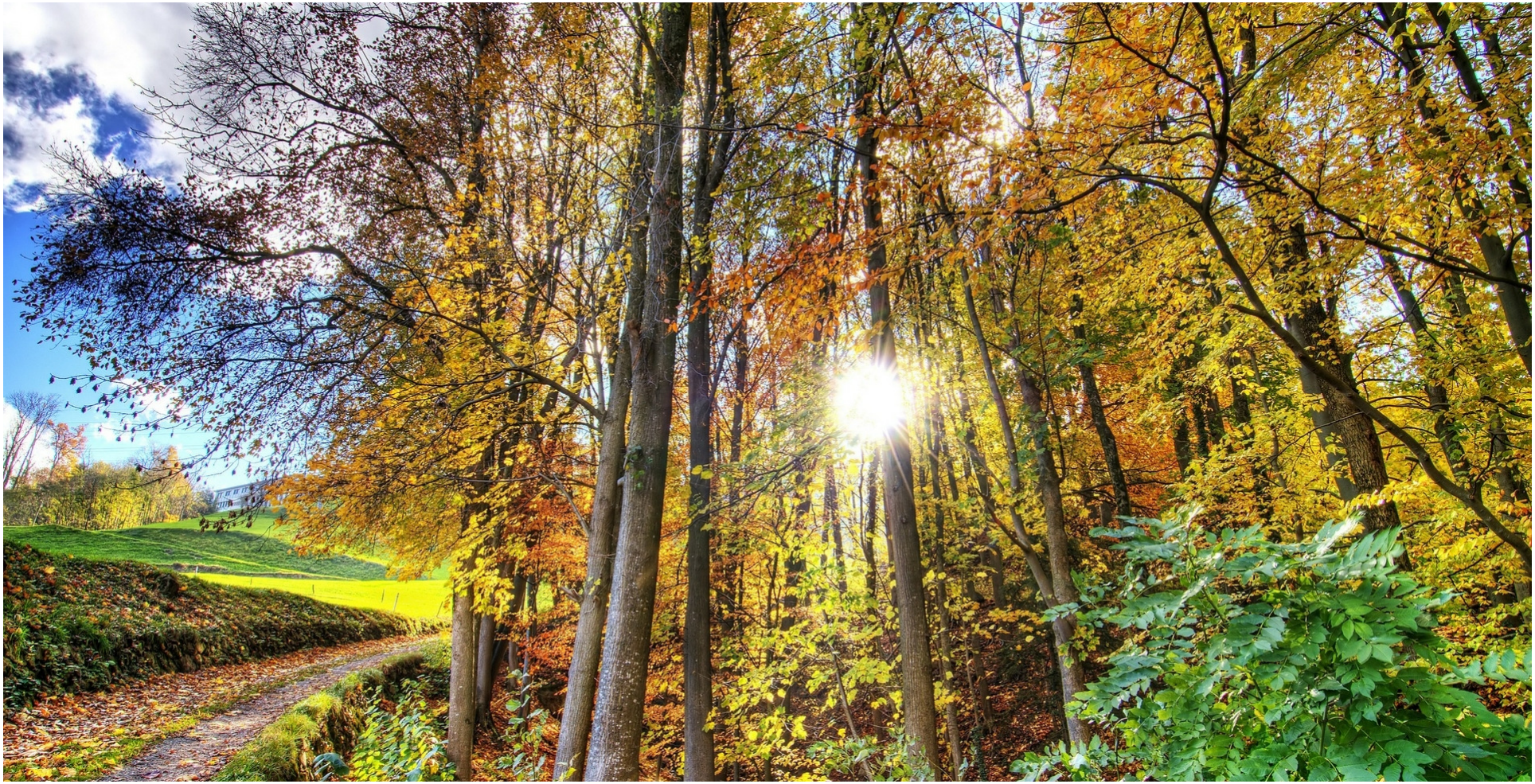


AcuityBrands.

The Way it Will Be

Tuneable White

White light contains the colors we see



The Way it Will Be

Tuneable White Choices

- Matching outside daylight
- Circadian rhythm Optimized for Health/Behavior

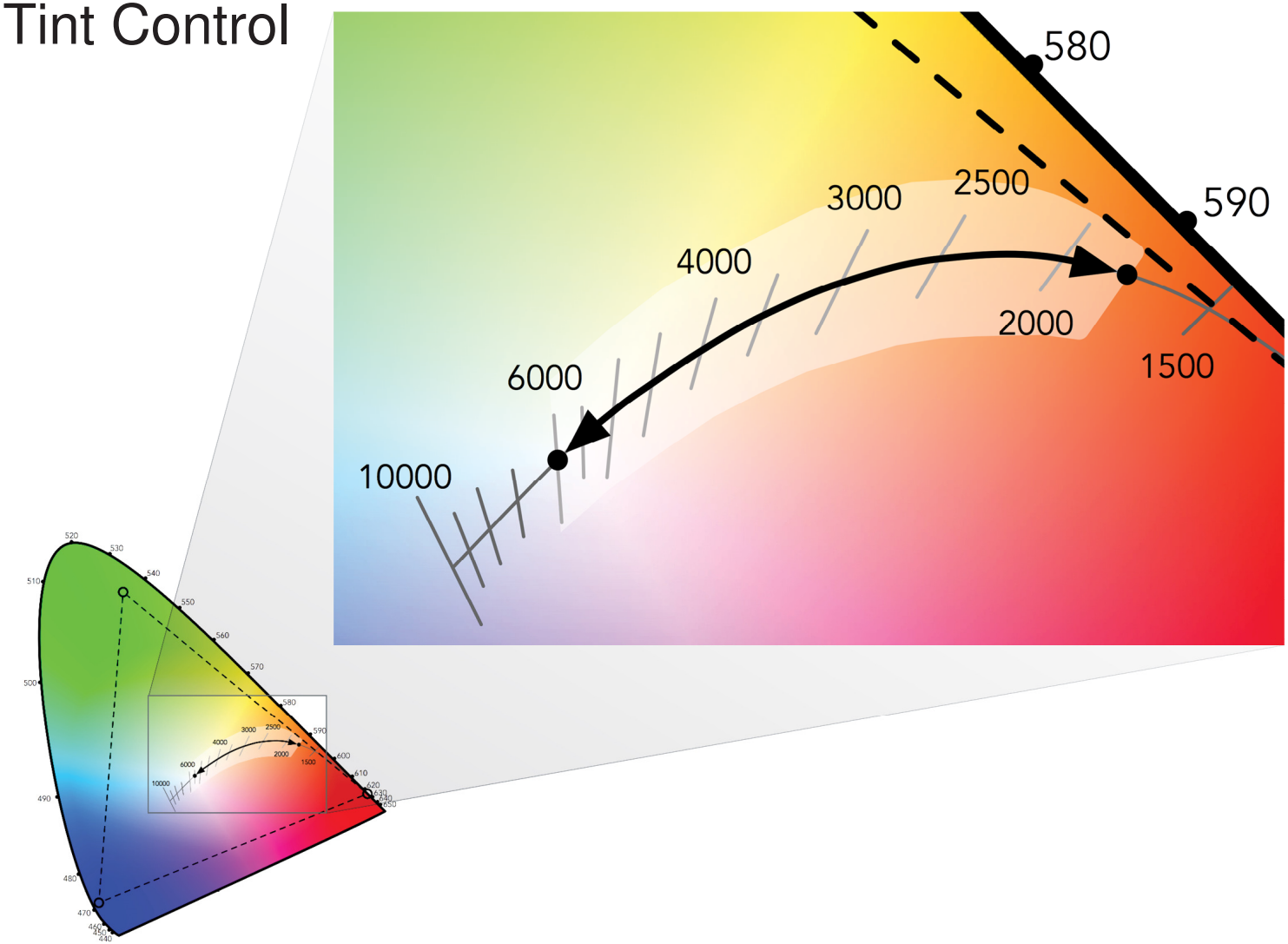
The Way it Will Be

Tunable White Choices

The Way it Will Be

Tunable White Choices

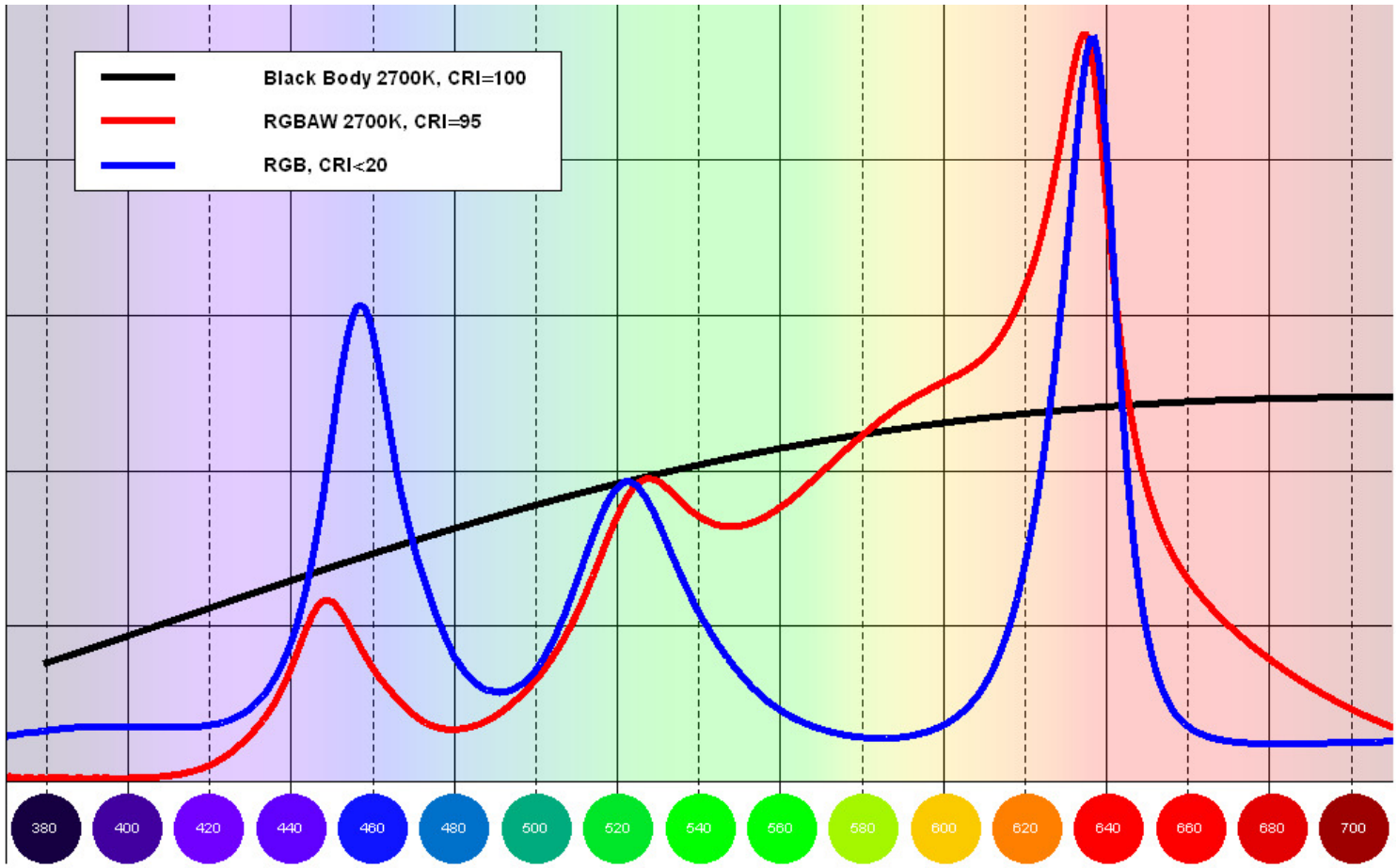
Tint Control



The Way it Will Be

Tunable White Choices

Tint Control



AcuityBrands.

The Way it Will Be

Tunable White Choices

Gamut Control : Delivering Enriched Experiences

The Way it Will Be

Visible Light Communication & Indoor Positioning

AcuityBrands.

The Way it Will Be

Visible Light Communication & Indoor Positioning

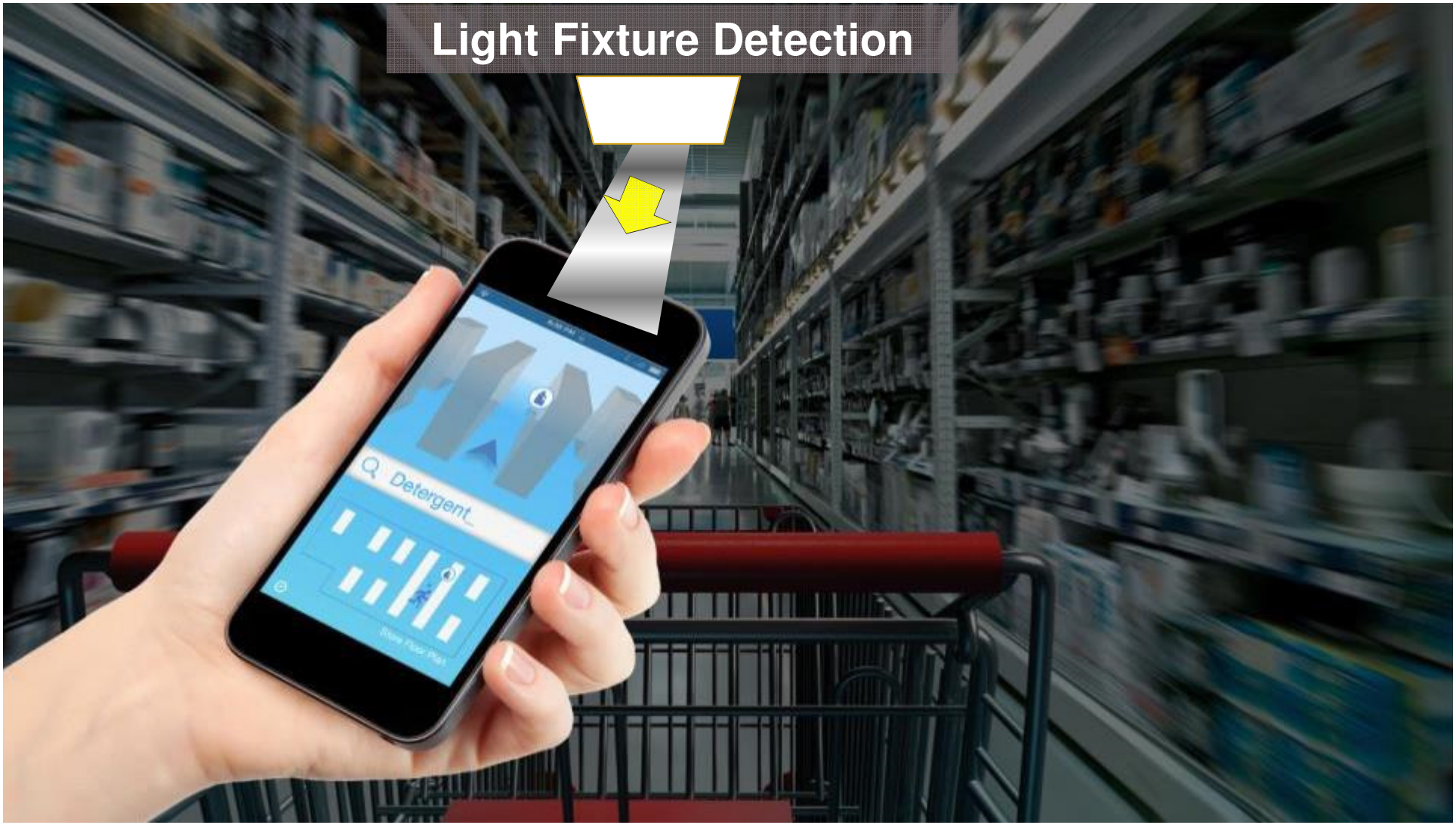
Wi-Fi
5 meters
X & Y

Multi-sensor
2 meters
X & Y, plus "floor"

Light Based
> 1 meter
X, Y, and Z

The Way it Will Be

LED Luminaire as a Positioning Platform



How it will be

Common Core Technology

- LED Modules
  - Color Set/Tune
  - Common Platforms
- Drivers – Programmable
  - mA
  - Dimming Level
  - Control Protocol
  - Curves
- Controls
  - Wireless
  - Wired
  - Both
  - Fully Interoperable, Pretested & Preconfigured

AcuityBrands.

Thank You

AcuityBrands.