Production Technology Experts

UHD & HDR
Overview for SMPTE Montreal

Jeff Moore
Executive Vice President
Ross Video

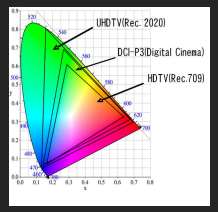
Troy English
Chief Technology Officer
Ross Video

ROSS
Production Technology Experts

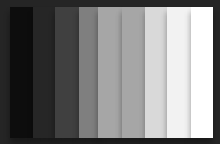
UHD – Ultra High Definition

Resolution

HFR – High Frame Rate



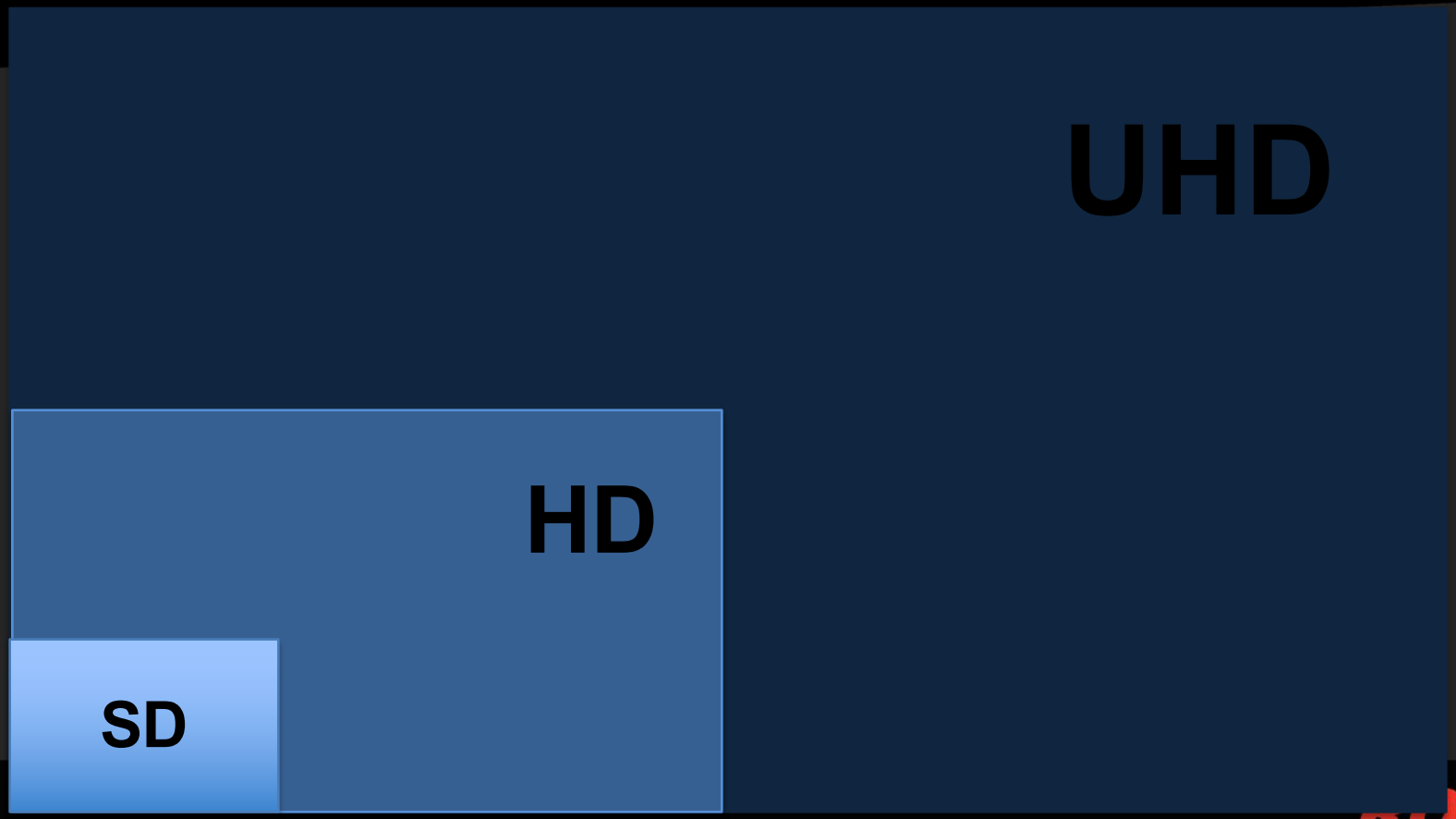
WCG – Wide Gamut Color



HDR – High Dynamic Range

ROSS
Production Technology Experts

UHD – Resolution



ROSS
Production Technology Experts

UHD – Resolution

Spatial Resolution

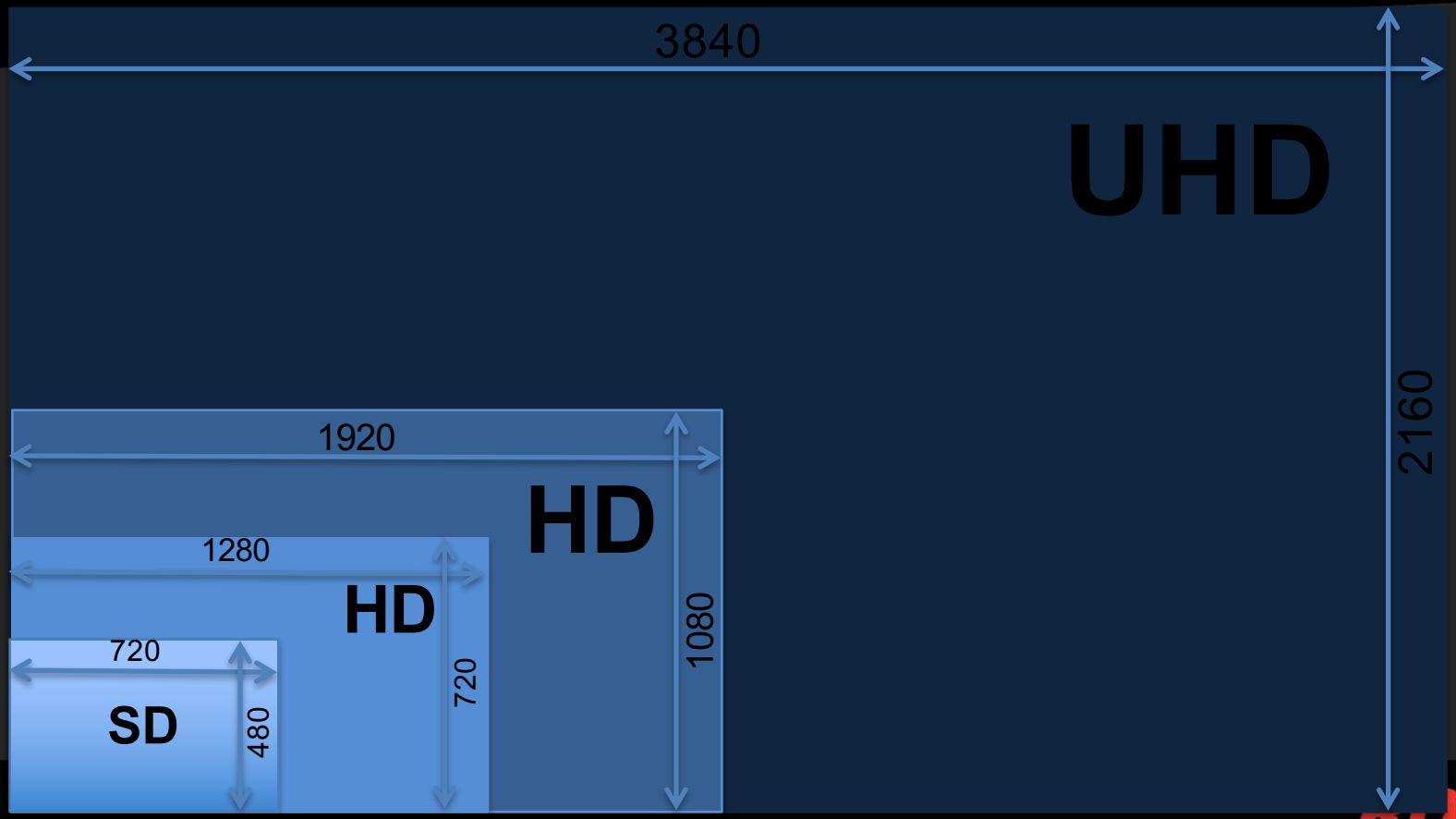
is the number of pixels in a frame of video.

Temporal Resolution

is the frames per second of video.

ROSS
Production Technology Experts

UHD – Spatial Resolution



ROSS
Production Technology Experts

Visual Acuity, Screen Size, Resolution & Viewing Distance

Resolution

More pixels are better, but at what distance?

Visual Acuity

With 20/20 Vision the average human can resolve 1/60 of a degree of arc.

Viewing Distance

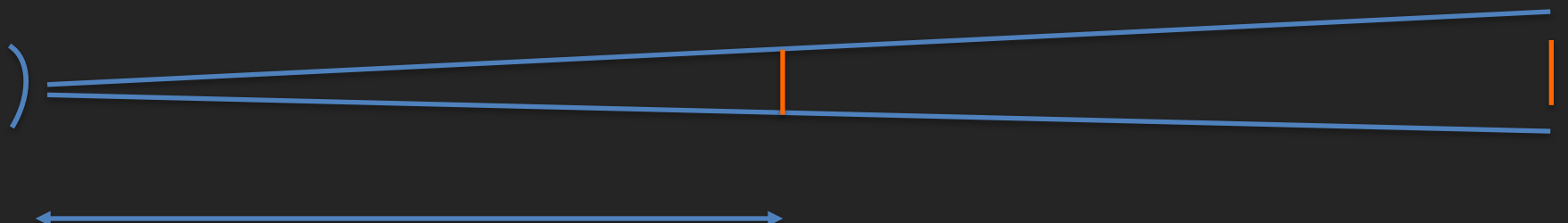
Closer to the screen, one can resolve more detail, further away less.

Screen Size

What is the appropriate screen size given a certain resolution and viewing distance?

ROSS
Production Technology Experts

Resolution Limits of the Human Eye



D1 – just able to resolve the width of the orange spot (pixel).

D2 – too far away to resolve the detail the pixel provides.

ROSS
Production Technology Experts

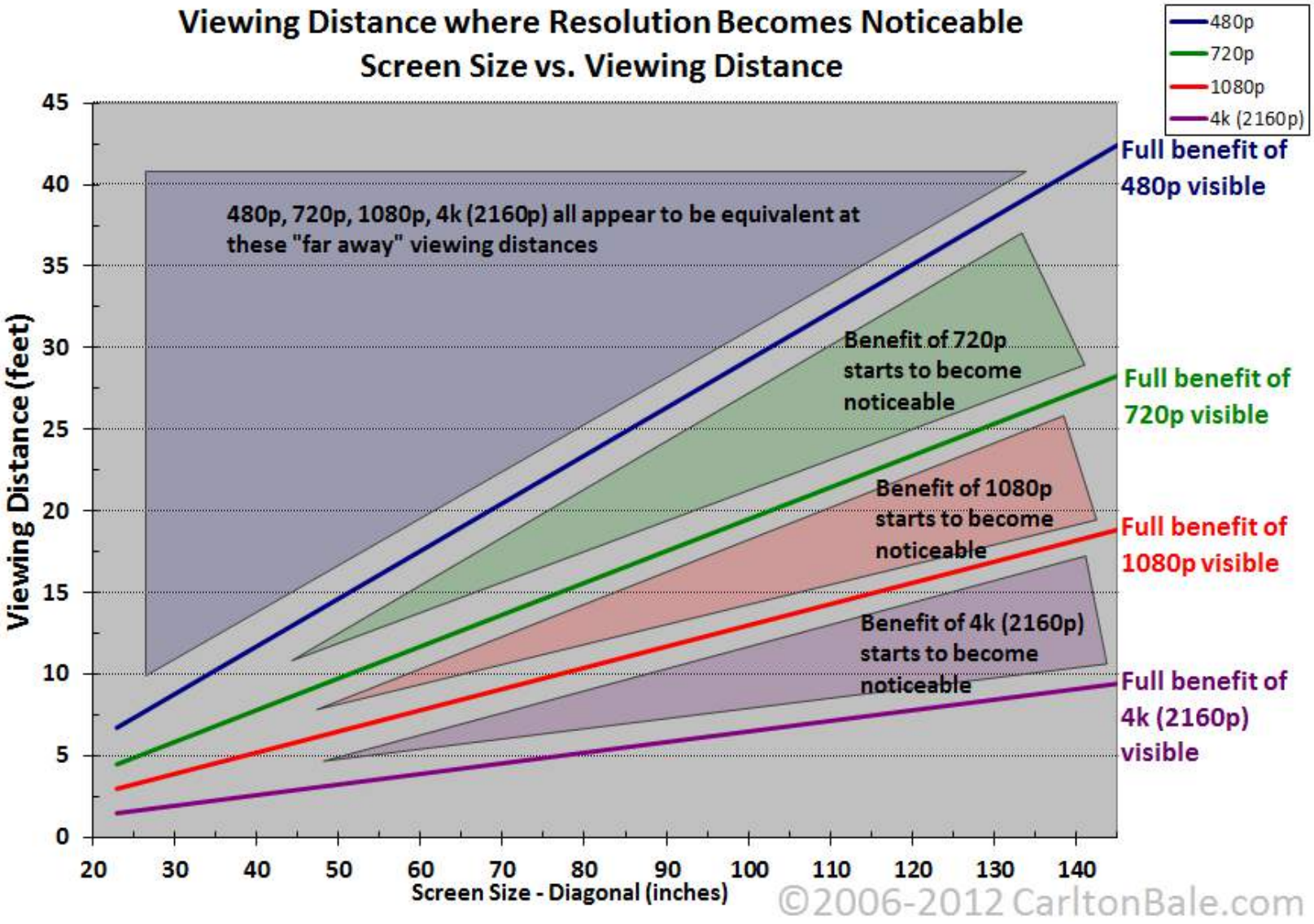
Bernard Lechner

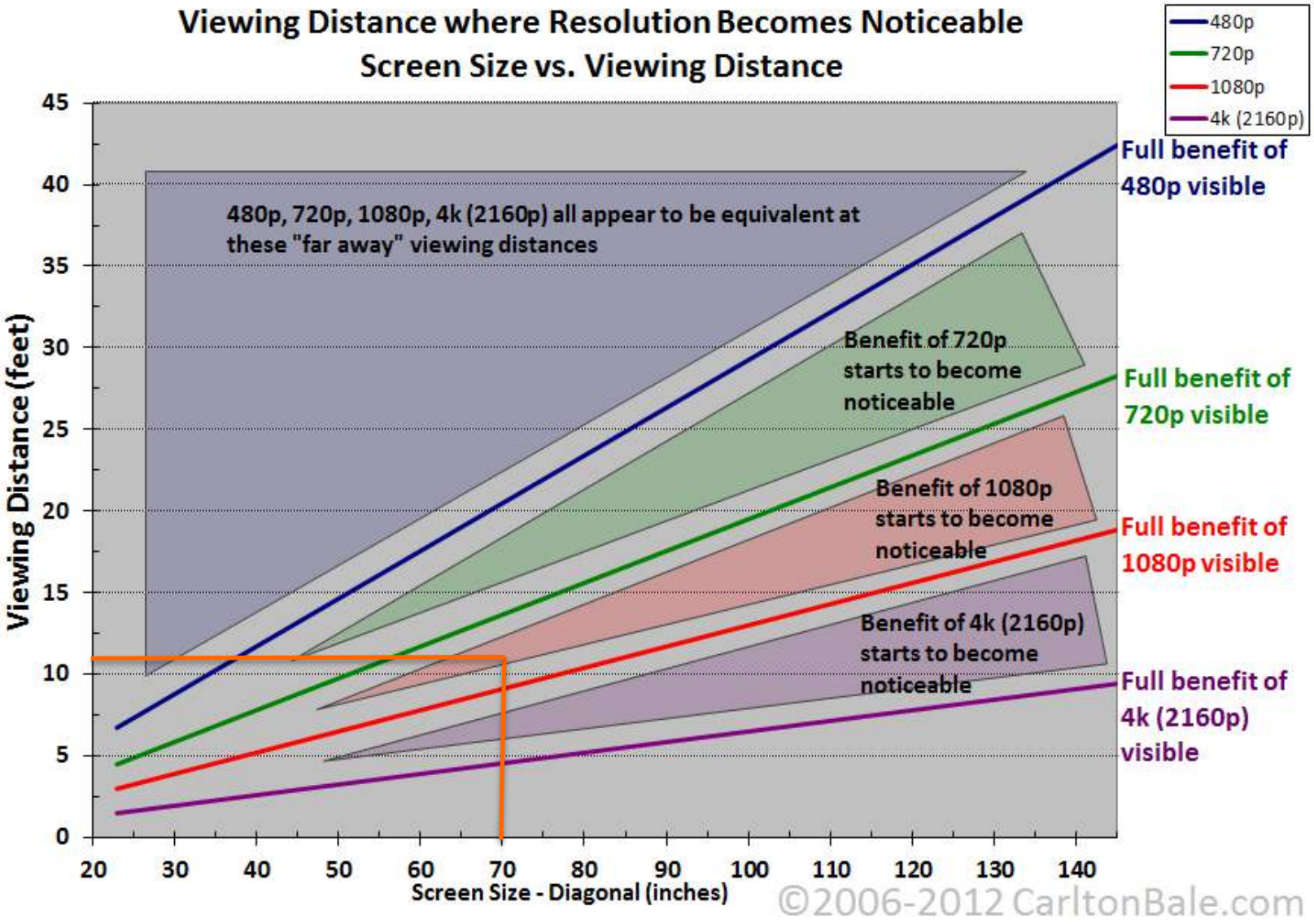
The Lechner Distance

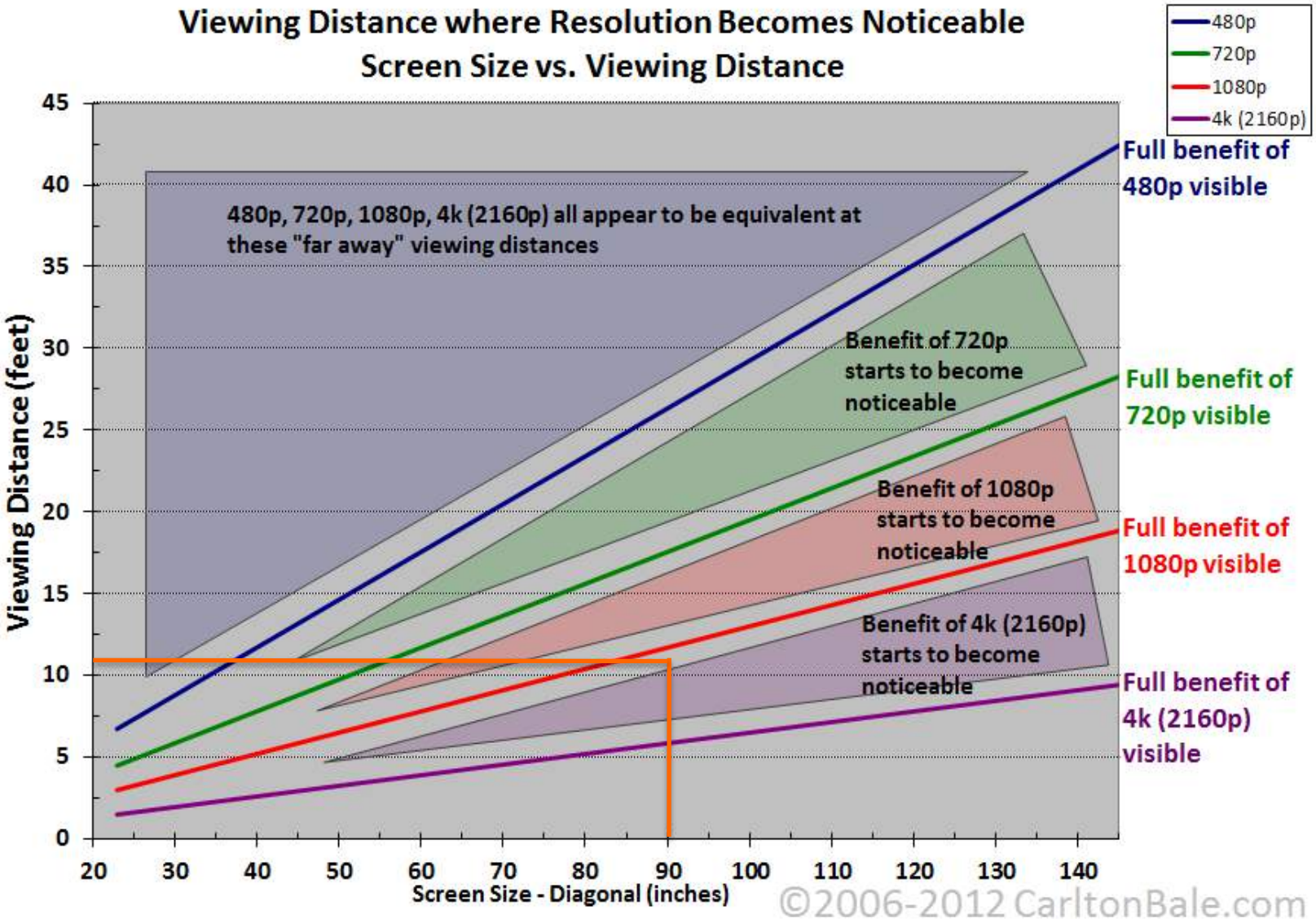
The Lechner Distance chart illustrates the optimal viewing distances at which the human eye can best process the details a specific TV resolution has to offer.

For example, the optimal viewing distance for a 42inch (110cm) Full HD TV (1080p) is 5.5 feet (170 cm).

ROSS
Production Technology Experts


Viewing Distance where Resolution Becomes Noticeable
Screen Size vs. Viewing Distance
480p
720p
1080p
4k (2160p)
480p, 720p, 1080p, 4k (2160p) all appear to be equivalent at these "far away" viewing distances
Benefit of 720p starts to become noticeable
Benefit of 1080p starts to become noticeable
Benefit of 4k (2160p) starts to become noticeable
Full benefit of 480p visible
Full benefit of 720p visible
Full benefit of 1080p visible
Full benefit of 4k (2160p) visible
Viewing Distance (feet)
0
5
10
15
20
25
30
35
40
45
20
30
40
50
60
70
80
90
100
110
120
130
140
Screen Size - Diagonal (inches)
©2006-2012 CarltonBale.com





Resolution

ROSS
Production Technology Experts

Resolution

ROSS
Production Technology Experts

Resolution

ROSS
Production Technology Experts


ROMA F3
3275


ROMA F3
3275

Today's Television Frame Rates

720P 50 / 60 FPS

1080i
25/30 FPS (50/60 fields per second)

ROSS
Production Technology Experts

Television Frame Rates

720P 50/60 FPS
1.5 Gb/s

1080i
25/30 FPS (60 fields per second)
1.5 Gb/s

1080P 50/60 FPS
3Gb/s

UHD
50/60 FPS
12 Gb/s

UHD
120 FPS
(future)
24 Gb/s

ROSS
Production Technology Experts

Television Frame Rates

720P 50/60 FPS
1.5 Gb/s

1080i
25/30 FPS (60 fields per second)
1.5 Gb/s

1080P 50/60 FPS
3 Gb/s

UHD
50/60 FPS
12 Gb/s

UHD
120 FPS
(future)
24 Gb/s

HFR

ROSS
Production Technology Experts

HFR = Increased Temporal Resolution

Higher frame rates result in less motion blur and higher apparent resolution.

Demo at: https://frames-per-second.appspot.com

What's the cost? Doubling the frame rate in a compressed signal results in roughly 50% more bits per second to be transmitted.

ROSS
Production Technology Experts

Naming Conventions – All over the map

1080i59.94: Number is vertical pixels followed by FIELD rate

720p50: Number is vertical pixels followed by FRAME rate

1080i29.97: Number is vertical pixels followed by FRAME rate**

How do you know Frame vs Field? You just have to.

3G: Typical way to talk about 1080p50/59.94

Number is now the DATA rate in Gb/s

4K: Typical way to talk about 2160p50/59.94

Number is now the horizontal number of pixels…

(and of course we don't actually have 4096, we have 3840)

UHD: Umbrella term though, often means many different things

Really just means better than HD, how? Who knows.

8K: Common way to talk about 4320p50/59.94

Number is again the horizontal number of pixels

WQHD: Computer format. 4x720p

So, 2560x1440 pixels

ROSS

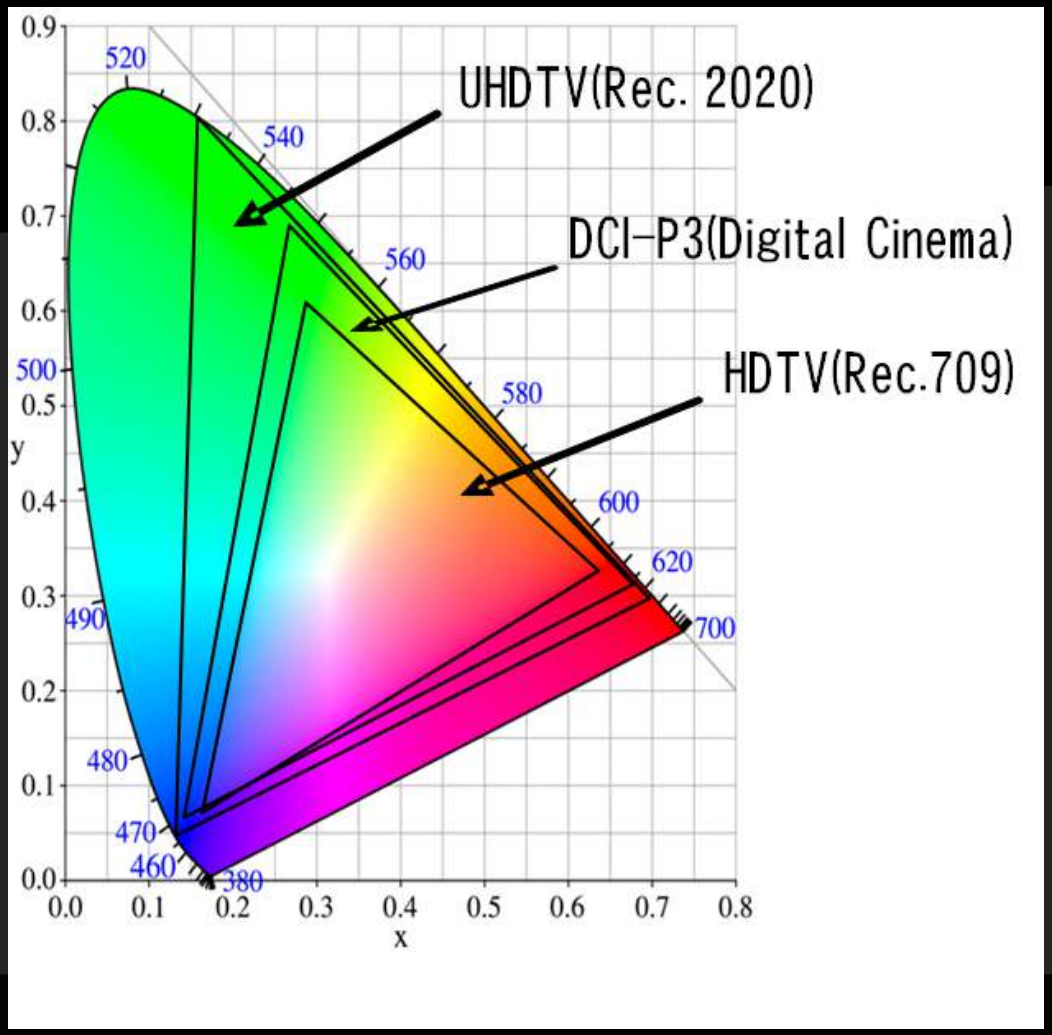
Production Technology Experts

UHD – Wide Color Gamut

Color Gamut

is the range of colors available on a particular device or within a system.

ROSS
Production Technology Experts



Color Gamut Comparison

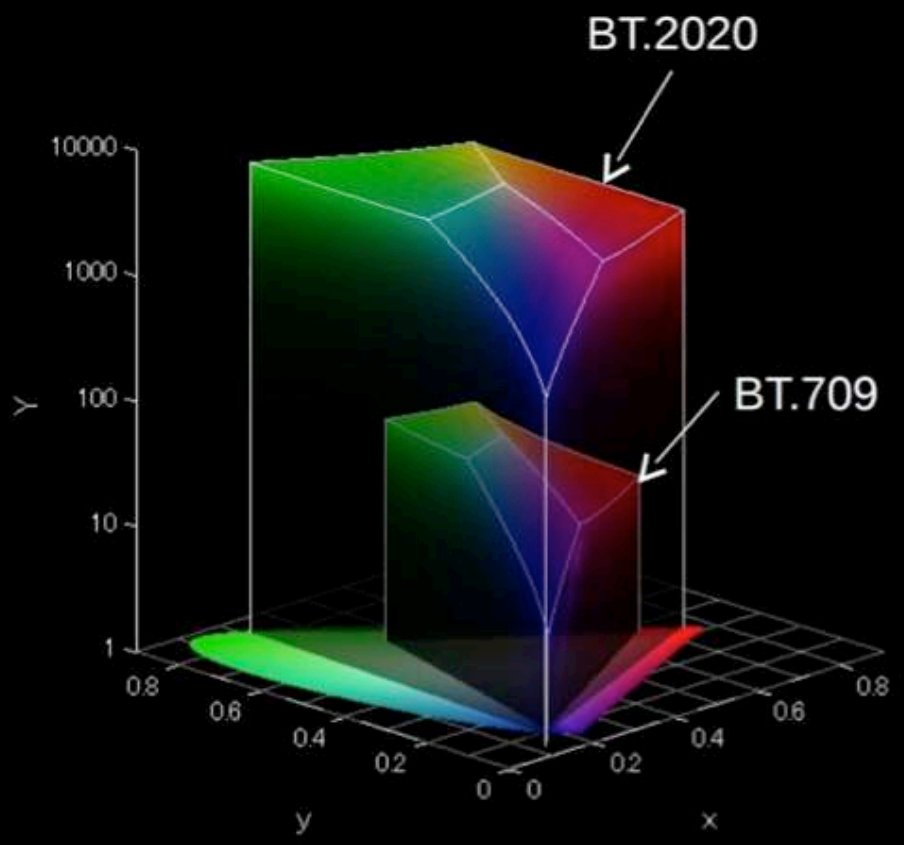
UHD – BT.2020

(also used in 8K)

Digital Cinema – P3

HD – Rec.709

ROSS
Production Technology Experts



UHD – BT.2020

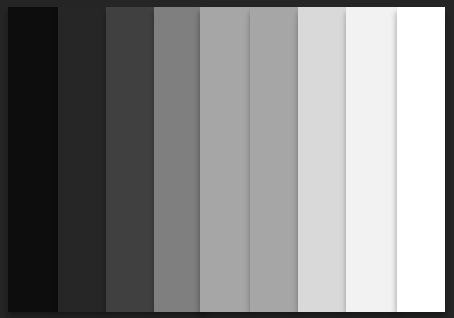
(also used in 8K)

Digital Cinema – P3

HD – Rec.709

ROSS
Production Technology Experts


Wide Color Gamut
local dimming
TCL
Normal
TCL



HDR – High Dynamic Range

ROSS
Production Technology Experts

What HDR Isn’t

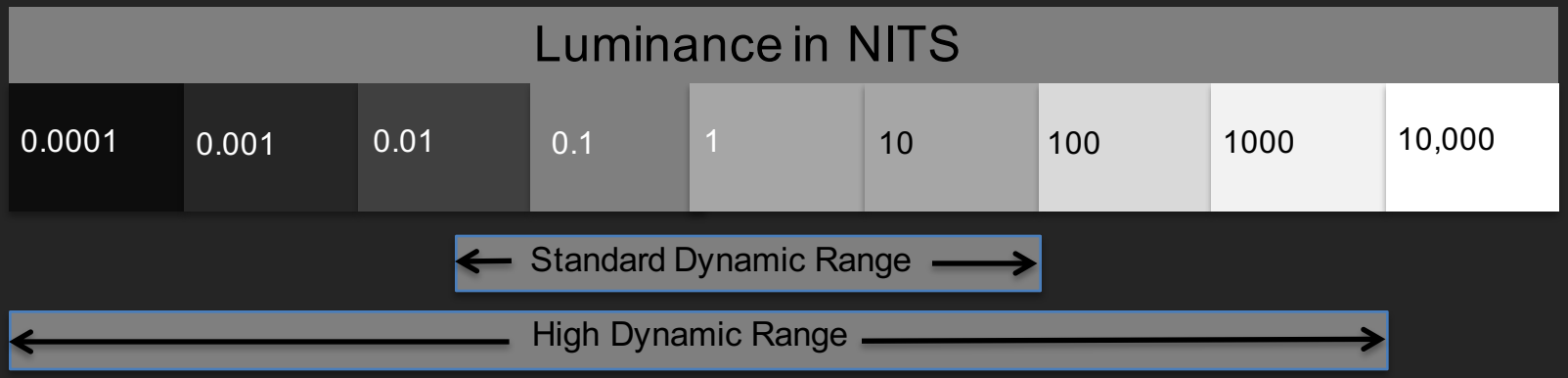
~~Multiple exposures on your iPhone.~~

ROSS
Production Technology Experts

Dynamic Range

Dynamic Range is the range of dark to light in an image or system.

High Dynamic Range has a wider range of dark to light.



ROSS
Production Technology Experts

NITS

What is a NIT?

Measure of light output over a given surface area.

100 Nits

500 Nits

1,000 Nits+

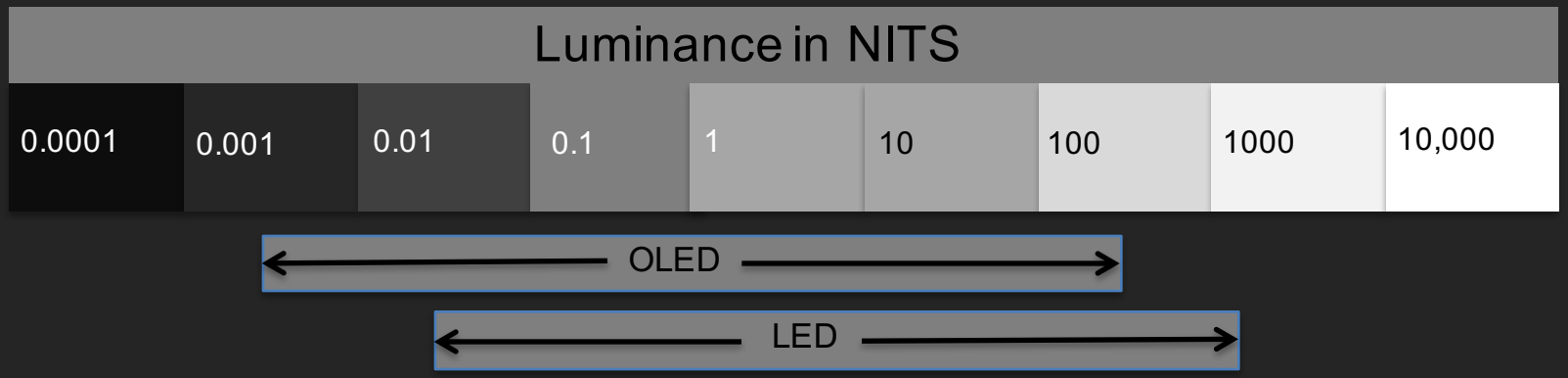
1 Nit = 1 Candela per Square Meter

ROSS
Production Technology Experts

Display Dynamic Range

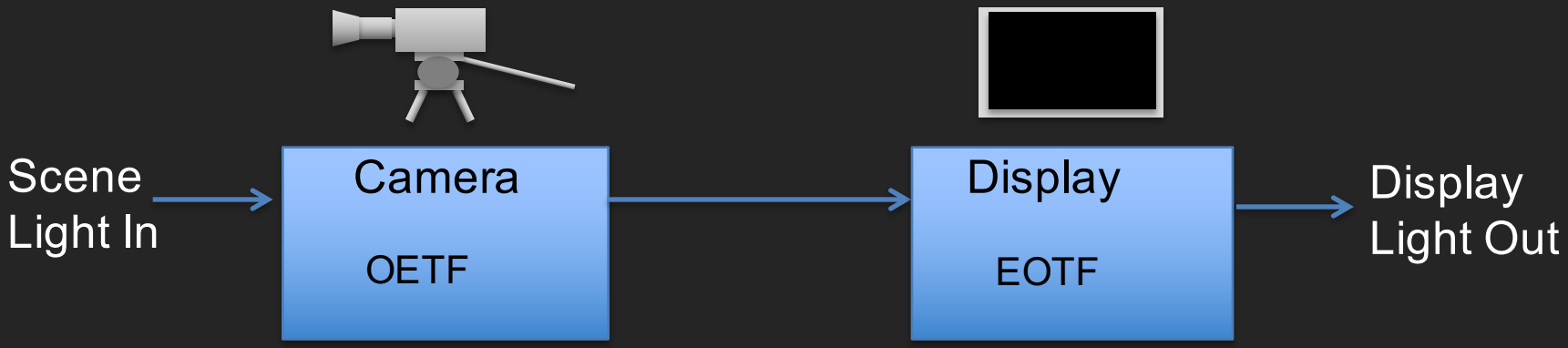
OLED has deeper blacks.

LED has higher light output.



ROSS
Production Technology Experts

OETF - EOTF

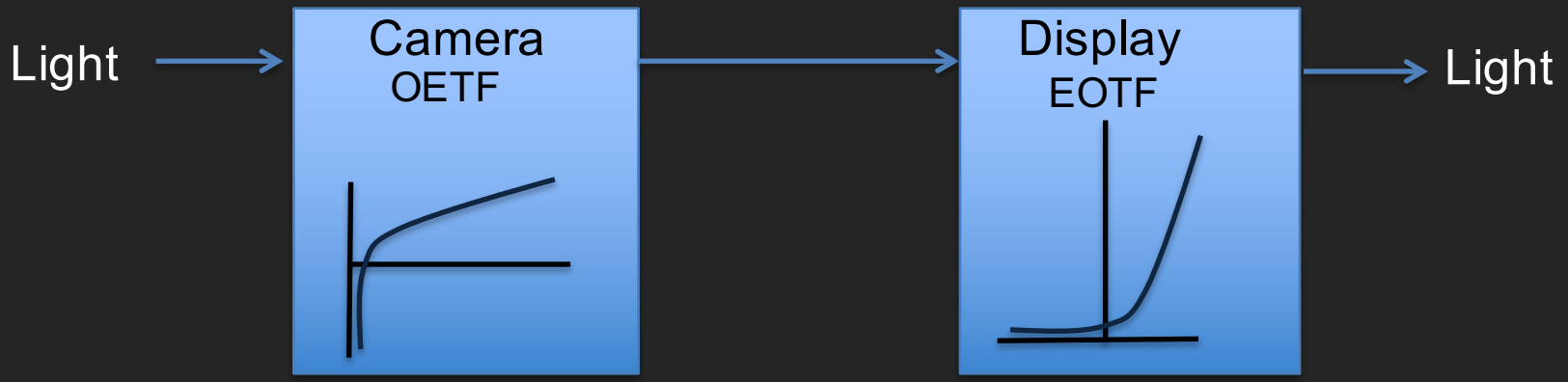


A video camera converts light to a video signal using an Optical to Electrical Transfer Function.

The display converts a video signal to light using the reverse Electrical to Optical Transfer Function.

ROSS
Production Technology Experts

OETF - EOTF



ROSS
Production Technology Experts

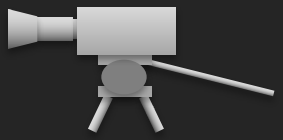
OETF – EOTF SDR vs HDR

SDR

SDR uses a Standard Gamma curve that has been in use since the CRT era.

ROSS
Production Technology Experts

OETF - EOTF



Scene Light In → **Camera** 100,000:1 → **Processing** 1,000:1 → **Display** 100,000:1 → Display Light Out

Todays Cameras have high bit depths at the front end, operating at 14 - 16 bits per sample (RAW).

Modern displays now have much higher light output and lower black levels.

ROSS
Production Technology Experts

OETF – EOTF SDR vs HDR

SDR

SDR uses a Standard Gamma curve that has been in use since the CRT era.

HDR

HDR uses an improved Perceptual Quantization (ST-2084) or Hybrid Log-Gamma (BBC / NHK) curve.

ROSS
Production Technology Experts

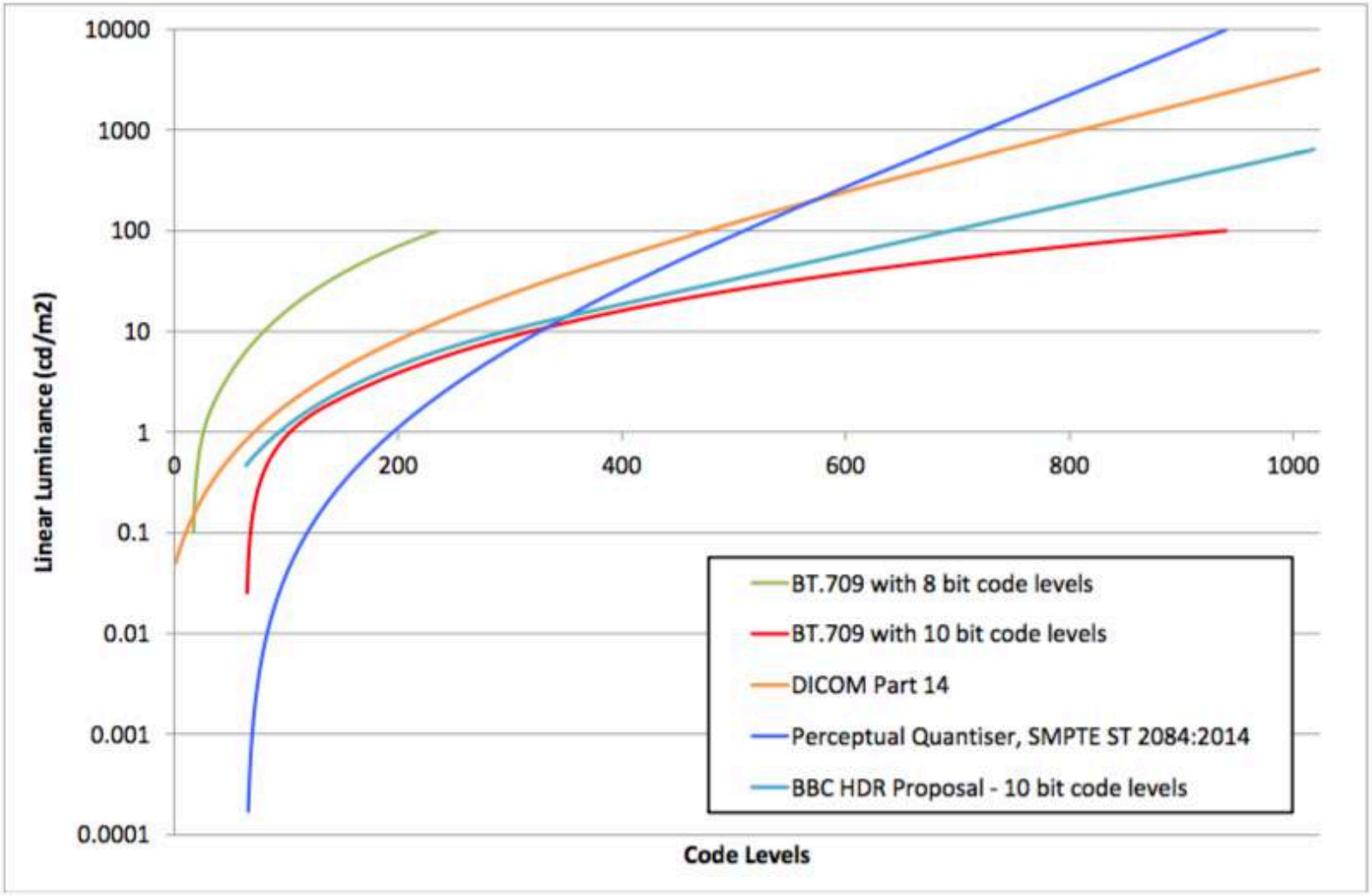
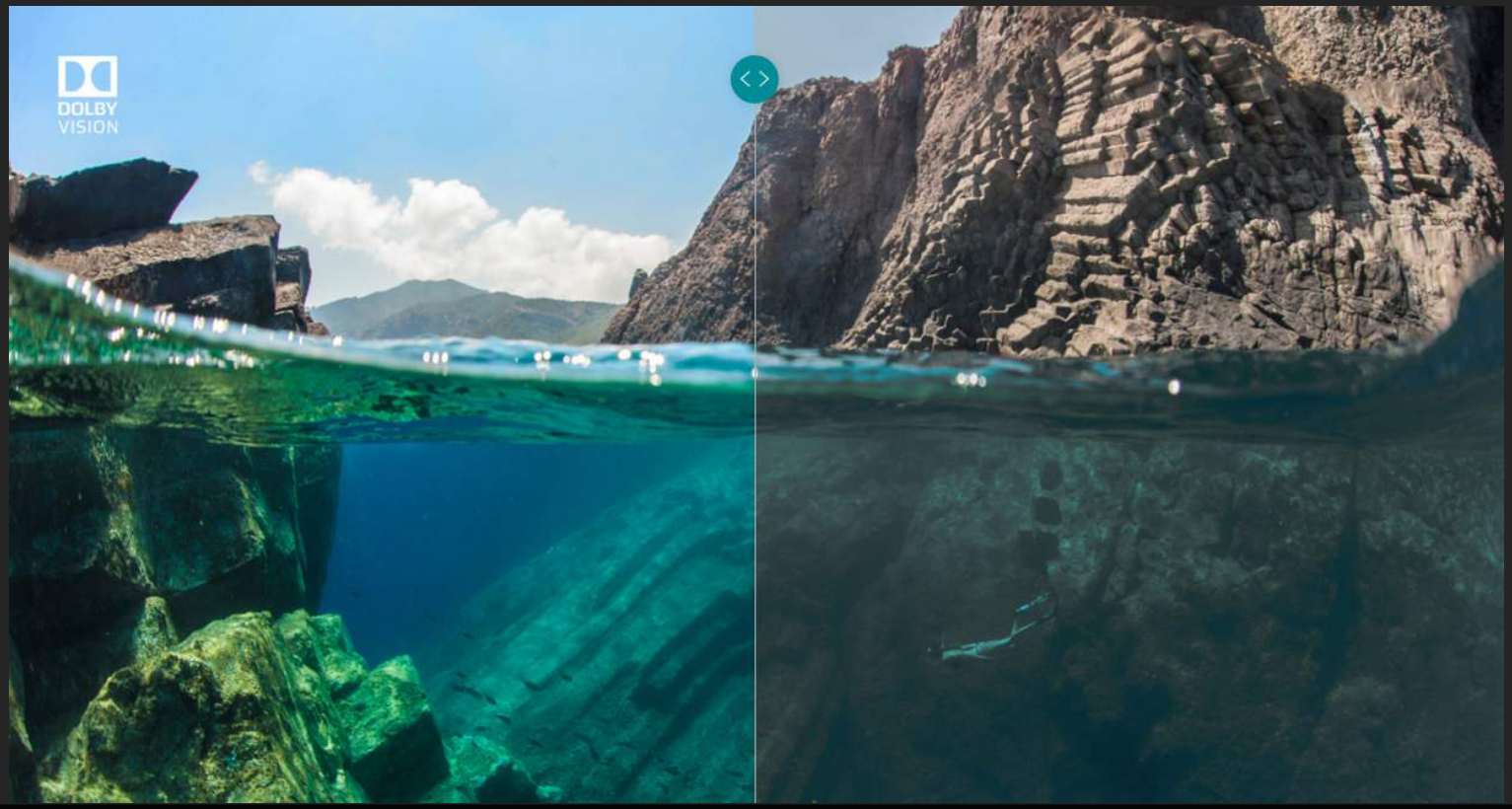


Figure 8. The mapping of linear light to code levels.

Dolby Vision Examples

ROSS
Production Technology Experts

Dolby Vision Examples



ROSS
Production Technology Experts

SMPTE-2084

Perceptual Quantizing

A quantizing function that mimics human perception.
Developed by Dolby, a key part of HDR10, Dolby Vision and Ultra HD Alliance Standards.

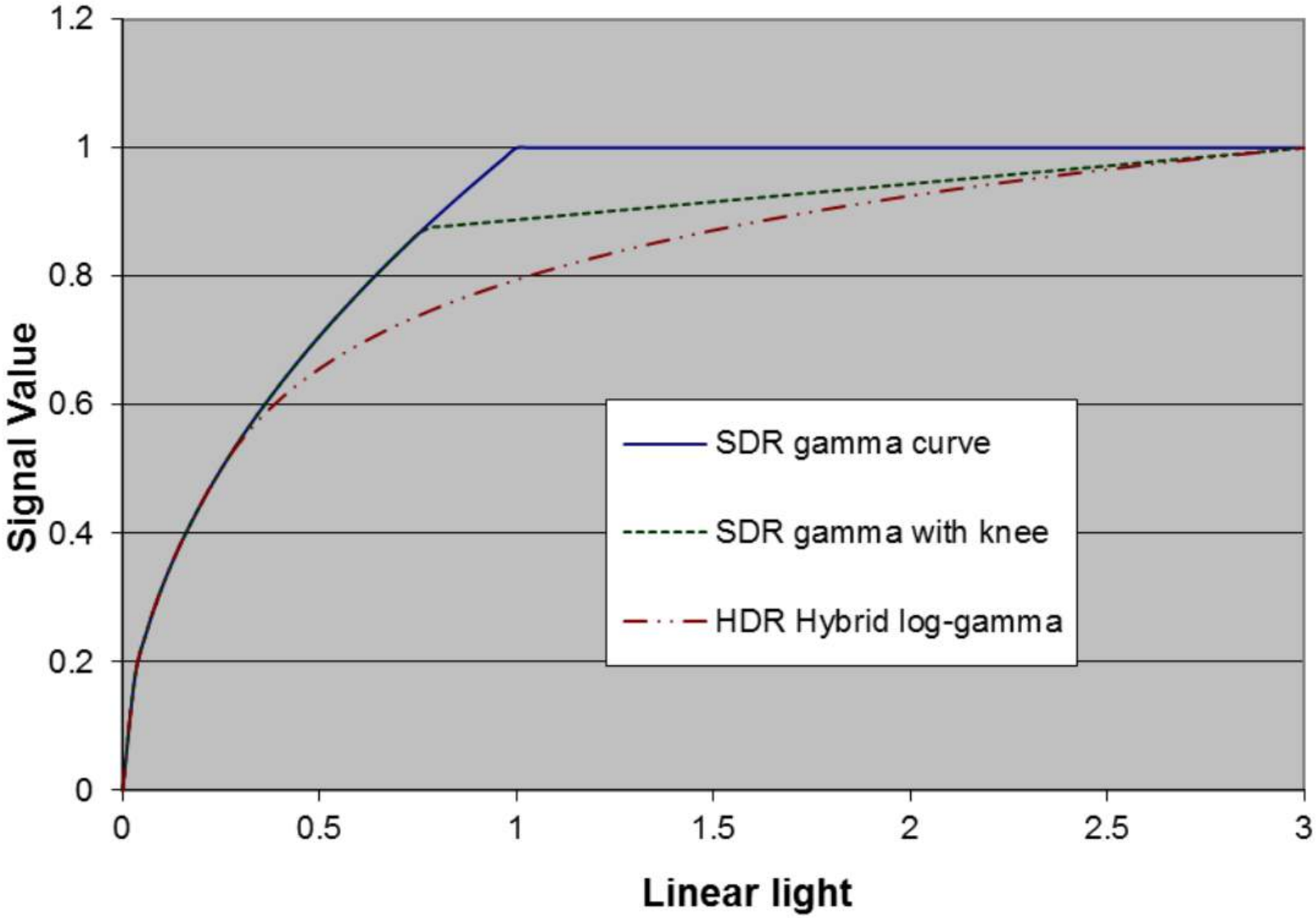
ROSS
Production Technology Experts

HLG – Hybrid Log-Gamma

HLG

Developed by the BBC and NHK as a backward compatible way of delivering HDR to the home.

ROSS
Production Technology Experts


1.2
1
0.8
0.6
0.4
0.2
0
Signal Value
0
0.5
1
1.5
2
2.5
3
Linear light
SDR gamma curve
SDR gamma with knee
HDR Hybrid log-gamma

Sony

SLog2 & SLog3

Developed by Sony as mid-way formats between PQ & HLG.

ROSS
Production Technology Experts

Conversions

SDR to/from HDR
WCG to/from 709 Colour spaces

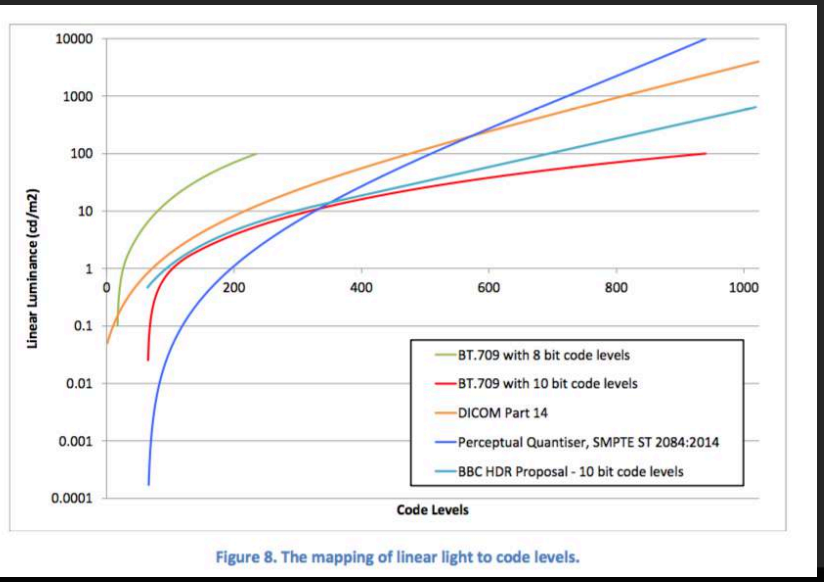
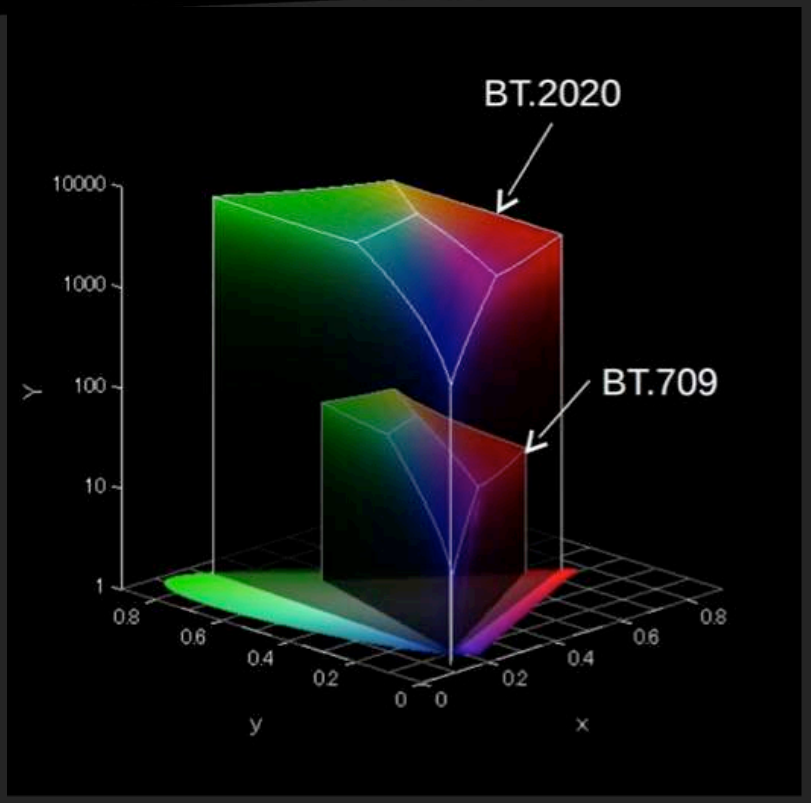


Figure 8. The mapping of linear light to code levels.

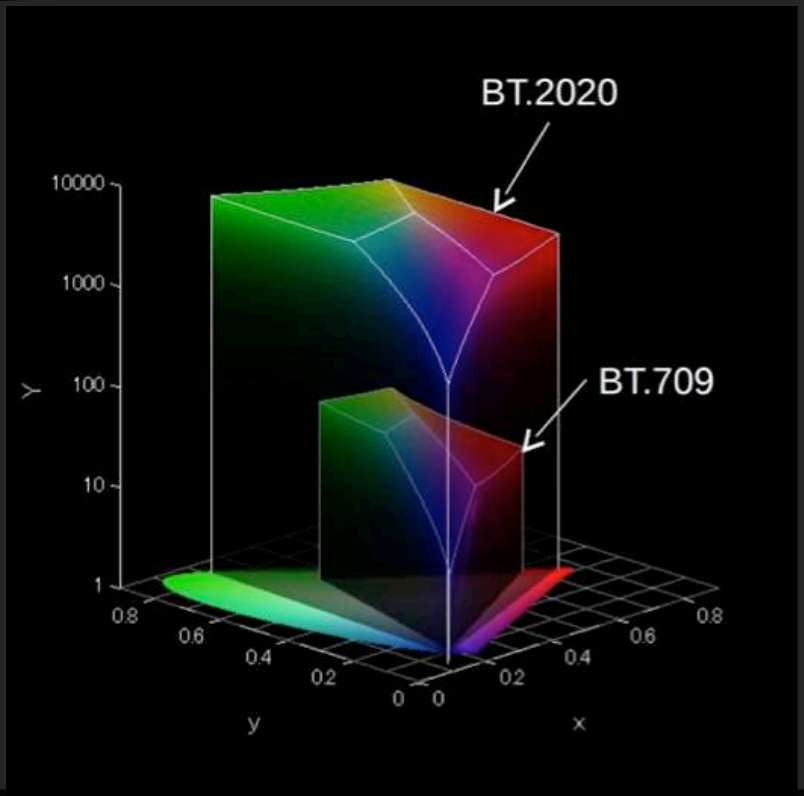


ROSS
Production Technology Experts

Conversions

In a live environment this is generally going to be on an independent pixel by pixel value.

Looking at the entire image and making decisions would add at least a frame of delay and cost more which matters if you have lots of sources.

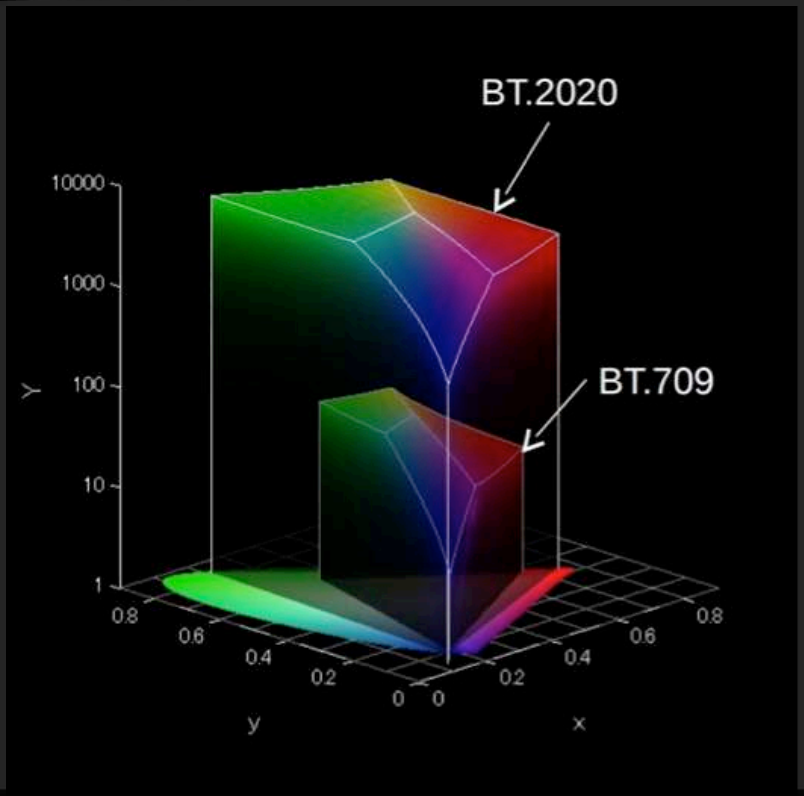


ROSS
Production Technology Experts

Conversions

Going from the smaller to the larger is *mostly* straightforward

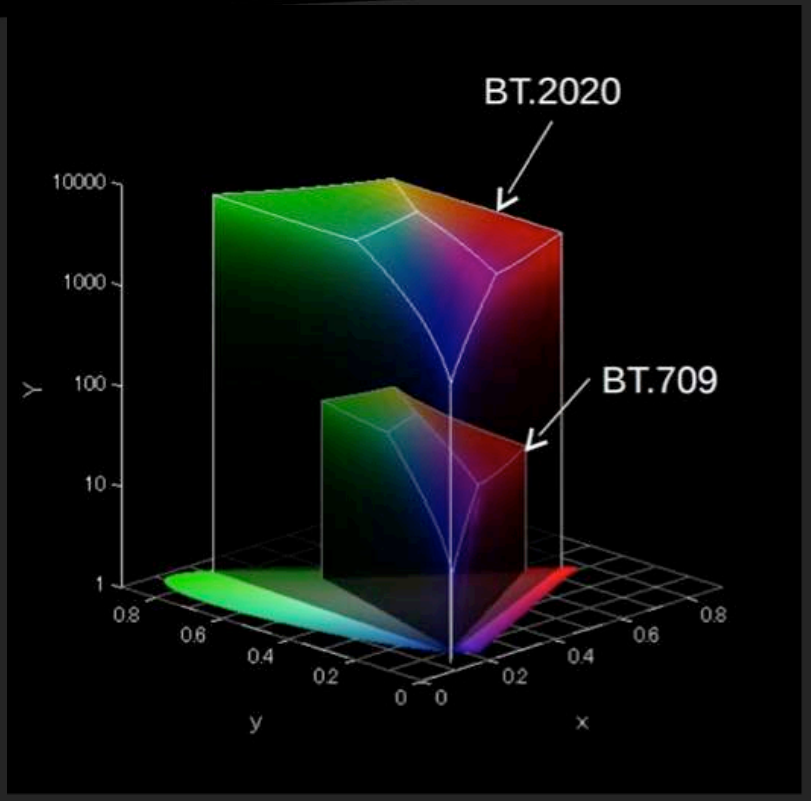
Simple approach is to simply convert pixel by pixel the values which leaves the ‘extra’ space empty.



ROSS
Production Technology Experts

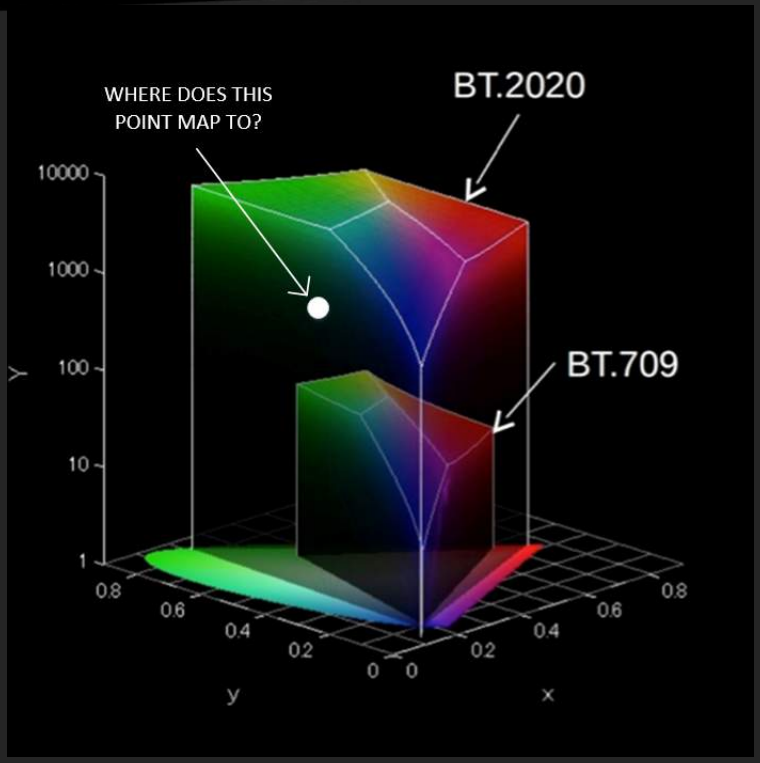
Conversions

Artistic choices may have you desire to ‘stretch’ a portion of the pixels near the boundaries into the ‘extra’ space



ROSS
Production Technology Experts

Conversions



Going from the larger to the smaller can be more complicated.

Not obvious when looking at it like this.

ROSS
Production Technology Experts

Conversions

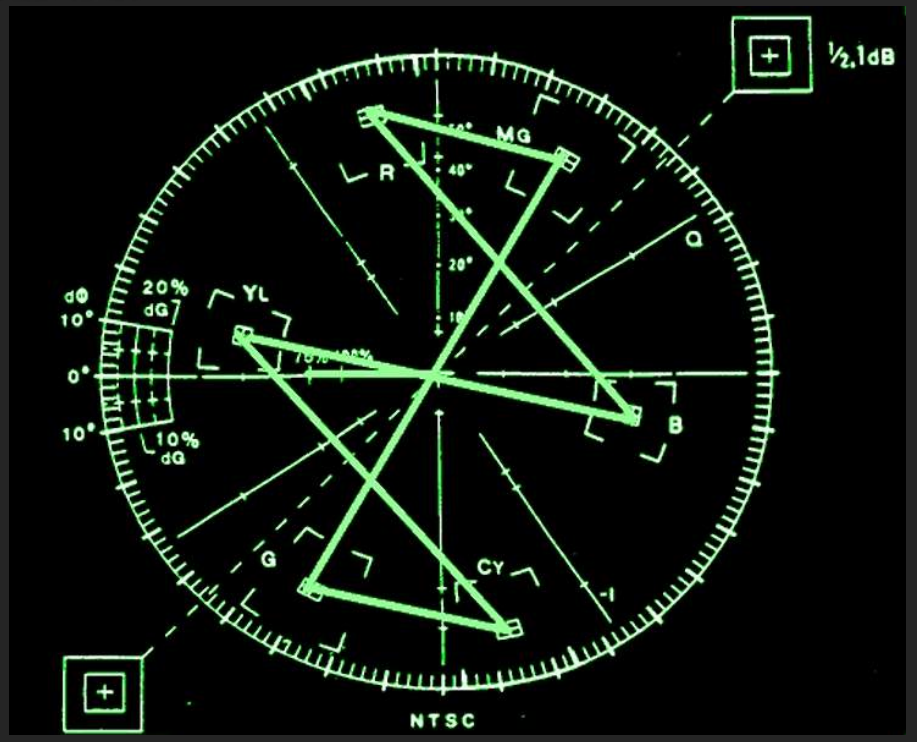
Lets look at it in a different way common to our industry.

Hue, Saturation and Luminance.

Luminance = Brightness

Hue = Red,Green etc..
(the Angle in the vectorscope)

Saturation = how much of that colour.
(The distance from the origin)

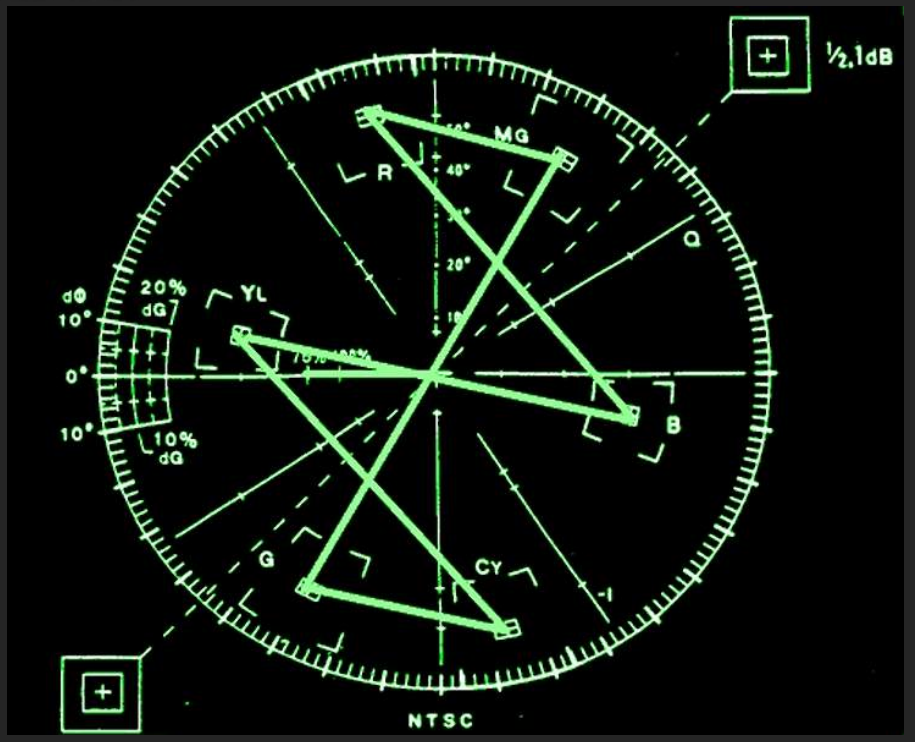


ROSS
Production Technology Experts

Conversions

Any modifications we make to a colour are going to change at least one of Hue, Sat or Lum.

We've worked so hard to get our HDR (luminance) values correct, do we really want to change this in a colour space mapping?



ROSS
Production Technology Experts

Conversions

A hue shift should **really** be avoided.

Do we want this:

Becoming this?:

ROSS
Production Technology Experts

Conversions

Which Leaves Saturation.

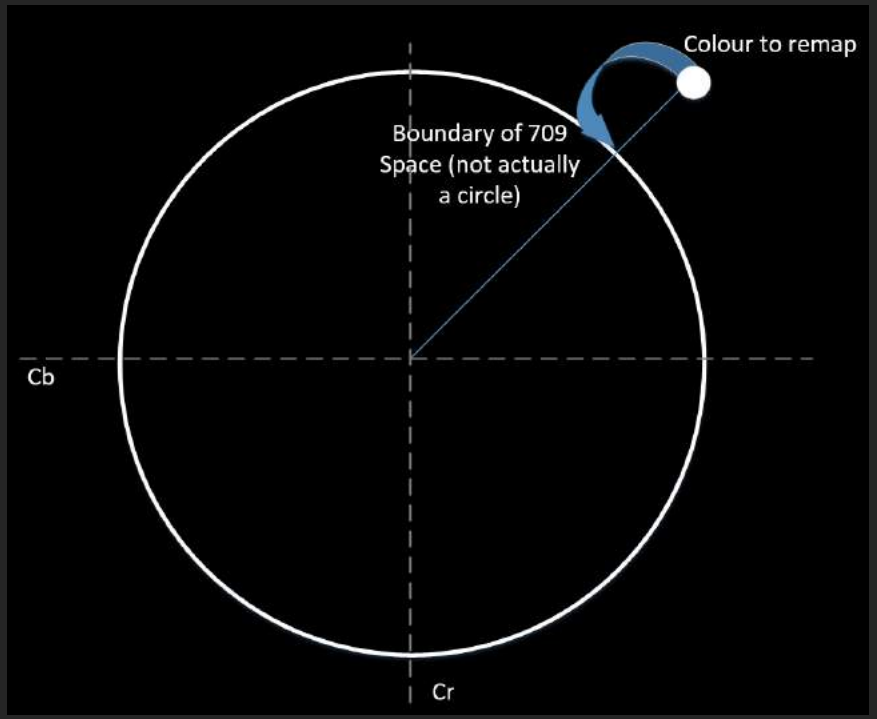
We can desaturate a colour until it is within the smaller colour space. Which makes sense since the larger colour space hasn't invented new hues, it has allowed us to show more vibrant colours than we could before.

Conversions

Going from the larger to the smaller can be more complicated.

Colours are remapped along the vector Towards the origin to the point they are legal

This means that ALL colours on that vector outside of the smaller space (709) become the same…



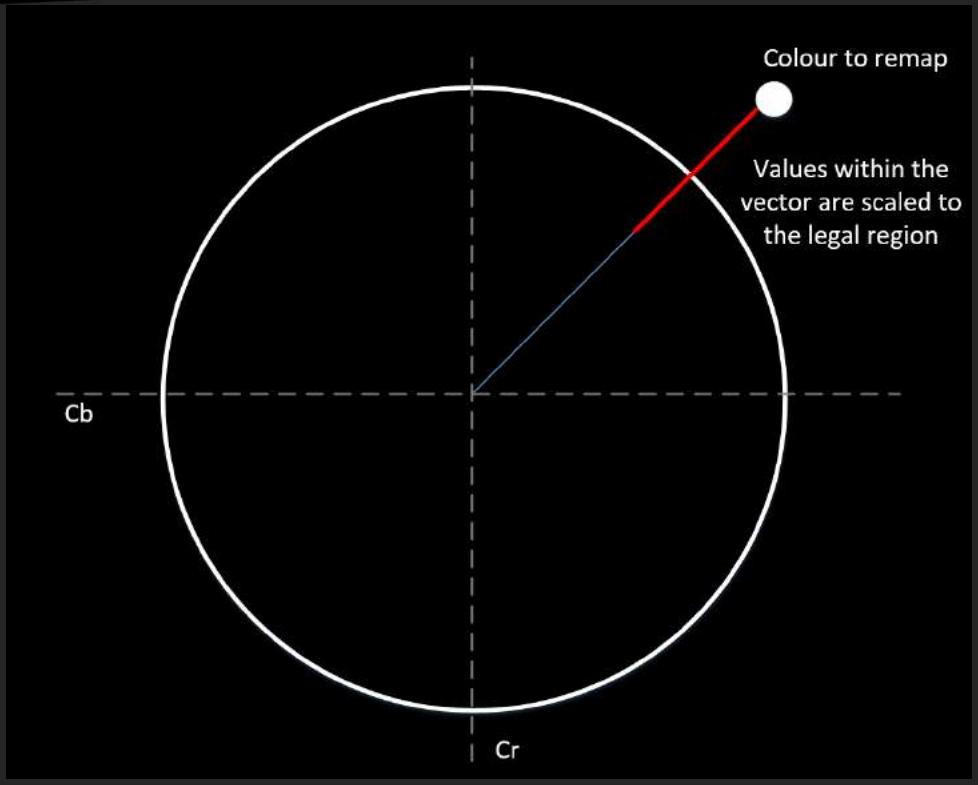
ROSS
Production Technology Experts

Conversions

A proposal in a paper by Schweiger, Borer and Pindoria at the 2016 SMPTE conference in LA is when doing these kinds of operations is to do it over a range which ‘cuts’ into the legal space.

(although the proposal in that paper represented the colour information visually differently and more accurately than this overview)

This **does** desaturate colours in the boundary that were within the legal space however.



ROSS
Production Technology Experts

Conversions

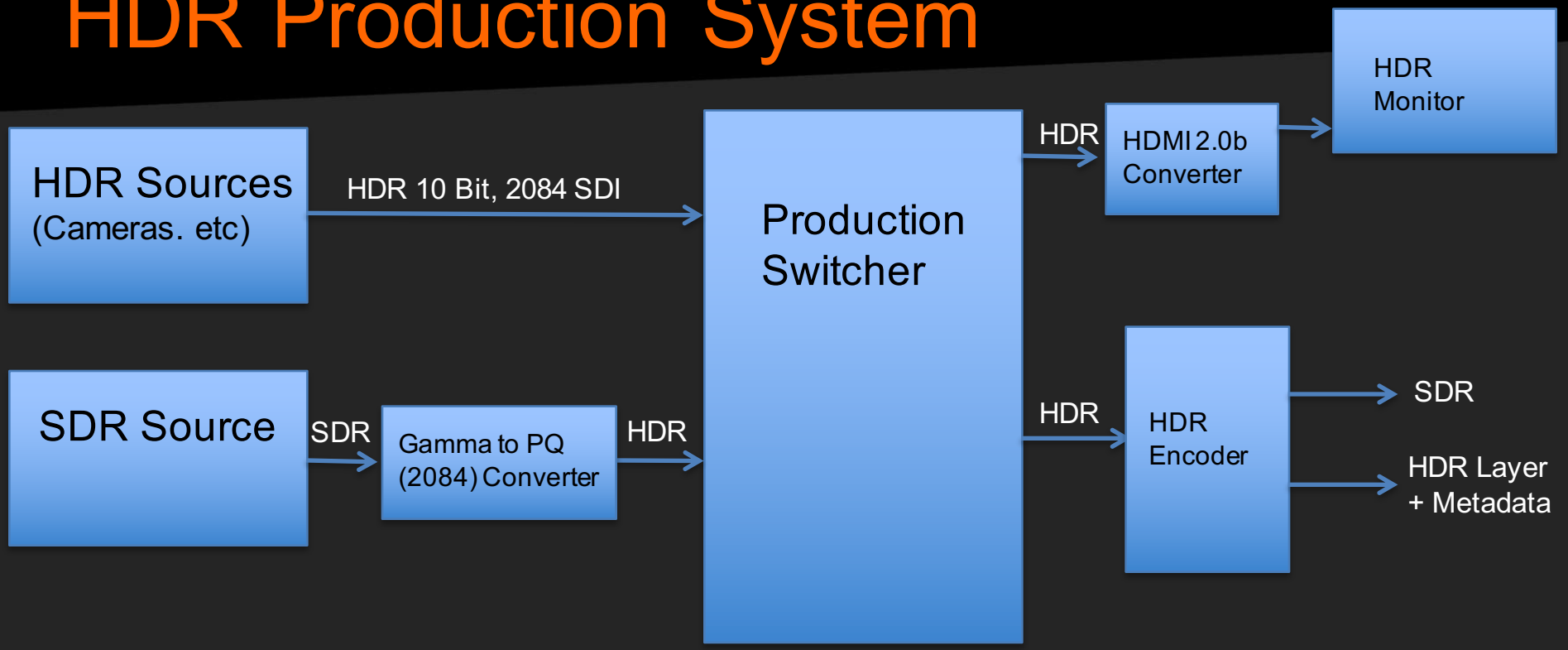
In the end, the visible differences to viewers are likely to be fairly subtle and the standard return vs. effort decisions will need to be done.

THESE ARE ARTISTIC CHOICES!

The amount of effort and cost to do this activity for something like a feature film with one source in post are likely to be different than what you use for a newscast with dozens of sources in real time.

ROSS
Production Technology Experts

HDR Production System



ROSS
Production Technology Experts

Live HDR Test Productions

Sport is one type of production that expanded dynamic range can help with, especially outdoor sports with sunlight and shadows.

ROSS
Production Technology Experts

HPA U.S. Broadcasters Panel

Sinclair, CBS, Fox, Cox & PBS

All expressed interest in 1080P60 HDR (not UHD) in moving to ATSC 3.0 as a bigger difference in picture quality versus going all the way to UHD.

ROSS
Production Technology Experts

HDR Delivery Methods

Dolby Vision

- ST-2084 (PQ) EOTF
- Base Content with Static Metadata
- Enhanced Content Layer with Dynamic Metadata
- Optionally Compatible with HDR10
- Compatible with SDR TVs
- Optional for Ultra HD Blu-ray

HDR10

- ST-2084 (PQ) EOTF
- Single Content Layer with Static Metadata
- Not Compatible with SDR TVs
- Mandated for Ultra HD Blu-ray
- Specified by the CTA for HDR compatible TVs

BBC / NHK

- HLG – Hybrid Log Gamma
- EOTF with no Metadata
- Playback on HLG Compatible Sets
- Most Compatible with SDR TVs

Technicolor / Philips

- ST-2084 (PQ) EOTF
- Single Content Layer with Metadata
- SDR TV Compatibility with External Encoder
- Optional for Ultra HD Blu-ray

ROSS
Production Technology Experts

HDR – Format War

Dolby Vision

- ST-2084 (PQ) EOTF
- Base Content with Static Metadata
- Enhanced Content Layer with Dynamic Metadata
- Optionally Compatible with HDR10
- Compatible with SDR TVs
- Optional for Ultra HD Blu-ray

HDR10

- ST-2084 (PQ) EOTF
- Single Content Layer with Static Metadata
- Not Compatible with SDR TVs
- Mandated for Ultra HD Blu-ray
- Specified by the CTA for HDR compatible TVs

Sony, Samsung

LG, Vizio, Philips, TCL

ROSS
Production Technology Experts

UHD ALLIANCE

Two different and independent organizations involved in the development and promotion of UHD Standards.

ROSS
Production Technology Experts

UHD ALLIANCE

Multi Industry Organization to Promote UHD Standards

The UHD Alliance was created with the consumer in mind. It provides information on premium UHD devices and content to deliver best-in-class home entertainment. The Alliance is also focused on helping consumers build a seamless, integrated and high-quality UHD ecosystem from end-to-end. Premium UHD devices and content will be clearly marked so consumers can easily identify them in-store.

Amazon, DIRECTV, Dolby, LG Electronics Inc., Netflix, Panasonic Corporation, Samsung Electronics Co., Ltd., Sharp Corporation, Sony Visual Product Inc., Technicolor, The Walt Disney Studios, 20th Century Fox and Warner Bros. Entertainment…

ROSS
Production Technology Experts

UHD Alliance ”Ultra HD Premium” Display Specifications

- 3840x2160 Image Resolution
- 10-bit Input Signals
- BT.2020 Wide Color Gamut
- 90% of Cinema P3 Color Reproduction
- SMPTE ST2084 EOTF High Dynamic Range
- A combination of peak brightness & black level measuring either:
  - ->1,000 nits peak brightness and <0.05 nits black level (LCD) or
  - ->540 nits peak brightness and <0.005 nits black level (OLED)

The UHD Alliance has specifcations for laptops, notebooks & tablets.

And now has certification programs.

ROSS
Production Technology Experts

UHD Alliance ”Ultra HD Premium” Display Specifications

The UHD Alliance offers certification and logo licensing programs for displays, BluRay players and now Mobile Devices.

They are also studying live broadcast to develop a UHD Premium Standard for it too.

ROSS
Production Technology Experts

The Ultra HD Forum is bringing together market leaders from every part of the industry; broadcasters, service providers, consumer electronics, and technology vendors to collaborate on solving the real-world hurdles, and accelerating Ultra HD deployment.

Comcast, Dolby, Ericsson, Harmonic, LG, Neulion, Broadcom, DTS, NAB, Sony, Fraunhoffer, Google, Technicolor, AMD, CableLabs, Fox, Irdeto, Astro, Brightcove, Verimatrix …

ROSS
Production Technology Experts

UHD Phase A Definition

Spatial Resolution	1080P* or 2160P
Color Gamut	BT.709, BT.2020
Bit Depth	10 Bit
Dynamic Range	SDR, PQ, HLG
Frame Rate	24, 25, 30, 50, 60
Video Codec	HEVC, Main 10, Level 5.1
Audio Channels	Stereo or 5.1 Multi-Channel
Audio Codec	AC-3, EAC-3, HE-ACC, AAC-LC
Captions	CTA-608/708, ETSI 300 743, ETSI 300 472, SCTE-27, IMSC1

**1080P together with WCG and HDR fulfills certain use cases for H=UHD Phase A Services.

ROSS
Production Technology Experts

Looking at:

End to End definition of UHD “Glass to Glass” Systems describing the entire production & distribution chain.

Starting Plug-Fests to work out compatibility needs / issues.

Compliance is voluntary among members of the UHD Forum.

ROSS
Production Technology Experts

Home Video HDR support

	HDR10	Dolby Vision
TV brands	Hisense, LG, Samsung, Sharp, Sony, Vizio	LG, Vizio, TCL
Streaming services	Amazon, Netflix, Ultra (Sony TVs)	Amazon, Netflix, Vudu
Hollywood studios	Fox, Warner Bros., Paramount, Sony, Lionsgate	MGM, Sony, Warner Bros., Universal
External devices	Samsung UBD-K8500	None yet
Disc-based media	4K Blu-ray	None yet

ROSS
Production Technology Experts

	HDR10	DV
UHD Blu-Ray	Yes	Planned for 2017
Netflix	Yes	Yes
Amazon Video	Yes	Yes
Vudu	Yes	Yes
PS4/PS4 Pro	Yes	No
Xbox One S	Yes	No
Samsung UBD-K8500	Yes	No
Panasonic DMP-UB900	Yes	No
Philips BDP-7501	Yes	No
Nvidia Shield	Yes	No
Chromecast Ultra	Yes	Yes
Nvidia GTX 900 Series and up	Yes	No
AMD Radeon RX and up	Yes	No

ROSS
Production Technology Experts

Standards

- ITU BT.2100 Production Specification for HDR
  - includes both SMPTE-2084 (PQ) & ARIB ST-B67 (HLG)
- CTA-861-G
  - Adds HDR to description tables used in HDMI signaling
- HDMI 2.0b
  - Latest HDMI specification which adds HDR support including HLG
- HDMI 2.1
  - Takes HDMI to 48Mb/s and supports Digital Display Compression (DSC).

UHD Pioneers

- Netflix, Sony, Amazon – HDR10 + Dolby Vision
- Bluray – Movie studio content available in both HDR10 and Dolby Vision
- Japan
  - Broadcasting Daily UHD & 8K, HLG-1200 HDR
- Korea
  - Broadcasters mandated to have UHD on the air by February 2018, will be HLG-1200 HDR.
- Rogers
  - 4K UHD on the air for two seasons now. No HDR or WCG yet.
- BT Sport
  - In second season of 4K UHD. No HDR or WCG yet.

ROSS
Production Technology Experts

Questions

- Should Graphics be in WCG? Colors will be possible in WCG that don't translate into SDR.
- Should Graphics be in HDR? Will the temptation to make graphics and commercials overly bright lead to a concern about too bright video content - ala the problem with audio loudness.
- Do we need an HDR maximum white screen or safe percentage detector to avoid burning peoples retinae?
- Is 1080P60 with WCG and HDR really UHD?
- Can HLG be used to improve results in SDR productions?

ROSS
Production Technology Experts

Questions

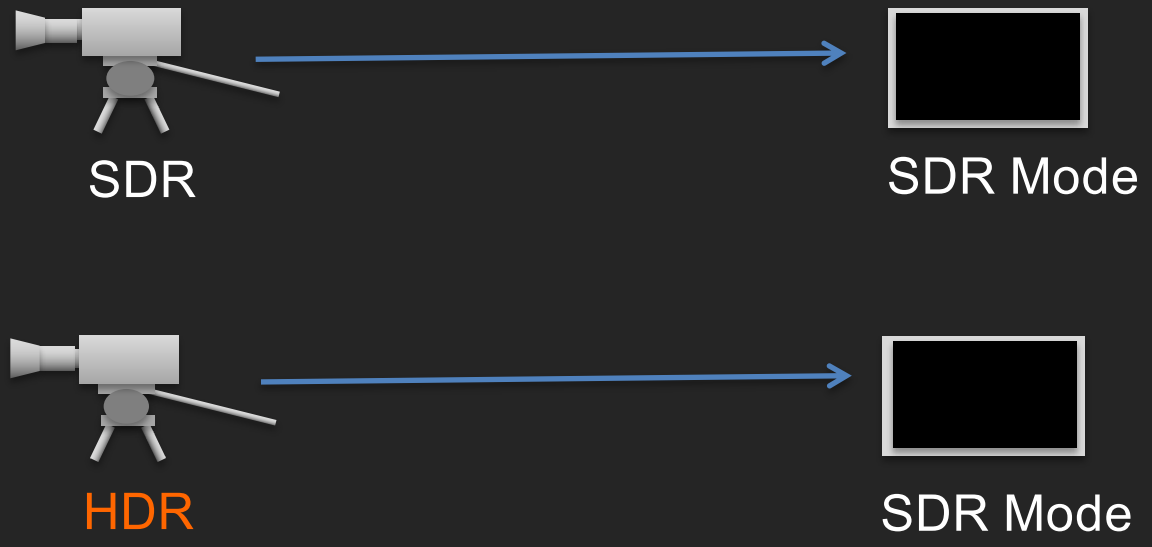
- What bit depth is required in live production is 10 enough or will 12 bits ultimately be required?
- Will High Frame Rates beyond 60fps ever take off? It's not a big topic of discussion right now.
- When will we get cameras and displays that close the gap to BT-2020 color space?
- Will HLG be the "sleeper" format that broadcasters adopt due to its compatibility with SDR?
- Will viewers at home notice the difference with full UHD resolution versus 1080P HDR?

ROSS
Production Technology Experts

Production Technology Experts

HLG Demo

Showing SDR versus HDR on a display set to SDR mode.



ROSS
Production Technology Experts

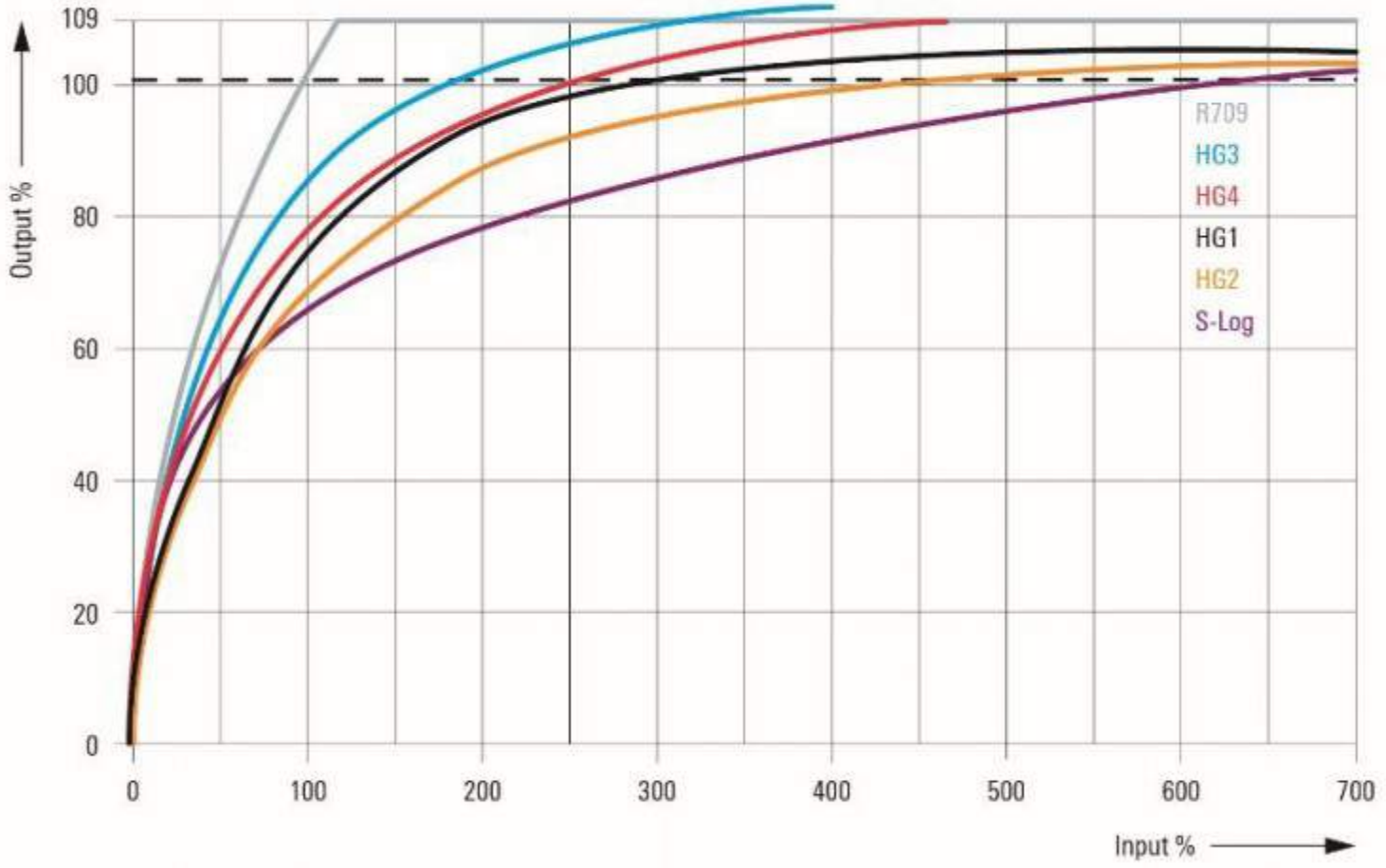
SI photometry quantities

V • T • E

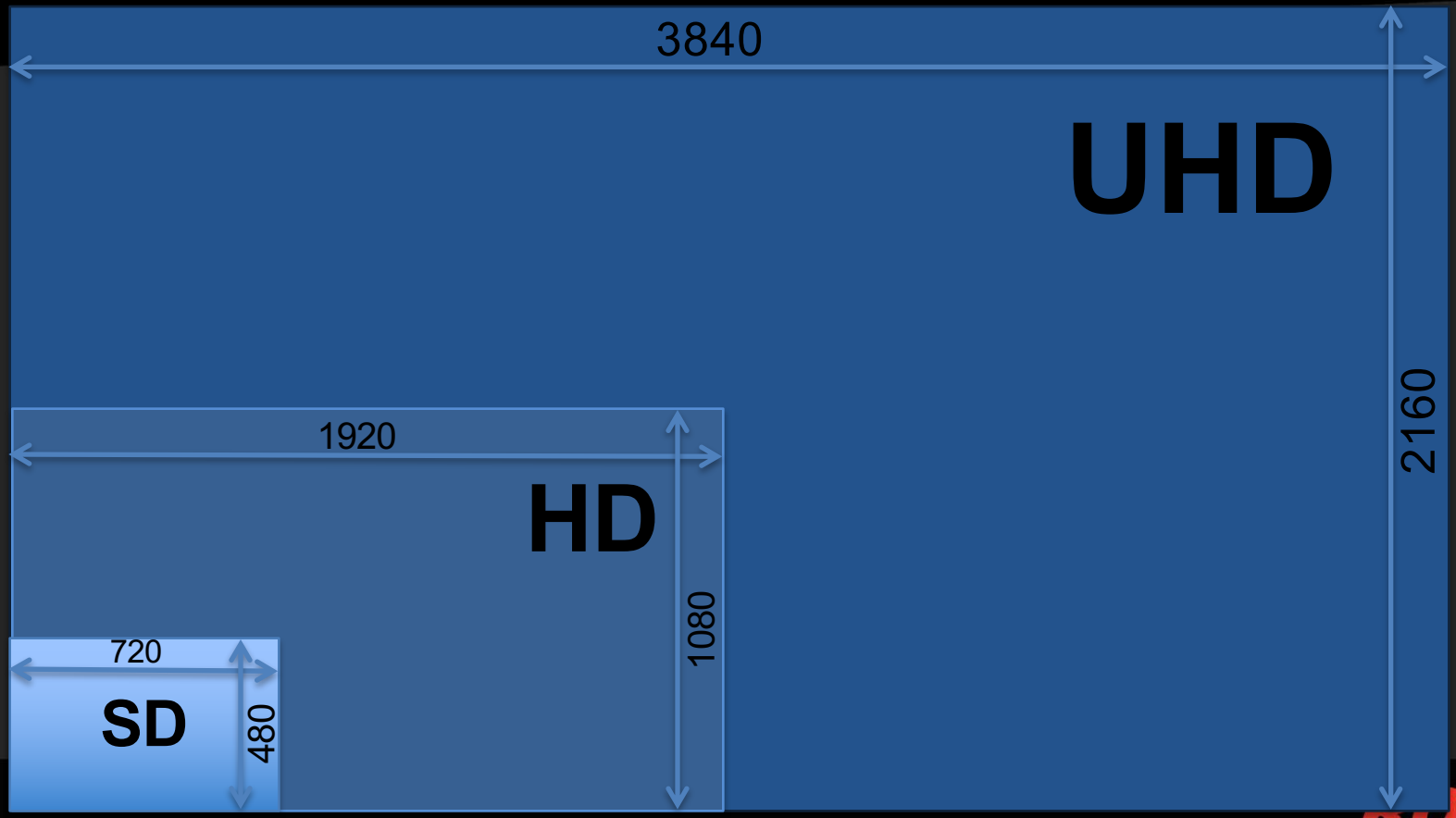
Quantity		Unit		Dimension	Notes
Name	Symbol[nb 1]	Name	Symbol	Symbol	
Luminous energy	Q_v [nb 2]	lumen second	lm·s	**T**·**J** [nb 3]	Units are sometimes called *talbots*.
Luminous flux / luminous power	Φ_v [nb 2]	lumen (= cd·sr)	lm	**J** [nb 3]	Luminous energy per unit time.
Luminous intensity	I_v	candela (= lm/sr)	cd	**J** [nb 3]	Luminous power per unit solid angle.
Luminance	L_v	**candela per square metre**	cd/m^2	$\mathbf{L}^{-2}$·**J**	Luminous power per unit solid angle per unit *projected* source area. Units are sometimes called *nits*.
Illuminance	E_v	lux (= lm/m^2)	lx	$\mathbf{L}^{-2}$·**J**	Luminous power *incident* on a surface.
Luminous exitance / luminous emittance	M_v	lux	lx	$\mathbf{L}^{-2}$·**J**	Luminous power *emitted* from a surface.
Luminous exposure	H_v	lux second	lx·s	$\mathbf{L}^{-2}$·**T**·**J**	
Luminous energy density	ω_v	lumen second per cubic metre	lm·s·m^{-3}	$\mathbf{L}^{-3}$·**T**·**J**	
Luminous efficacy	η [nb 2]	lumen per watt	lm/W	$\mathbf{M}^{-1}$·$\mathbf{L}^{-2}$·$\mathbf{T}^{3}$·**J**	Ratio of luminous flux to radiant flux or power consumption, depending on context.
Luminous efficiency / luminous coefficient	V			1	

See also: SI · Photometry · Radiometry

Different gamma curves for HDR



UHD – Spatial Resolution



ROSS
Production Technology Experts

Resolution

ROSS
Production Technology Experts

Resolution

ROSS
Production Technology Experts

Resolution

ROSS
Production Technology Experts