SMPTE CONFERENCE 2016 ULTRAHD FORUM ITALIA Beyond Definition

Emerging Technology
SMPTE Seminar
8th edition
one century of international standards

PASSAGGI
COMUNICAZIONE E TECNOLOGIE
OLTRE LE FRONTIERE

Next Generation Entertainment:

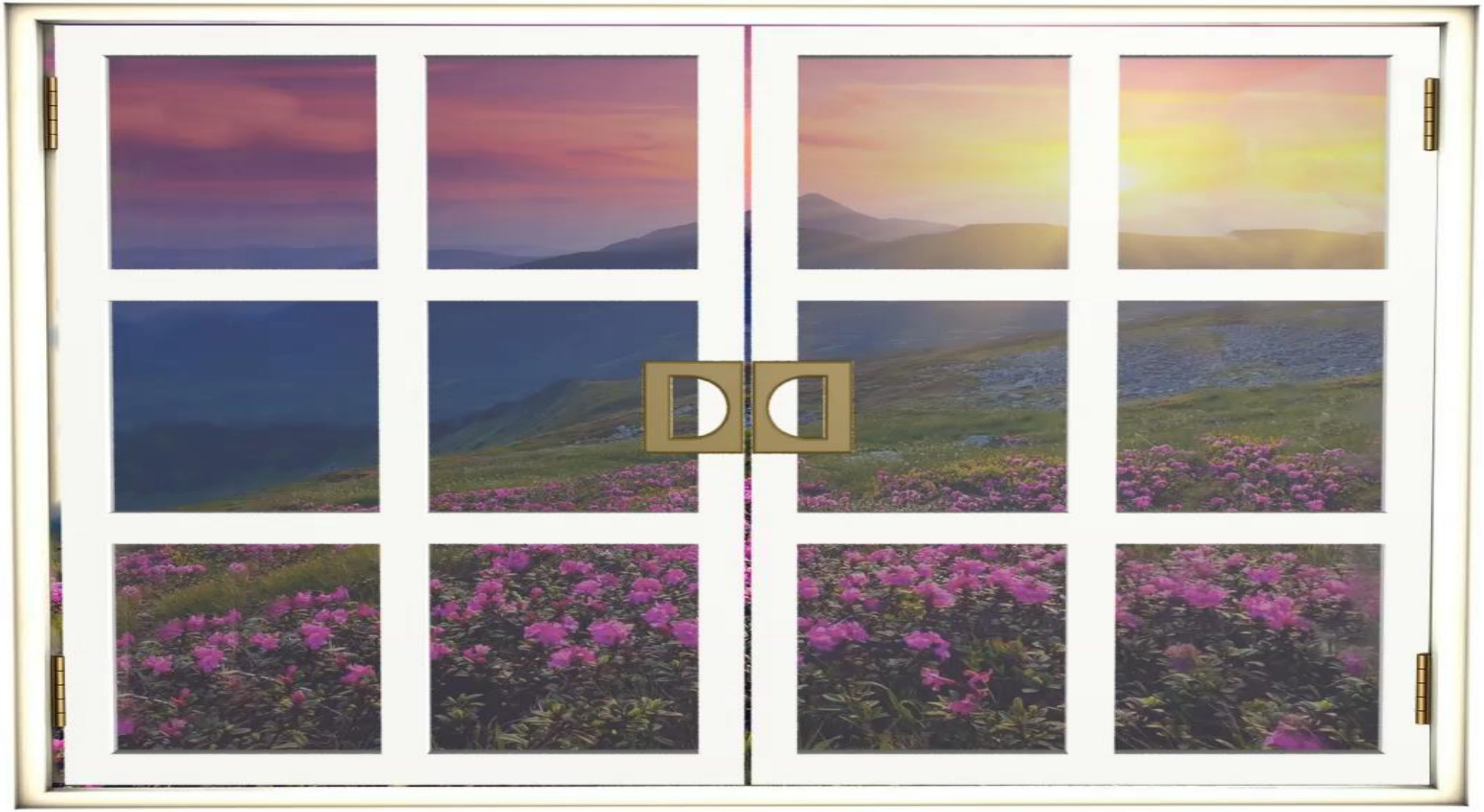
More, Faster, Better, Smarter and Perceptually Quantized Pixels

Patrick Griffis, SMPTE Vice President, VP Technology Dolby Lab

Vatican City ~ October 7, 2016

Next Generation Entertainment:
More, Faster, Better, Smarter and Perceptually Quantized Pixels

Patrick Griffis
SMPTE Vice President, Education
Vice President Technology
Office of the CTO
Dolby Laboratories, Inc.



Courtesy: Thad Beier, Dolby Labs

How Do We Get There?

Higher Spatial Resolution

More Pixels

Higher Temporal Resolution

Faster Pixels

Larger Luminance Range & Color Palette

Better Pixels

MORE PIXELS

FASTER PIXELS

More and Faster Pixels Part 1- "4K"

SYSTEM CATEGORY	SYSTEM NOMENCLATURE	LUMA OR R' G' B' SAMPLES PER LINE	LINES PER FRAME	FRAME RATE (HZ)
(4K) UHDTV-1 ~8 Megapixels (3840 x 2160)	3840 x 2160/24/P	3840	2160	24
	3840 x 2160/25/P	3840	2160	25
	3840 x 2160/30/P	3840	2160	30
	3840 x 2160/50/P	3840	2160	50
	3840 x 2160/60/P	3840	2160	60
	3840 x 2160/100P	3840	2160	100
	3840 x 2160/120/P	3840	2160	120
				LEGACY
	3840 x 2160/29.97/P	3840	2160	30/1.001
	3840 x 2160/23.98/P	3840	2160	24/1.001
	3840 x 2160/59.94/P	3840	2160	60/1.001
	3840 x 2160/119.88/P	3840	2160	120/1.001

More and Faster Pixels Part 2 - "8K"

SYSTEM CATEGORY	SYSTEM NOMENCLATURE	LUMA OR R' G' B' SAMPLES PER LINE	LINES PER FRAME	FRAME RATE (HZ)
(8K) UHDTV-2 ~33 Megapixels (7680 x 4320)	7680 x 4320/24/P	7680	4320	24
	7680 x 4320/25/P	7680	4320	25
	7680 x 4320/30/P	7680	4320	30
	7680 x 4320/50/P	7680	4320	50
	7680 x 4320/60/P	7680	4320	60
	7680 x 4320/100/P	7680	4320	100
	7680 x 4320/120/P	7680	4320	120
				LEGACY
	7680 x 4320/23.98/P	7680	4320	24/1.001
	7680 x 4320/29.97/P	7680	4320	30/1.001
	7680 x 4320/59.94/P	7680	4320	60/1.001
	7680 x 4320/119.88/P	7680	4320	120/1.001

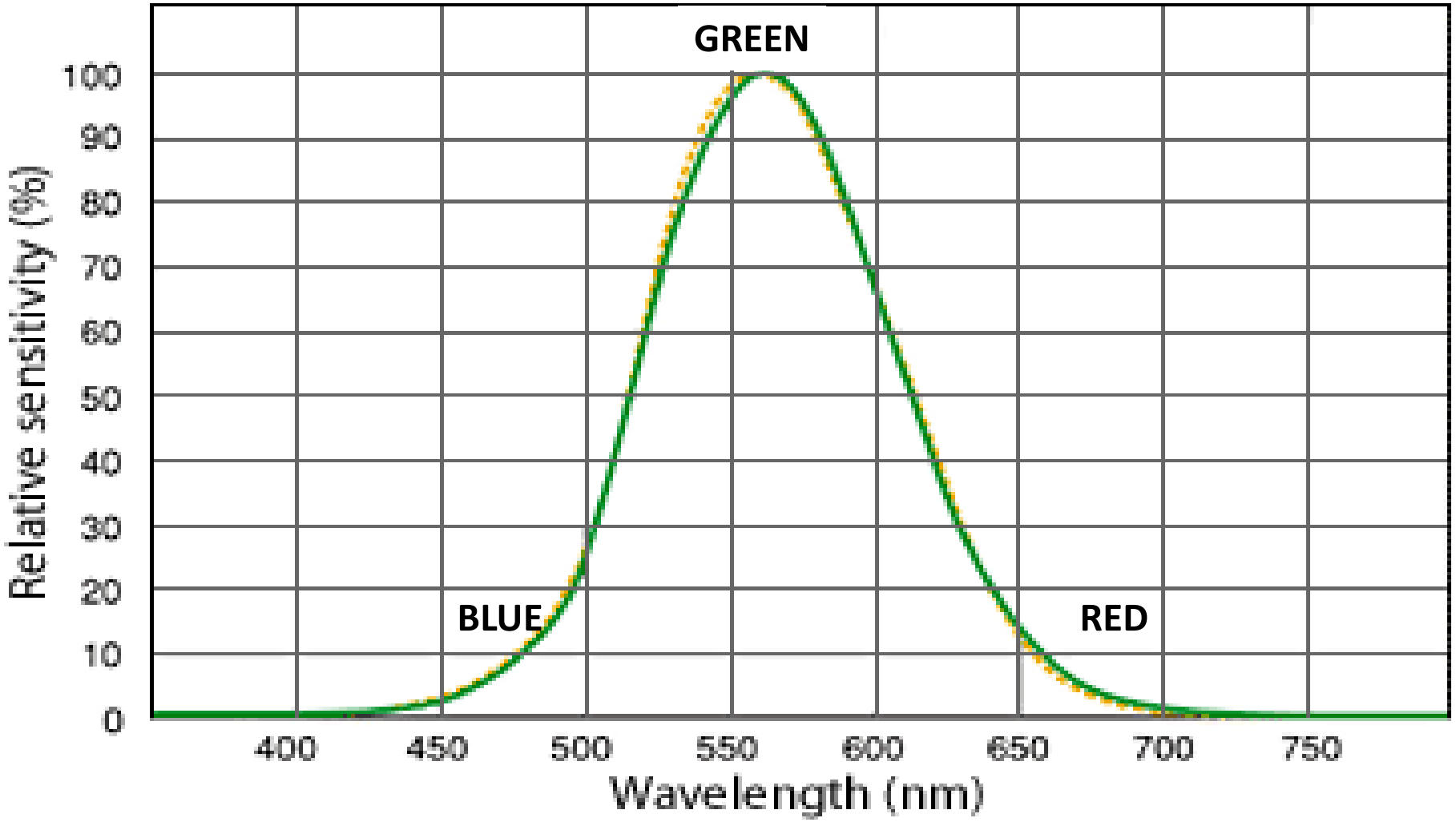
Better Pixels

Some "Light" Terminology

LUMINANCE

The luminous intensity of a light source in a given direction ***weighted*** by the spectral response of the human eye for photopic (i.e. color) vision. Measured in candela/meter squared (cd/m^2) conveniently called **"nits".**

Human Eye Spectral Response for Color Vision



Some more "Light" Nomenclature

BLACK LEVEL
Minimum scene Luminance
in nits

DIFFUSE WHITE
Scene reflective white
Luminance in nits.

HIGHLIGHTS
Specular reflections & light sources (e.g. sunlight, etc.)
Luminance
in nits

Luminance Levels

cd/m² or ***nits***

10^{9} 1.6 Billion

10^{8} 100 Million

10^{6} 1 Million

10^{4} 10,000

10^{2} 100

10^{0} 1

10^{-2} 0.01

10^{-4} 0.0001

10^{-6} 0.000001

0 *(abs. black)*

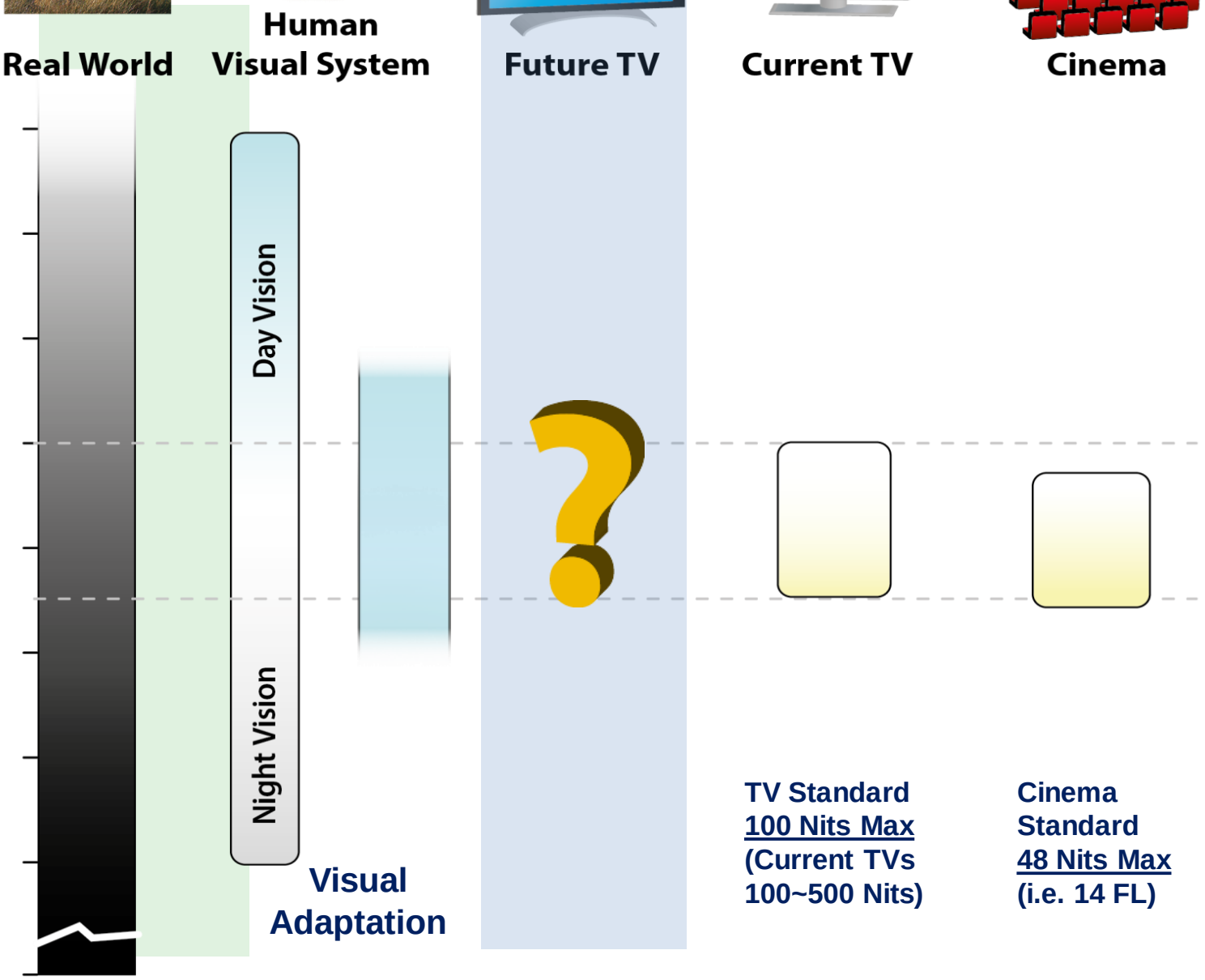
Real World

Human Visual System

Future TV

Current TV

Cinema



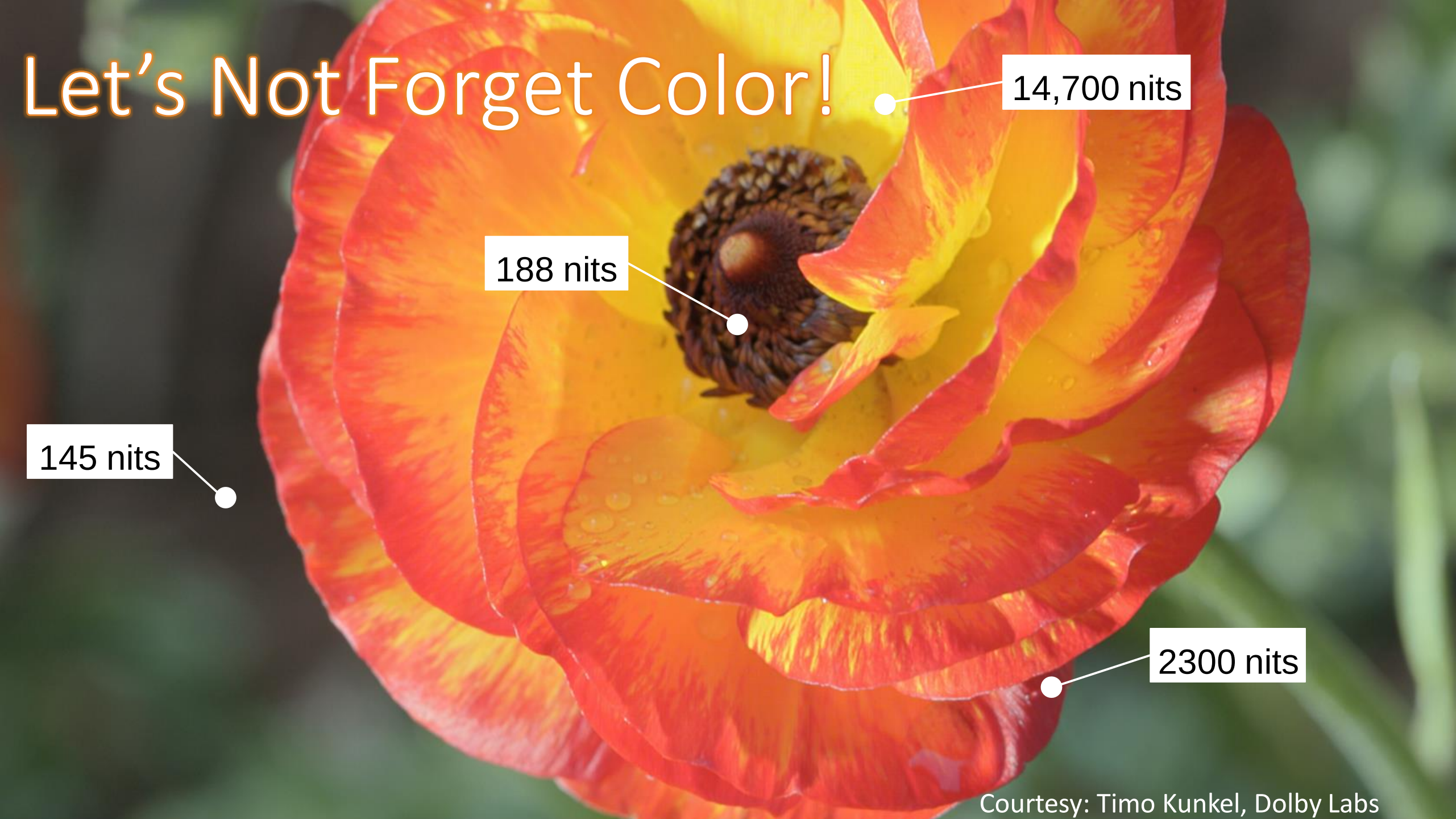
Visual Adaptation

TV Standard
100 Nits Max
(Current TVs 100~500 Nits)

Cinema Standard
48 Nits Max
(i.e. 14 FL)

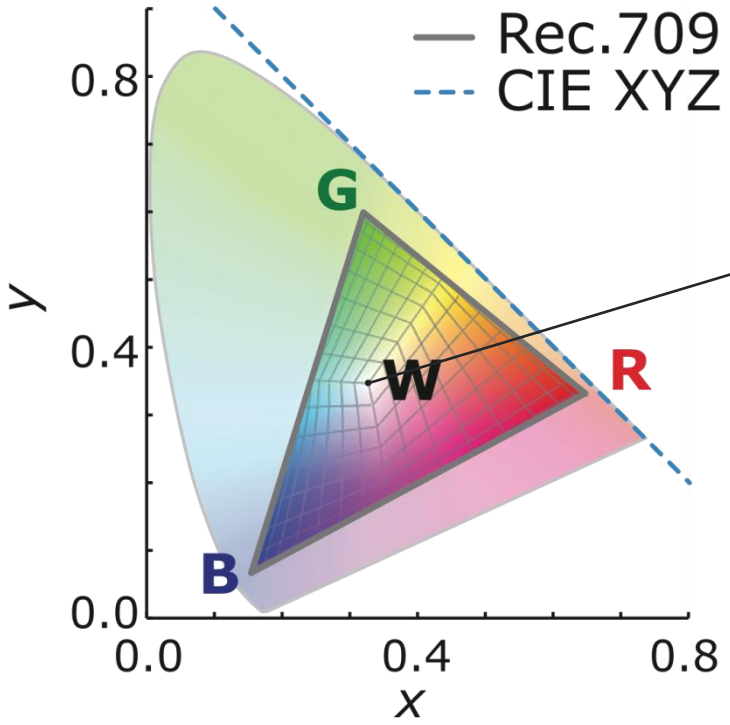
Real World Luminance Examples

Courtesy: Timo Kunkel, Dolby Labs

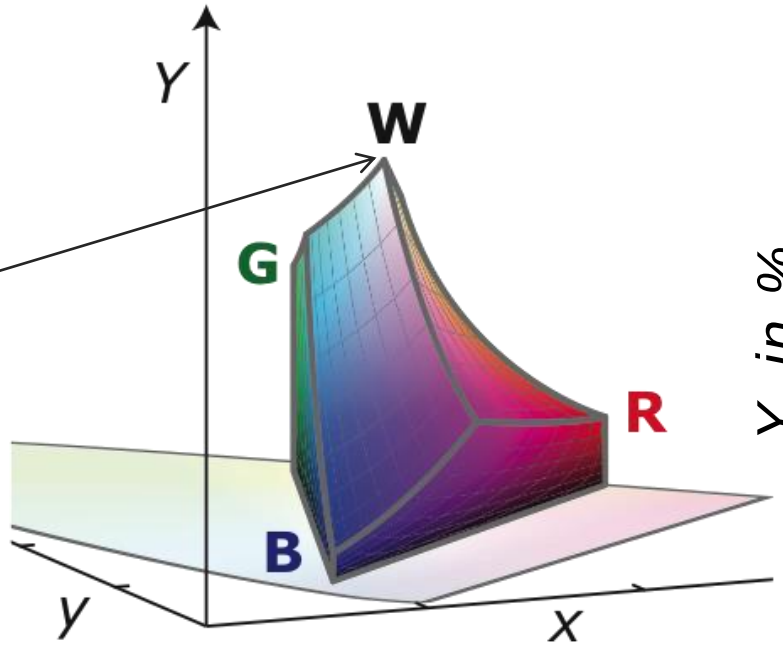

Let’s Not Forget Color!
14,700 nits
188 nits
145 nits
2300 nits
Courtesy: Timo Kunkel, Dolby Labs

What is a “Color Volume”?

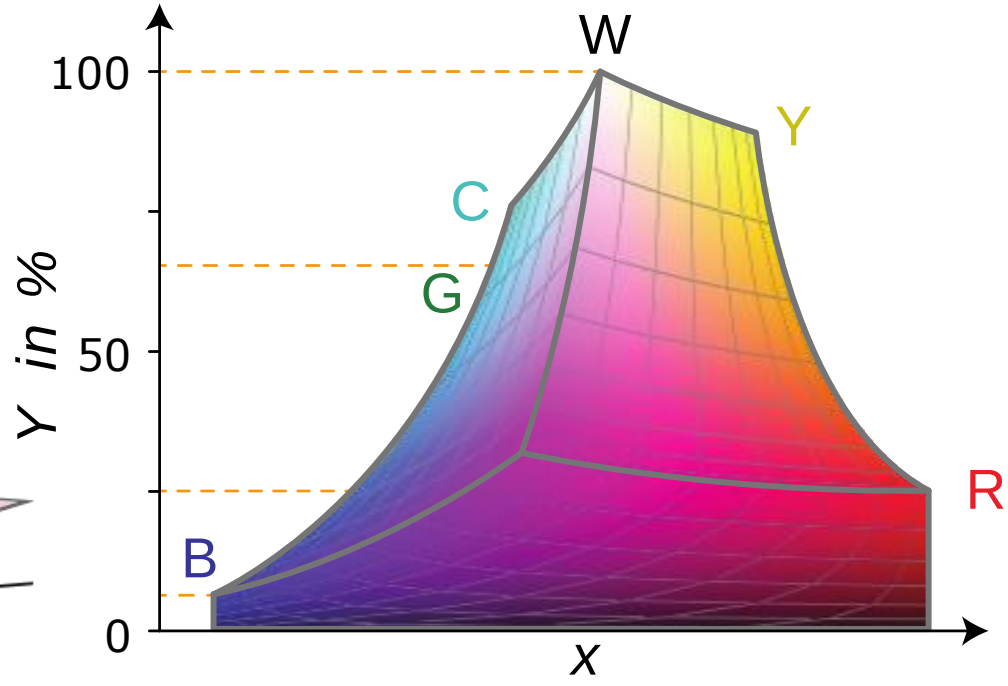
2D Chromaticity Diagram



3D **Color Volume**

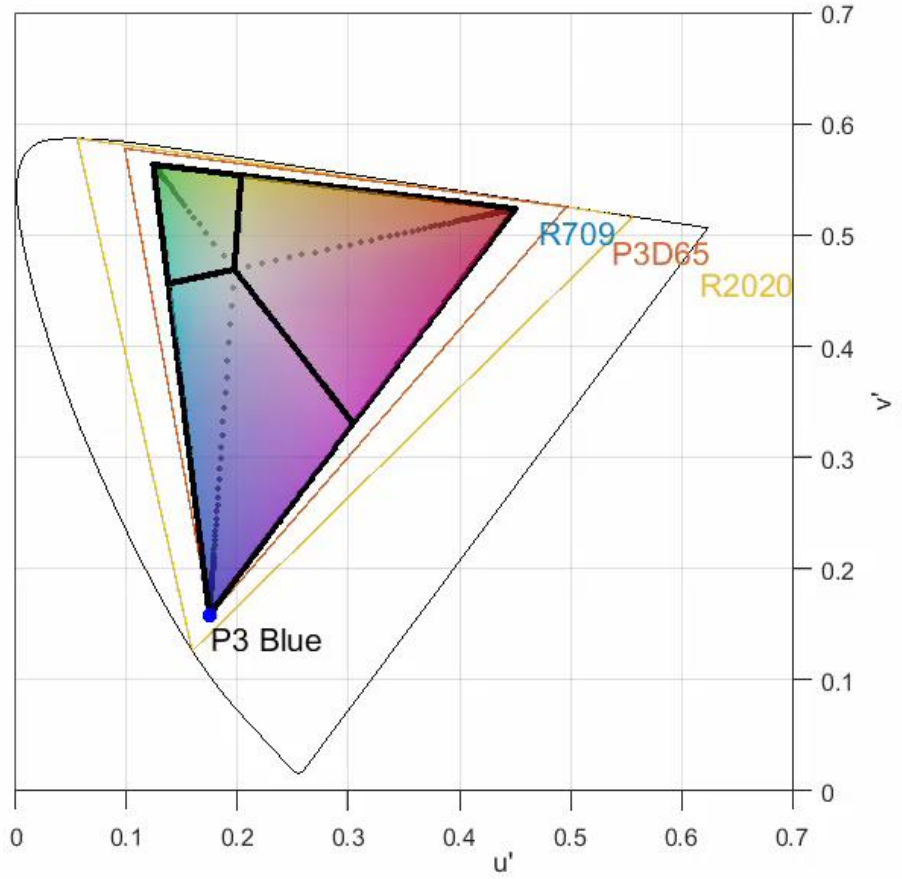


3D **Color Volume** (xY Viewpoint)



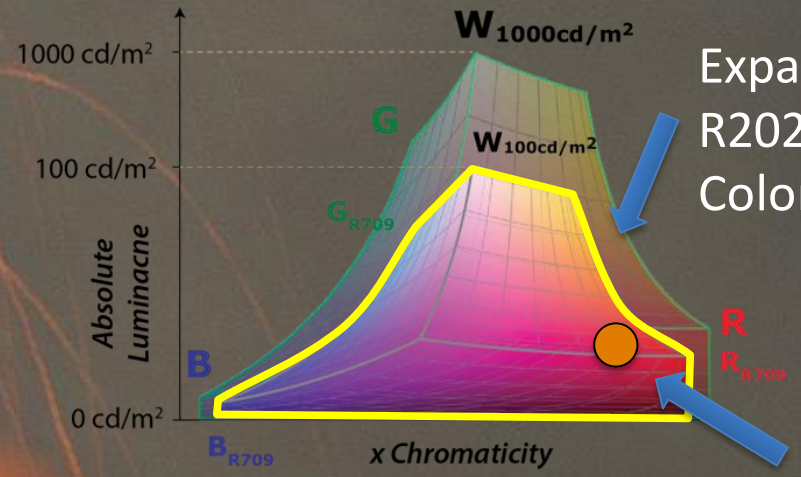
Courtesy: Timo Kunkel, Dolby Labs

What is a Color Volume?



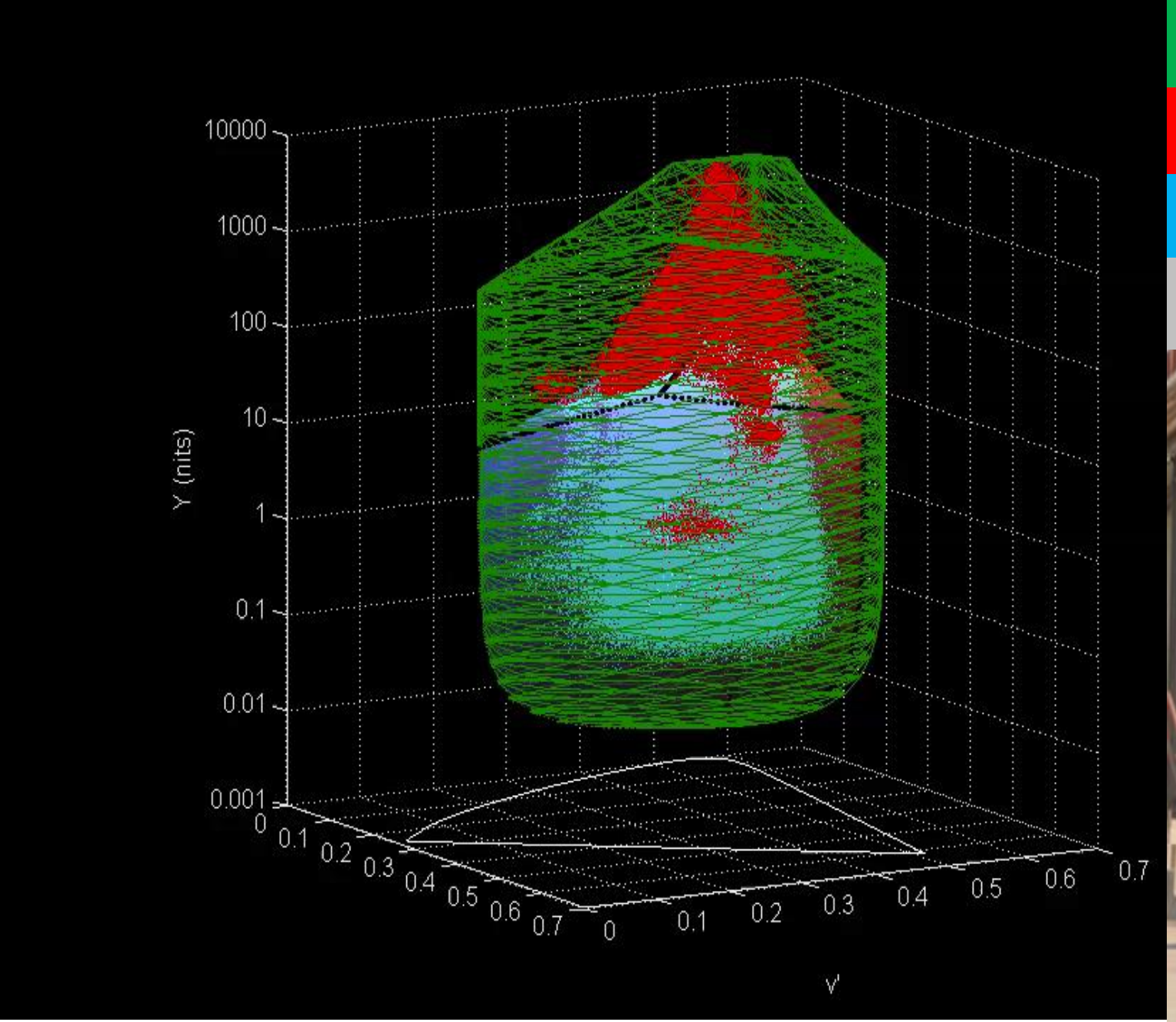
- **Color Volume**: The three dimensional palette of all available colors at all allowable intensities
  - More than just 2D color gamut
  - Need both color **and** its intensity to describe an image pixel appearance
- Bright colors need a bright peak white
  - P3 blue is only 8nits with 100nits peak white

Benefits of a Large Color Volume



Expanded to R2020/1000cd/m² Color Volume

Limited to R709/100cd/m² Color Volume



4000 Nit Color Volume

Pixels Outside SDR Color Volume

Pixels Inside SDR 100 Nit Color Volume

SDR Color Volume

Courtesy: Robins Atkins, Dolby Labs

Luminance Levels

cd/m² or *nits*

Sun Direct

10^{9} 1.6 Billion

10^{8} 100 Million

Sunlight

10^{6} 1 Mio

10^{4} 10,000

Indoor Lighting

10^{2} 100

10^{0} 1

Moon-light

10^{-2} 0.01

10^{-4} 0.0001

Starlight

10^{-6} 0.000001

0 *(abs. black)*

Real World

Human Visual System

Future TV

Current TV

Cinema

Day Vision

Night Vision

Entertainment Dynamic Range

0.005 to 10k nits satisfies 84% of viewers

How “Dark” is Black?

- Reference Video Today: ~0.1 Nit (cd/m^2)
- Reference Cinema (DCI Spec): 0.01 – 0.03 Nit
- Best consumer devices today: ~ 0.005 Nit
- “True Black” is an elusive target
  - 0.0001 Nit is **very** dark
    - Takes a minute or two to see this level after turning off lights
    - Still very dim looking even after full visual adaptation
  - ~0.00001– 0.000001 is the human visual system limit (cone threshold ~0.003)
  - With long enough adaptation time, you can see handfuls of photons!!
- To deal with any possibility, assume a minimum of zero nits.

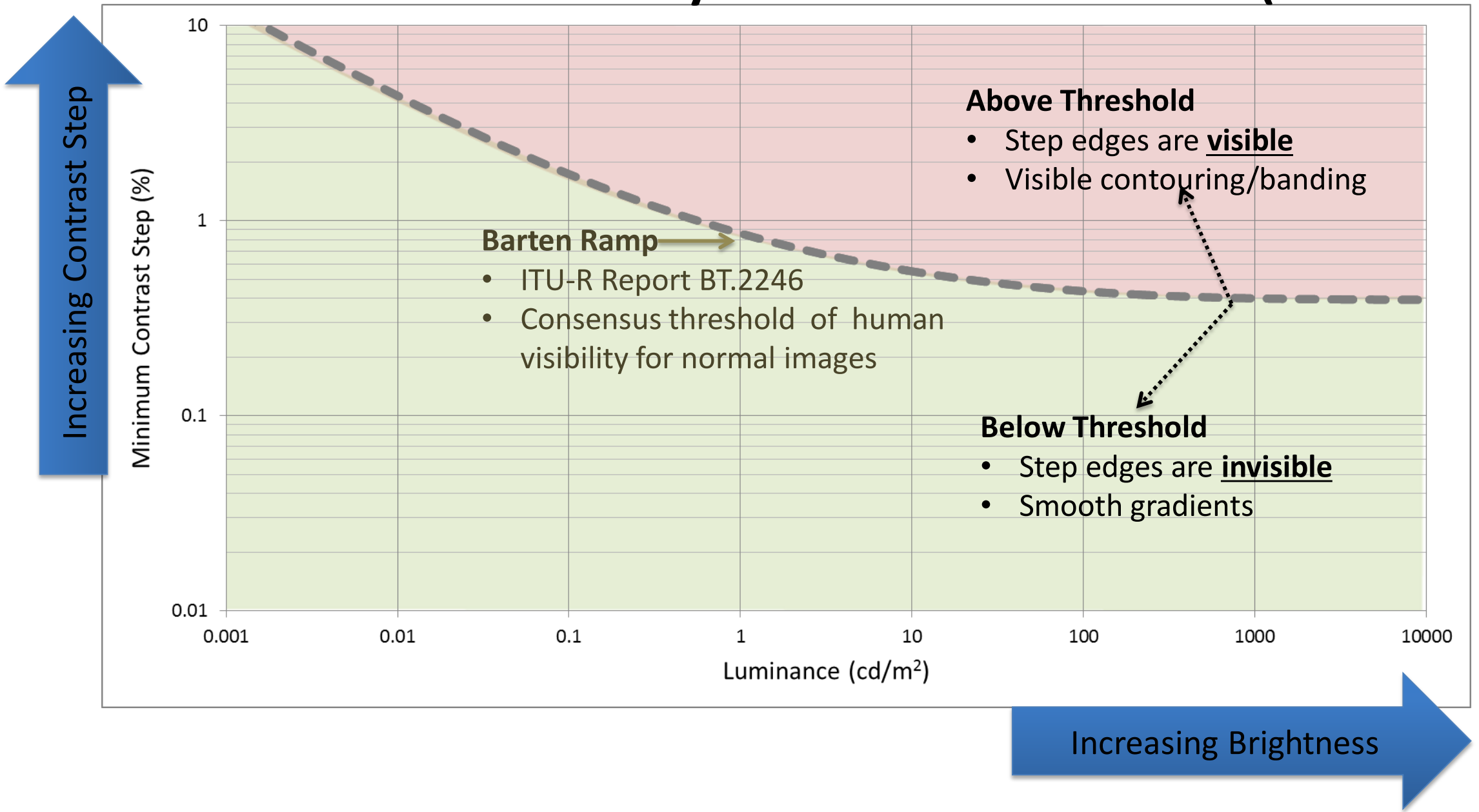
How “Bright” is White?

- Reference Video Today: 80 – 120 Nits
- Reference Cinema (DCI): 48 Nits (14 foot-lamberts)
- Brightest consumer devices today: ~ 1500 Nits
- Some commercial devices today: 4000 – 5000 Nits
- 10,000 nits is easy to get a look at & measure
  - Specular highlights are much brighter than this in the real world

Building a New EOTF: SMPTE ST-2084

- Current “Electro-Optic Transfer Function” (EOTF) standard (BT-1886) based on “gamma” is typically used in a range of .1 to 100 nits.
- Instead use 0 to 10,000 nits dynamic range (84% of Viewers) as a design goal to better cover preferences & provide future headroom
- Assume practical system will need to be 10-12 bits for sufficient precision due to current infrastructure and silicon constraints
- Use Human Visual System (HVS) model based on Barten’s work which models human contrast sensitivity to determine performance
- A new SMPTE standard ST-2084 aka “Perceptual Quantizer” (PQ) based these criteria is now being deployed in products and services.

Contrast Sensitivity vs. Luminance (Barten)

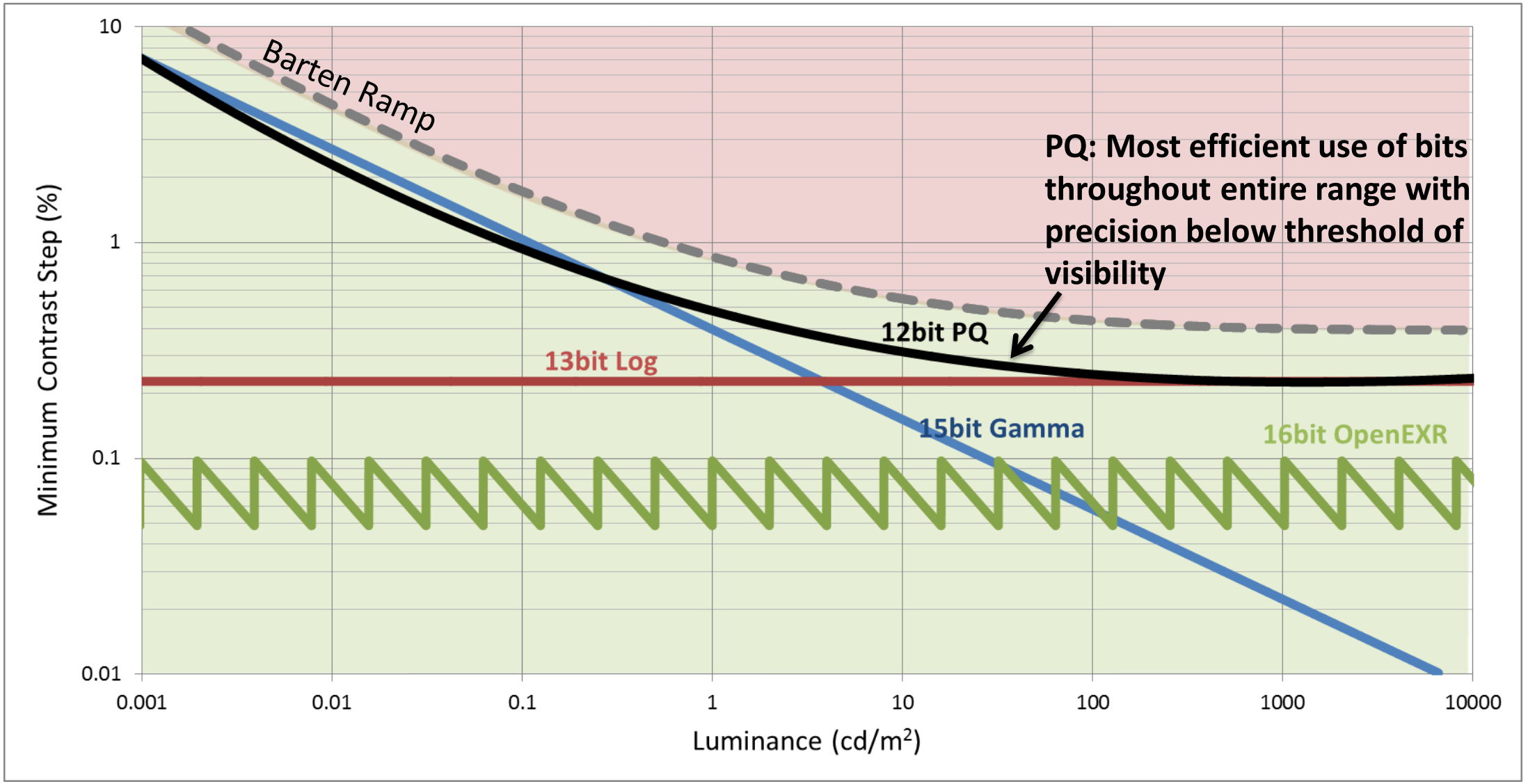


Visually Observable Levels per F-Stop (Barten)

1 Stop Luminance Range	# of Visible Levels
8192 – 4096 cd/m^2	276
4096 – 2048 cd/m^2	275
2048 – 1024 cd/m^2	274
1024 – 512 cd/m^2	271
512 – 256 cd/m^2	266
256 – 128 cd/m^2	260
128 – 64 cd/m^2	251
64 – 32 cd/m^2	238
32 – 16 cd/m^2	224
16 – 8 cd/m^2	206
8 – 4 cd/m^2	186
4 – 2 cd/m^2	165

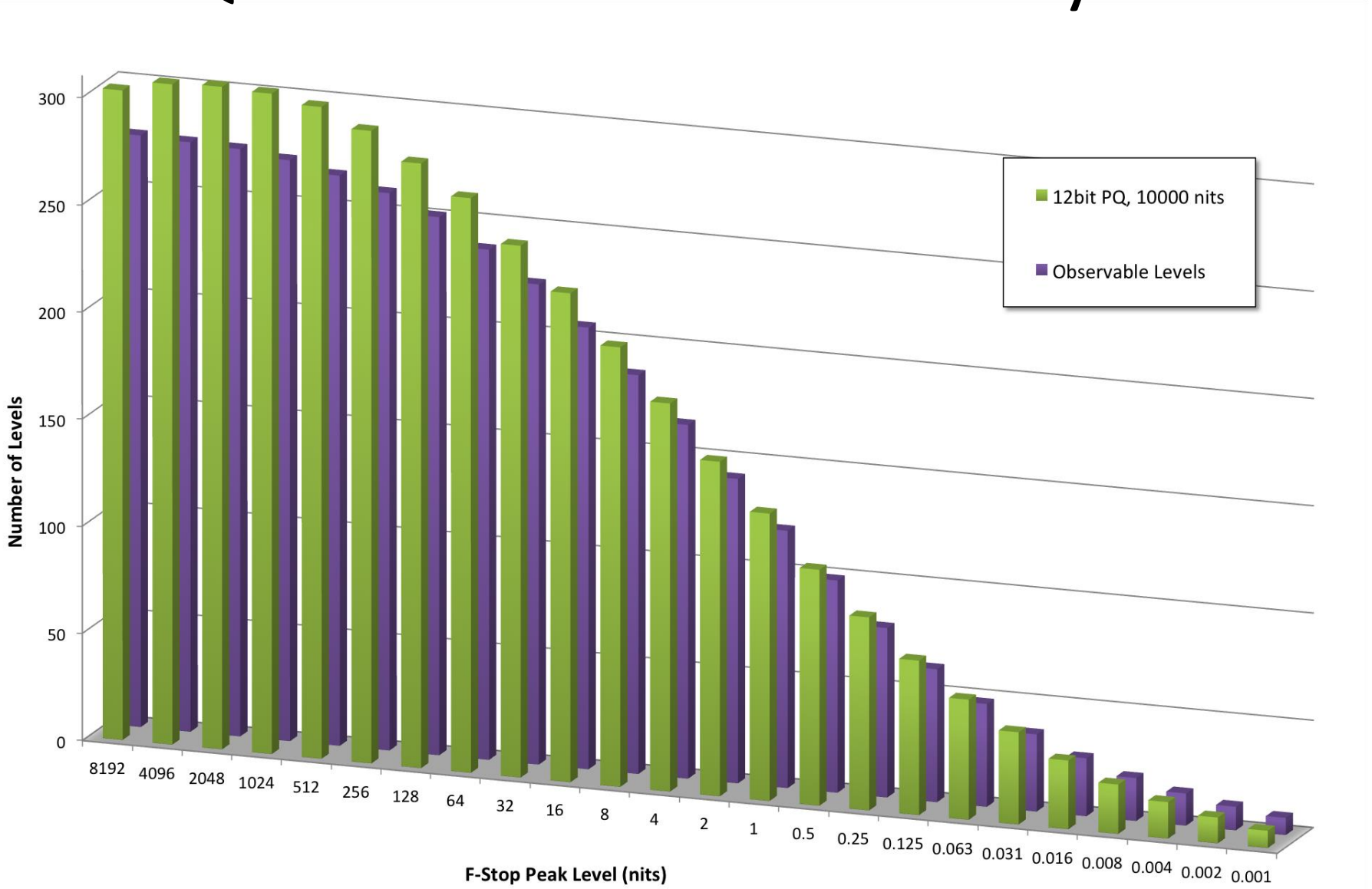
1 Stop Luminance Range	# of Visible Levels
2 – 1 cd/m^2	142
1 – 1/2 cd/m^2	120
1/2 – 1/4 cd/m^2	99
1/4 – 1/8 cd/m^2	79
1/8 – 1/16 cd/m^2	62
1/16 – 1/32 cd/m^2	48
1/32 – 1/64 cd/m^2	36
1/64 – 1/128 cd/m^2	27
1/128 – 1/256 cd/m^2	20
1/256 – 1/512 cd/m^2	15
1/512 – 1/1024 cd/m^2	11
1/1024 – 1/2048 cd/m^2	8

SMPTE ST-2084: “Perceptual Quantizer”(PQ)



Courtesy: Scott Miller, Dolby Labs

12 Bit PQ – Puts Levels Where They are Needed



Smarter Pixels

Color Volume & Pixels

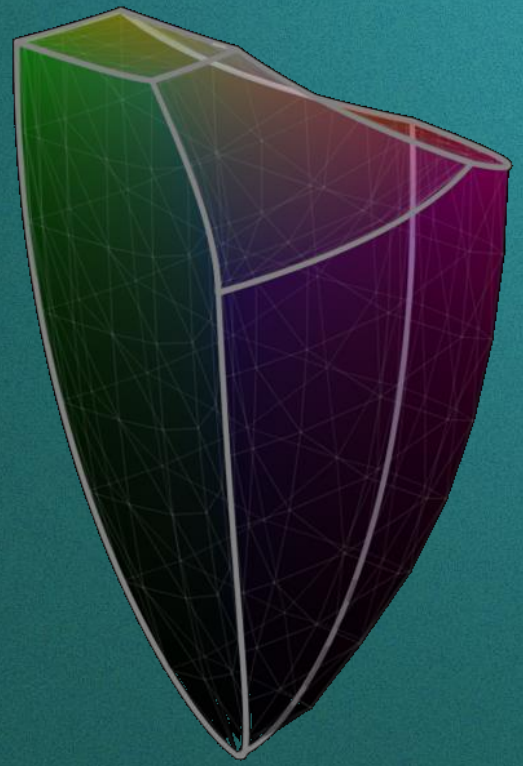
The Image's *Color Volume*

The pixels that comprise the HDR image change location on a frame by frame basis

An HDR Image

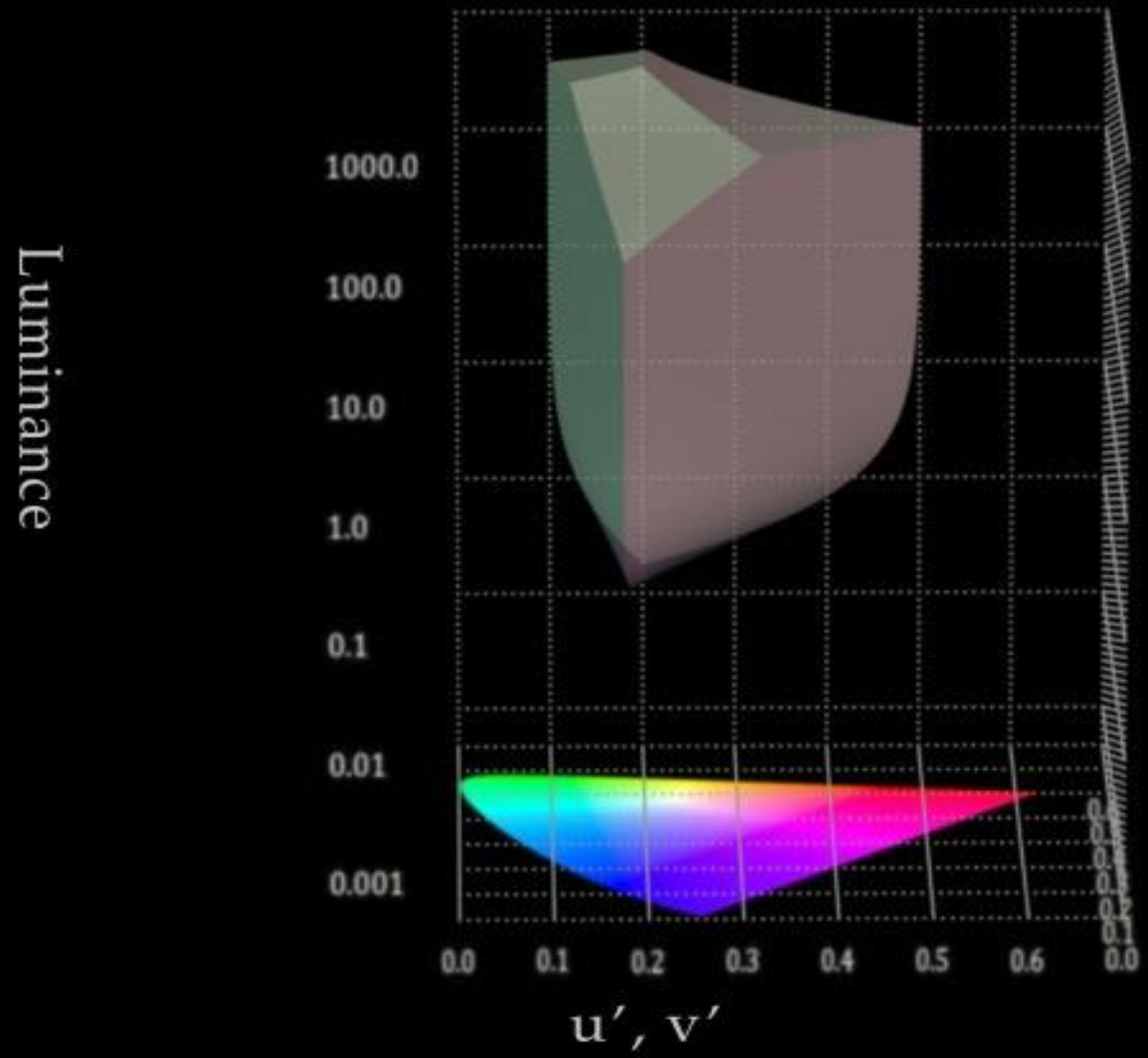
Color Volume Mapping

- “HDR” target displays have different Color Volumes (TV’s, Tablets, Mobile Phones, etc.)
- Use Color Volume Mapping to map content into the target display color volume
  - » Color Volume Mapping considers both Tone Mapping (intensity) and Gamut Mapping (color)
- Note: Color Volume mapping is also required for 4K Rec 2020 to HD Rec 709 conversion independent of HDR



Consumer

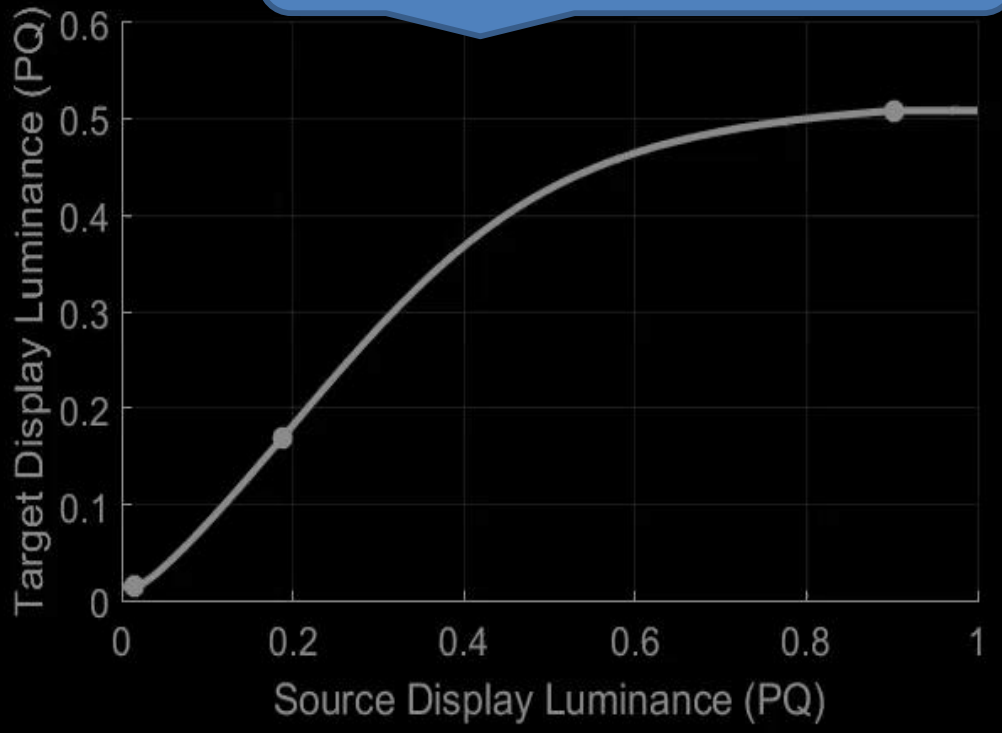
Comparative Color Volumes: UHD Alliance



LCD
Max Brightness: 1000 nits
Black Level: 0.05 nits

Tone Curve vs Image Priority

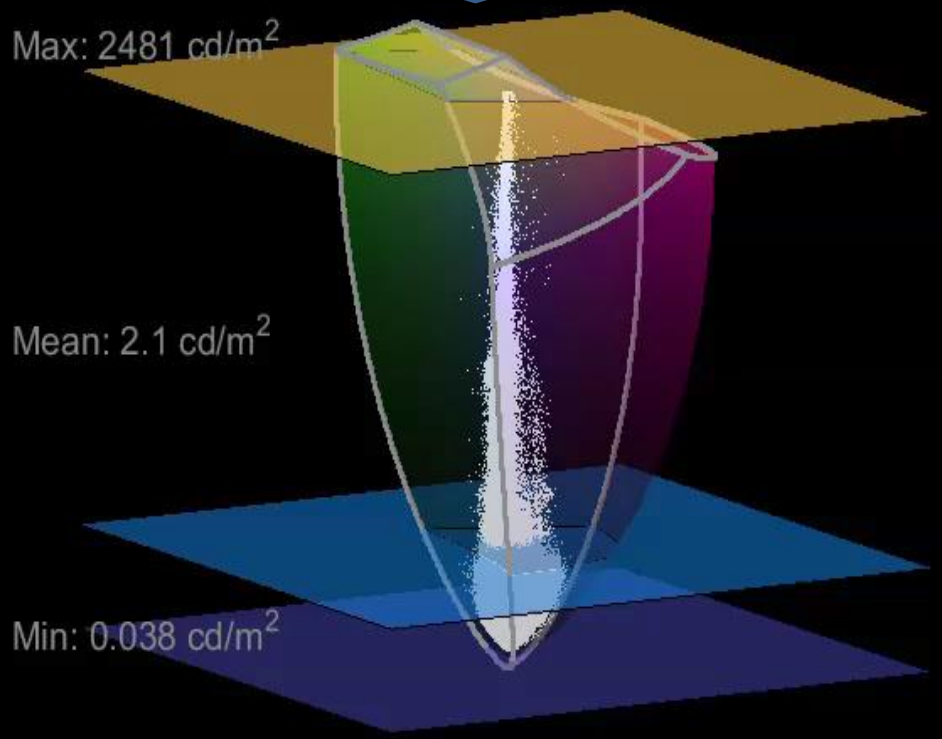
Resulting Tone Curve
Dots show min, mean, & max



Region of the image to prioritize

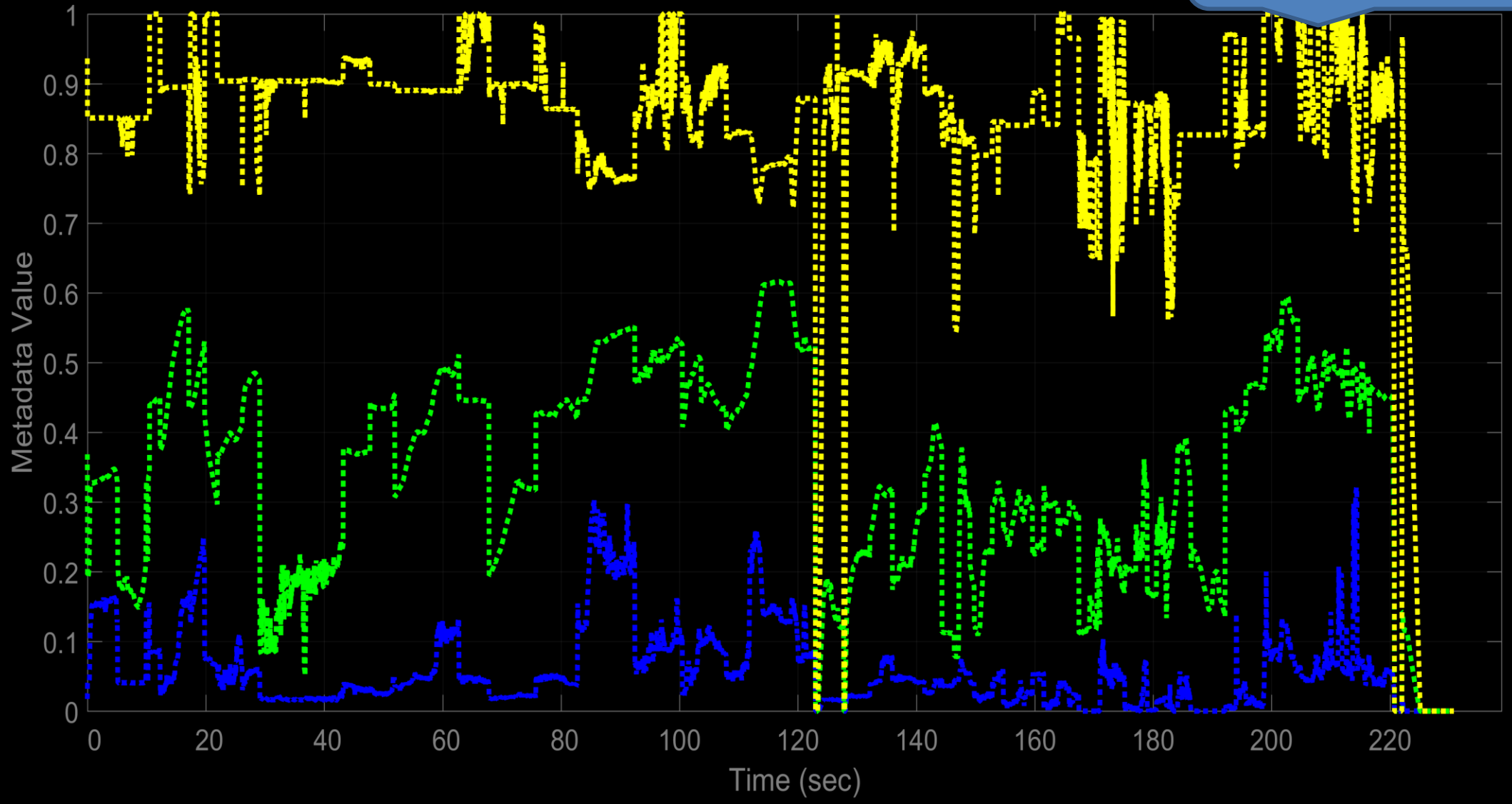
Image Metadata: Min, Mean, Max

Per-Frame Metadata
The minimum, mean, and maximum brightness of the image

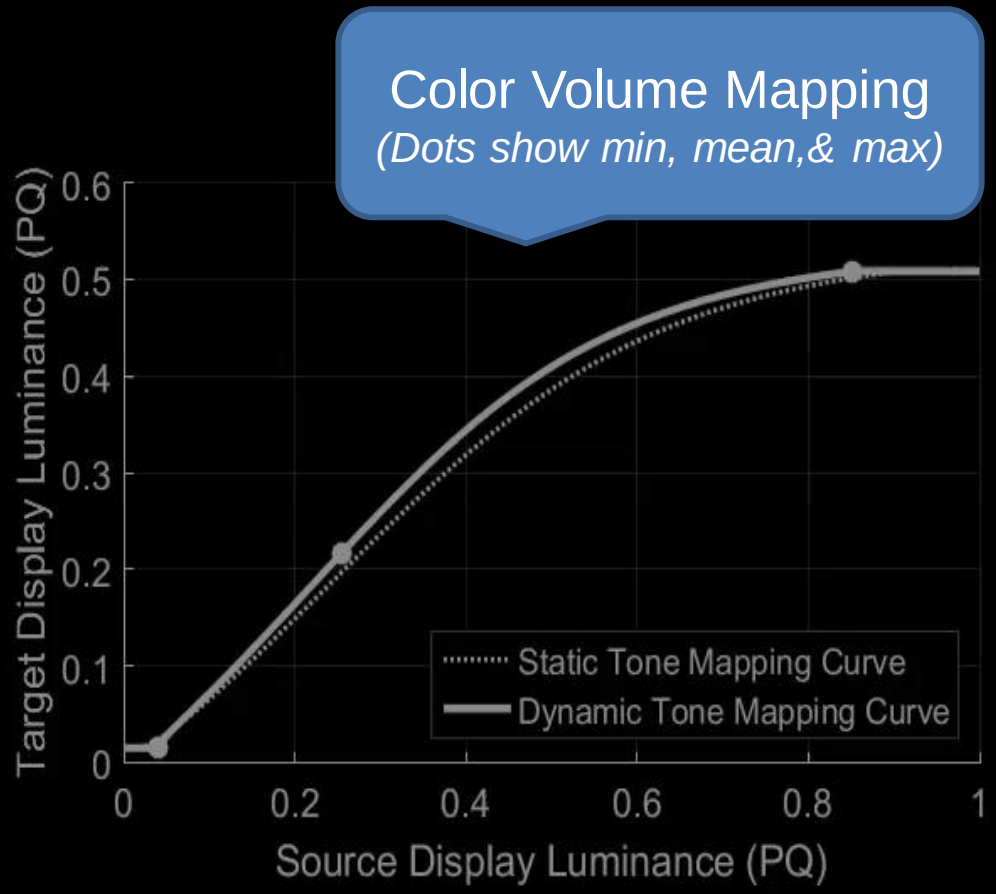


Per Frame: Min, Mean, Max

Per-Frame Metadata
Very dynamic



Color Volume Mapping: Consumer Display



Metadata Makes Pixels “Smarter”

- Static Metadata (SMPTE ST-2086)
  - Constant for the entire set of data (ie movies, commercial, etc.)
  - Use to describe the content representation, such as primaries, EOTF, mastering display color volume, etc.
  - Everything you need to calculate how it was presented to the content producer
- Dynamic Metadata (SMPTE ST-2094)
  - Used to describe the content, such as minimum, mean, maximum brightness
  - Tracks changes on a per-frame or per-scene basis
  - Reduces or eliminates the need to analyze the content at a display
    - Better quality
    - Less latency
    - Less processing power
  - Allows temporal stability when desired

Take Aways: Nits, Bits, and Bucks ($)

- The next generation entertainment image experience will be mix of more, faster, and better pixels **ALL** requiring more bits.

Take Aways: Nits, Bits, and Bucks ($)

	Raw Data Rate Increase Factor	Human Visual System Acuity
Resolution: HD → 4K	400%	LOW
Frame Rate: 24 fps → 48 fps	200%	MEDIUM HIGH
Color Volume: Rec 709 →Rec 2020	125% (8→10 bits)	MEDIUM LOW
Dynamic Range: 100 nits →10,000	125% (8→10 bits)	HIGH

Source: Warner Brothers, 2013

Take Aways: Nits, Bits, and Bucks ($)

- The next generation entertainment image experience will be mix of more, faster, and better pixels **ALL** requiring more bits.
- The choice of which mix will depend on application, bit budgets, and delivery methods.
- New approaches for light output curve (EOTF) will add to the options for finding the best “bang for the bit”.
- Metadata can make pixels smarter to enhance reproduction quality and consistency across consumer displays

Thank You!