UHD – Ultra High Definition

Resolution

HFR – High Frame Rate

WCG – Wide Gamut Color

HDR – High Dynamic Range
UHD – Resolution

UHD

HD

SD
UHD – Resolution

Spatial Resolution
is the number of pixels in a frame of video.

Temporal Resolution
is the frames per second of video.
UHD – Spatial Resolution

- UHD: 3840 × 2160
- HD: 1920 × 1080
- SD: 1280 × 720
- 480: 720 × 480
- 720: 1280 × 720
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?
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.
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).
Viewing Distance where Resolution Becomes Noticeable

Screen Size vs. Viewing Distance

- 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.

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Viewing Distance where Resolution Becomes Noticeable

Screen Size vs. Viewing Distance

480p, 720p, 1080p, 4k (2160p) all appear to be equivalent at these “far away” viewing distances.

- Full benefit of 480p visible
- Full benefit of 720p visible
- Full benefit of 1080p visible
- Full benefit of 4k (2160p) visible

Benefit of 720p starts to become noticeable
Benefit of 1080p starts to become noticeable
Benefit of 4k (2160p) starts to become noticeable

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Viewing Distance where Resolution Becomes Noticeable
Screen Size vs. Viewing Distance

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

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Resolution
Resolution
Today’s Television Frame Rates

720P 50 / 60 FPS

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

- **720P** 50/60 FPS  
  1.5 Gb/s

- **1080P** 50/60 FPS  
  3Gb/s

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

- **UHD** 50/60 FPS  
  12 Gb/s

- **UHD** 120 FPS (future)  
  24 Gb/s
Television Frame Rates

- **720P**: 50/60 FPS, 1.5 Gb/s
- **1080P**: 50/60 FPS, 3 Gb/s
- **1080i**: 25/30 FPS (60 fields per second), 1.5 Gb/s
- **UHD**: 50/60 FPS, 12 Gb/s
- **UHD**: 120 FPS (future), 24 Gb/s

*HFR*
**HFR = Increased Temporal Resolution**

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

Demo at: [https://frames-per-second.appspot.com](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.
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
UHD – Wide Color Gamut

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

**UHD** – BT.2020  
(also used in 8K)

**Digital Cinema** – P3

**HD** – Rec.709
UHD – BT.2020
(also used in 8K)

Digital Cinema – P3

HD – Rec.709
Wide Color Gamut
local dimming

Normal
HDR – High Dynamic Range
What HDR Isn’t

Multiple exposures on your iPhone.
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.
What is a NIT?

Measure of light output over a given surface area.

- Older TV Sets: 100 Nits
- OLED HDR: 500 Nits
- LCD HDR: 1,000 Nits+

1 Nit = 1 Candela per Square Meter
**Display Dynamic Range**

**OLED** has deeper blacks.

**LED** has higher light output.

<table>
<thead>
<tr>
<th>Luminance in NITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0001</td>
</tr>
</tbody>
</table>

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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.
OETF - EOTF

Light → Camera OETF → Display EOTF → Light
OETF – EOTF SDR vs HDR

SDR

Light → Camera
OETF = Gamma

Display
EOTF = Gamma

→ Light

SDR uses a Standard Gamma curve that has been in use since the CRT era.
Today's 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.
OETF – EOTF SDR vs HDR

**SDR**

- **Camera**
  - OETF = Gamma
- **Display**
  - EOTF = Gamma

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

**HDR**

- **Camera**
  - OETF = PQ (2084) or HLG
- **Display**
  - EOTF = PQ (2084) or HLG

HDR uses an improved **Perceptual Quantization (ST-2084)** or **Hybrid Log-Gamma (BBC / NHK)** curve.
**Figure 8.** The mapping of linear light to code levels.
Dolby Vision Examples
Dolby Vision Examples
Perceptual Quantizing

A quantizing function that mimics human perception. Developed by Dolby, a key part of HDR10, Dolby Vision and Ultra HD Alliance Standards.
HLG – Hybrid Log-Gamma

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

SLog2 & SLog3
Developed by Sony as mid-way formats between PQ & HLG.
Conversions

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

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

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

Not obvious when looking at it like this.
Conversions

Let's 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)
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?
Conversions

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

Do we want this:

![STOP](image1)

Becoming this?:

![STOP](image2)
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…
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.
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.
HDR Production System

HDR Sources (Cameras, etc) → HDR 10 Bit, 2084 SDI

SDR Source → SDR

Gamma to PQ (2084) Converter

Production Switcher

HDMI 2.0b Converter

HDR Monitor

HDR Encoder

SDR

HDR Layer + Metadata
Sport is one type of production that expanded dynamic range can help with, especially outdoor sports with sunlight and shadows.
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.
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
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
Two different and independent organizations involved in the development and promotion of 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.

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 specifications for laptops, notebooks & tablets.

And now has certification programs.
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.
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 …
## UHD Phase A Definition

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

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

<table>
<thead>
<tr>
<th></th>
<th>HDR10</th>
<th>Dolby Vision</th>
</tr>
</thead>
<tbody>
<tr>
<td>TV brands</td>
<td>Hisense, LG, Samsung, Sharp, Sony, Vizio</td>
<td>LG, Vizio, TCL</td>
</tr>
<tr>
<td>Streaming services</td>
<td>Amazon, Netflix, Ultra (Sony TVs)</td>
<td>Amazon, Netflix, Vudu</td>
</tr>
<tr>
<td>Hollywood studios</td>
<td>Fox, Warner Bros., Paramount, Sony, Lionsgate</td>
<td>MGM, Sony, Warner Bros., Universal</td>
</tr>
<tr>
<td>External devices</td>
<td>Samsung UBD-K8500</td>
<td>None yet</td>
</tr>
<tr>
<td>Disc-based media</td>
<td>4K Blu-ray</td>
<td>None yet</td>
</tr>
<tr>
<td></td>
<td>HDR10</td>
<td>DV</td>
</tr>
<tr>
<td>------------------------</td>
<td>-------</td>
<td>-------</td>
</tr>
<tr>
<td>UHD Blu-Ray</td>
<td>Yes</td>
<td>Planned for 2017</td>
</tr>
<tr>
<td>Netflix</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Amazon Video</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Vudu</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>PS4/PS4 Pro</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Xbox One S</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Samsung UBD-K8500</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Panasonic DMP-UB900</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Philips BDP-7501</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Nvidia Shield</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Chromecast Ultra</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Nvidia GTX 900 Series and up</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>AMD Radeon RX and up</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>
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.
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 retinas?

• Is 1080P60 with WCG and HDR really UHD?

• Can HLG be used to improve results in SDR productions?
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?
HLG Demo
Showing SDR versus HDR on a display set to SDR mode.
### SI photometry quantities

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Symbol[^nb 1]</th>
<th>Unit</th>
<th>Symbol</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luminous energy</td>
<td>$Q_v$[^nb 2]</td>
<td>lumen second</td>
<td>lm·s</td>
<td>Units are sometimes called talbets.</td>
</tr>
<tr>
<td>Luminous flux / luminous power</td>
<td>$\Phi_v$[^nb 2]</td>
<td>lumen ($= cd\cdot sr$)</td>
<td>lm</td>
<td>Luminous energy per unit time.</td>
</tr>
<tr>
<td>Luminous intensity</td>
<td>$I_v$</td>
<td>candela ($= lm/sr$)</td>
<td>cd</td>
<td>Luminous power per unit solid angle.</td>
</tr>
<tr>
<td>Luminance</td>
<td>$L_v$</td>
<td>candela per square metre</td>
<td>cd/m²</td>
<td>Luminous power per unit solid angle per unit projected source area. Units are sometimes called nits.</td>
</tr>
<tr>
<td>Illuminance</td>
<td>$E_v$</td>
<td>lux ($= lm/m^2$)</td>
<td>lx</td>
<td>Luminous power incident on a surface.</td>
</tr>
<tr>
<td>Luminous exitance / luminous emittance</td>
<td>$M_v$</td>
<td>lux</td>
<td>lx</td>
<td>Luminous power emitted from a surface.</td>
</tr>
<tr>
<td>Luminous exposure</td>
<td>$H_v$</td>
<td>lux second</td>
<td>lx·s</td>
<td></td>
</tr>
<tr>
<td>Luminous energy density</td>
<td>$\omega_v$</td>
<td>lumen second per cubic metre</td>
<td>lm·s·m⁻³</td>
<td></td>
</tr>
<tr>
<td>Luminous efficacy</td>
<td>$\eta$[^nb 2]</td>
<td>lumen per watt</td>
<td>lm/W</td>
<td>Ratio of luminous flux to radiant flux or power consumption, depending on context.</td>
</tr>
<tr>
<td>Luminous efficiency / luminous coefficient</td>
<td>$\nu$</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

[^nb 1]: see Notes column.
[^nb 2]: Per Luminous Flux or Energy.
Different gamma curves for HDR

- R709
- H63
- H64
- H61
- H62
- S-Log

Output % vs. Input %

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UHD – Spatial Resolution

- **UHD**: 3840 x 2160
- **HD**: 1920 x 1080
- **SD**: 720 x 480
Resolution
Resolution
Resolution