Comparison of Linear vs. Composited HDR Pipelines

Timo Kunkel, PhD

Dolby Laboratories, Inc., San Francisco

timo.kunkel@dolby.com

The Big Picture

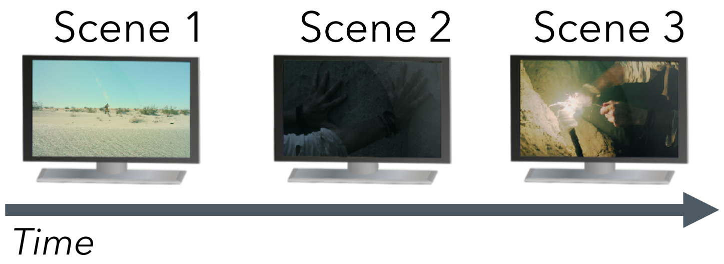
- HDR pipelines for **full-screen content (e.g., movies & video) are well established**, covering all parts of the HDR ecosystem such as content production, delivery and display.
- However, successfully facilitating **HDR content that is composited in real-time (e.g., websites & GUIs) is still in its infancy**
- This presentation compares the different approaches and discusses the aspects that need to be considered towards a successful rendering pipeline for composited HDR content.

Intended Audience

- This presentation is intended for web technologists working on implementing HDR capable workflows.
- It can also be beneficial to technologists working in the field of established linear video pipelines and everyone interested in identifying the differences between the pipeline approaches.

LINEAR VS. REALTIME COMPOSITED CONTENT

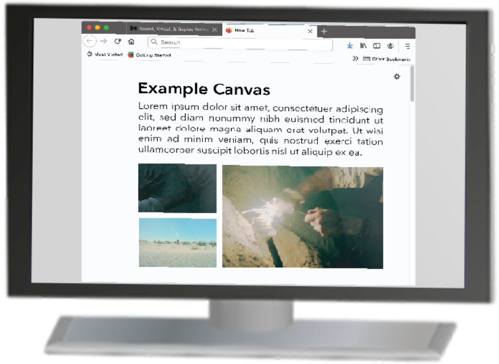
Linear vs. Composited Content



Linear Content

- Movie and Video content is **temporally linear** (one frame follows another)
    - Typically **presented full screen**
    - Frames are pixel/raster based with fixed dimension, framerate, encoding type, etc.
    - Content properties are known for the duration of playback
- Individual clips with different properties can succeed each other

Linear Content can be **Temporally Mixed Media.**

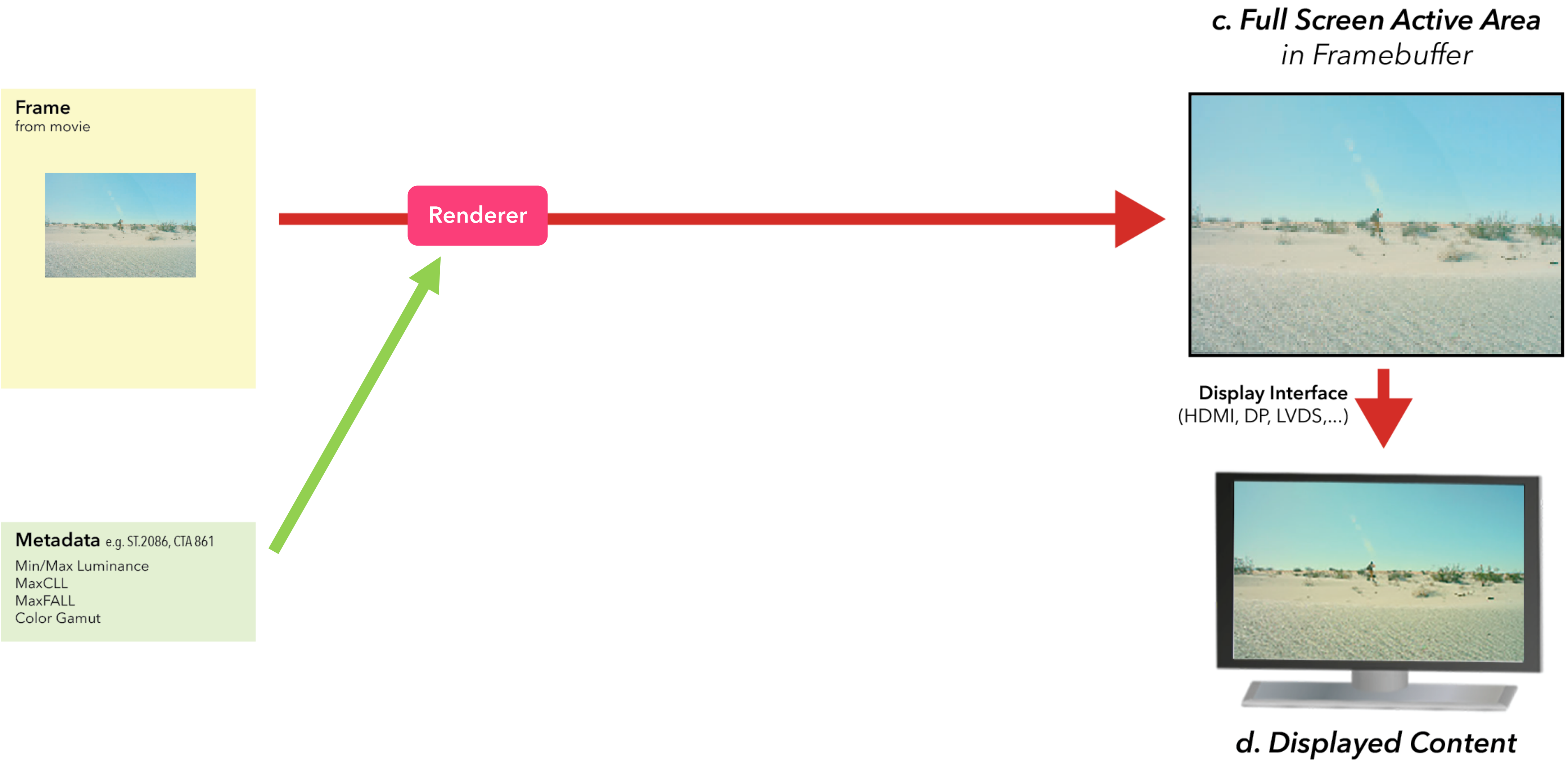


Composited Content

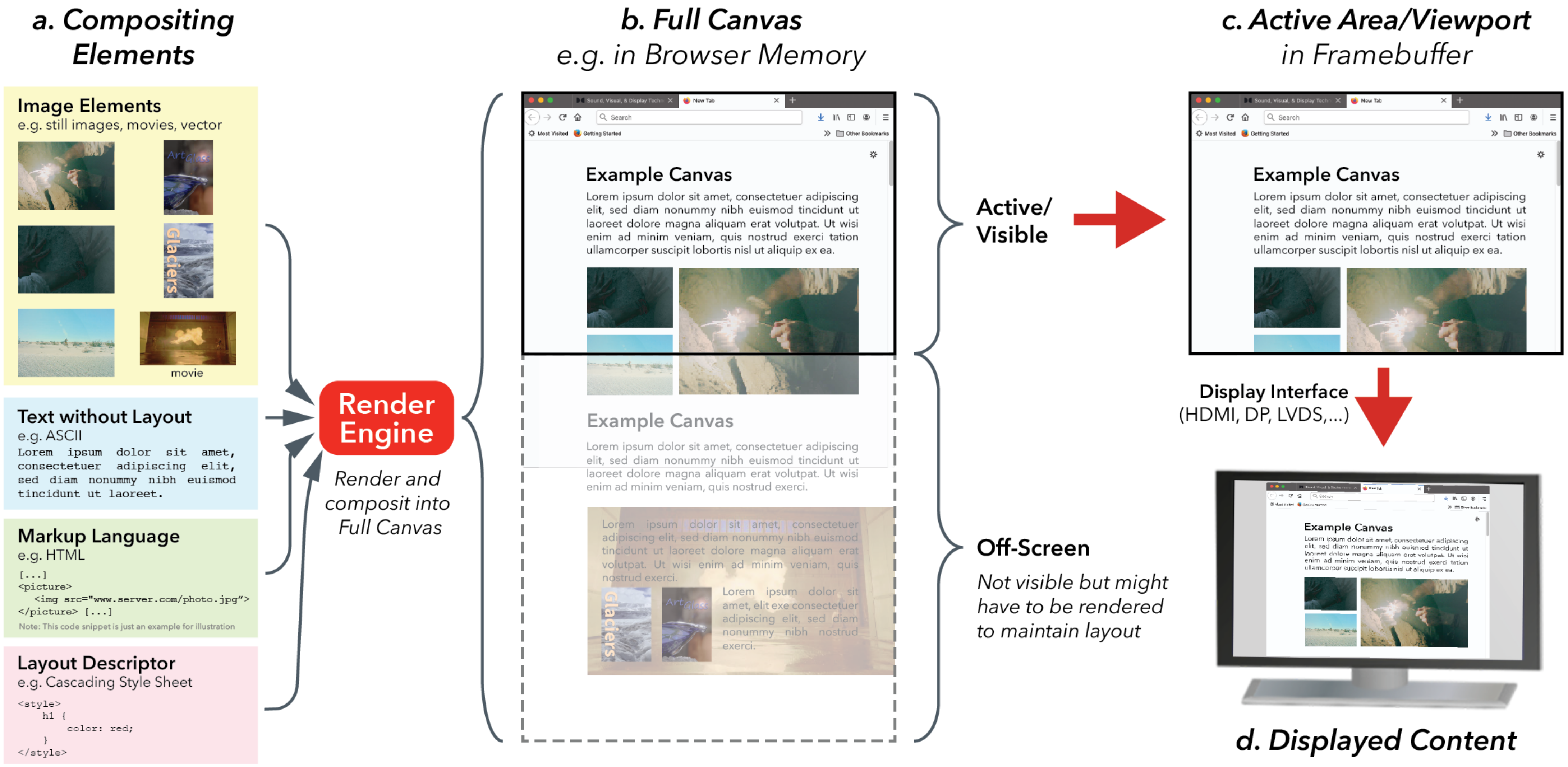
- Composited media content includes web sites, GUIs & Operating System level graphics rendering
- General approach: composite and render several graphical elements on **rendering canvas**
- These elements are **placed spatially** but can also **offer a temporal aspect** (animations, videos)
- Content Elements used for compositing are often **not shown full-screen**

Composited content can therefore be **Spatially & Temporally Mixed Media**

Fundamental Linear Rendering Pipeline



Fundamental Canvas Rendering Pipeline



Traditional Canvas Rendering Pipeline

a. SDR Content Elements

b. Markup Language

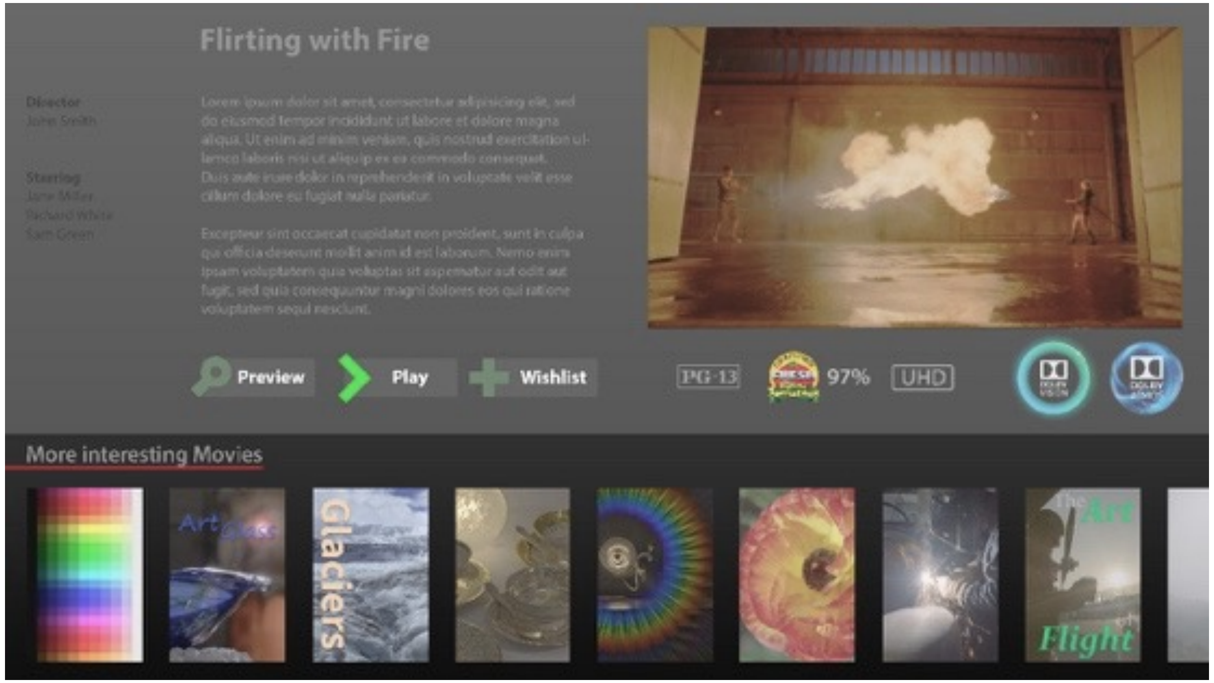
```
[...]
<picture>
      <img src="photo-srgb.jpg">
</picture> [...]
```

Note: This code snippet is just an example for illustration

Composite

c. SDR Canvas

Rendered using SDR Content Elements and Markup Language



Full Single Screen Canvas Example

- Common with Media Players and Smart Devices

Increase of Complexity: HDR Capable Pipeline

a. Mixed SDR & HDR Content Elements

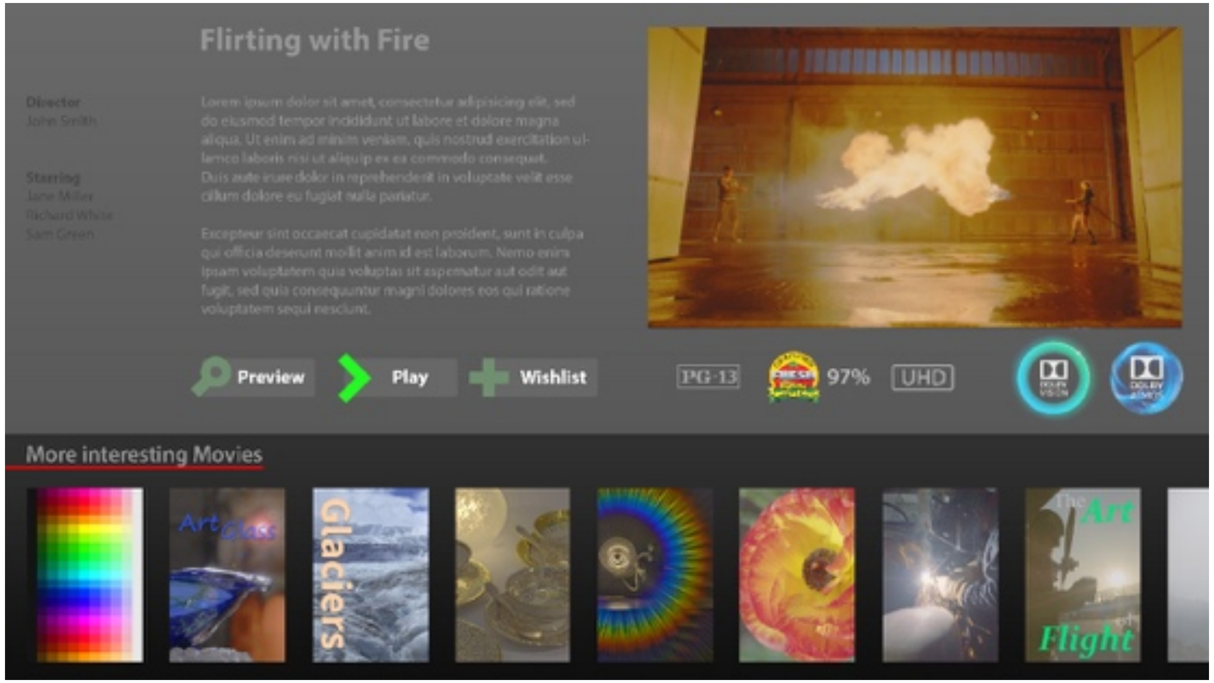
b. Markup Language with WCG & HDR

```
[...]
<picture>
        <source media="(color-gamut: p3)">
        <img src="photo-srgb.jpg">
</picture> [...]
```

Note: This code snippet is just an example for illustration

c. HDR Canvas

Rendered using both HDR & SDR Content Elements and Markup Language, etc.



Full Single Screen Canvas Example

- Common with Media Players and Smart Devices

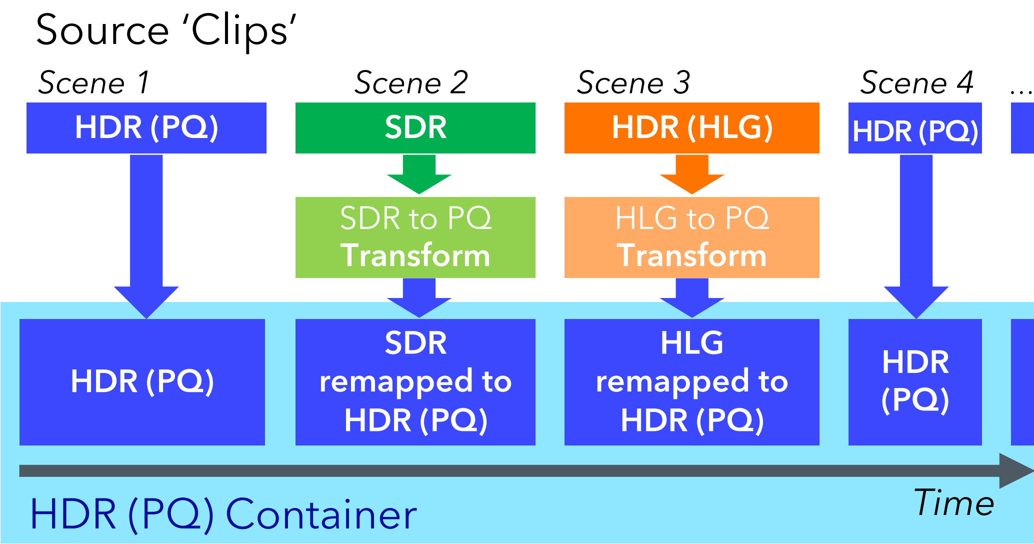
Key Take-Aways #1

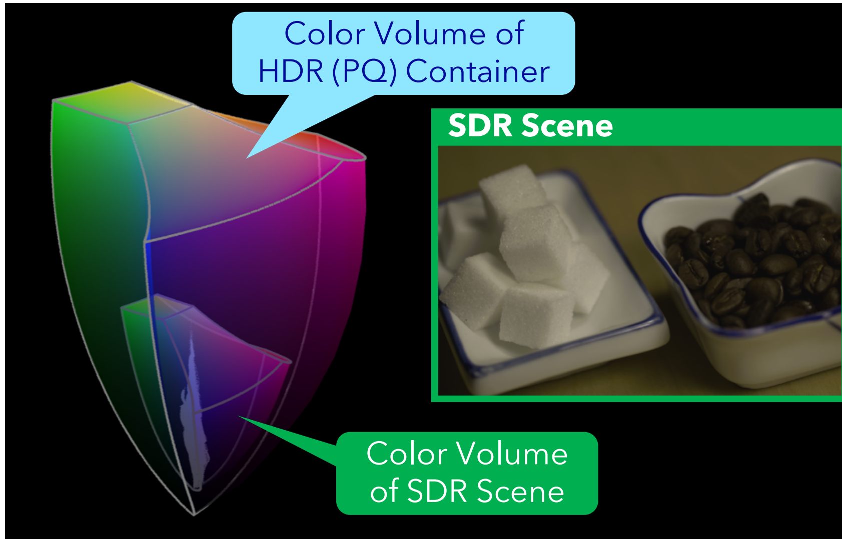
- HDR imaging pipelines for linear content more complex than pure SDR ones
- Adding HDR functionality to spatial canvas compositing increases complexity even further
- This Includes spatial compositing of content elements with varying source encoding and properties

CONTENT ELEMENTS & CANVAS

'Canvas' for Linear Content

- With linear content, the **term 'canvas' is not used**
- **'Container'** is a common term that is close in context
- A container **contains all the movie frames** & represents a **constant color volume**
- Common HDR containers use
  - PQ (absolute) and HLG (relative) **EOTFs*** (ITU-R Rec. BT.2100)
  - **Color Primaries** following DCI-P3@D65 and ITU-R Rec. BT.2100 (same as BT.2020)
- **All frames are in the same encoding**
- If they are in different encoding apply **transformation from source into container encoding**





The related concepts of OETF (opto-electrical) and OOTF (optical-optical transfer function) must also be considered, where applicable. See ITU-R Rec. BT.2100 for more detail.

Canvas-Based Approach

In a **canvas-based pipeline**, diverse content elements must be accurately ingested and placed on a canvas (spatially and sometimes temporally)

- Several encoding options for the canvas
  - **Linear Light** (Absolute or Relative, e.g., 16-bit float)
  - **PQ** (Perceptual Quantizer, ST.2084; BT2100): Absolute luminance encoding
  - **HLG** (Hybrid Log Gamma, BT.2100): Relative luminance encoding
- Identify and/or define particularities such as universal ('global') luminance levels
  - **Graphics white**: e.g., website background, luminance of closed caption

Canvas

Content Elements

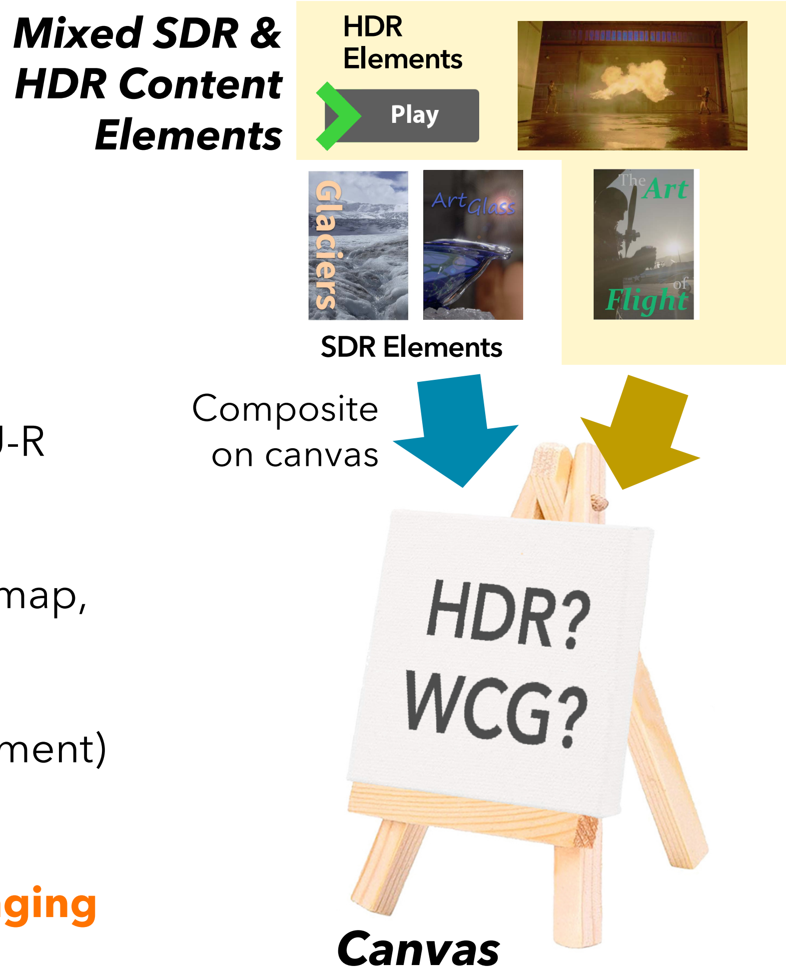
Diverse **content elements** must be placed on a canvas in a meaningful way

- How to map SDR into HDR canvas (luminance anchors or scaling required?)
- How to map different types of HDR content to same canvas?

Properties of SDR Content (and to some extent relative HDR encodings)

- Standards provide some approaches for conversion among formats (e.g., ITU-R Rec. BT.709 & BT.2100)
- There is no standard (yet?) specifying <u>all</u> properties of how to render how to map, composite and render SDR and different HDR content elements
- Properties also depend on **content creation context** (dark or bright environment) and **purpose of content.**

This makes mapping and compositing content from diverse sources challenging

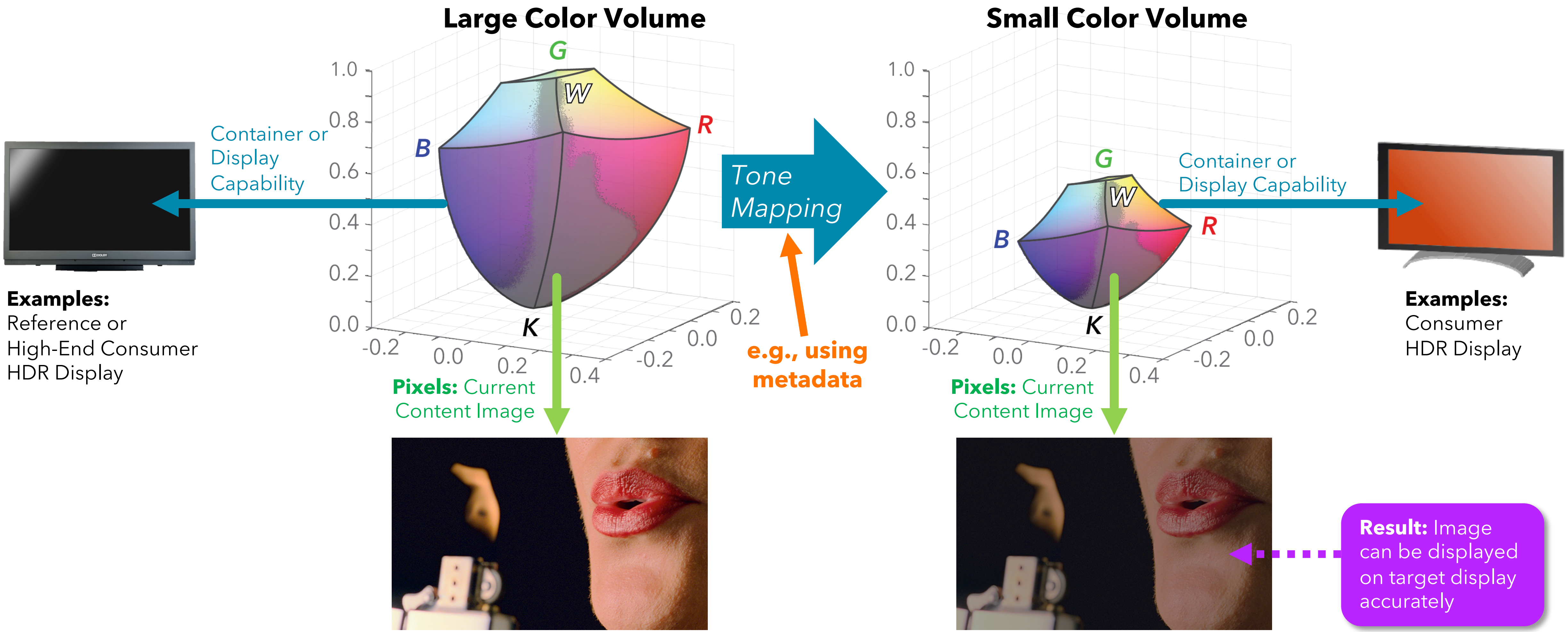


Key Take-Aways #2

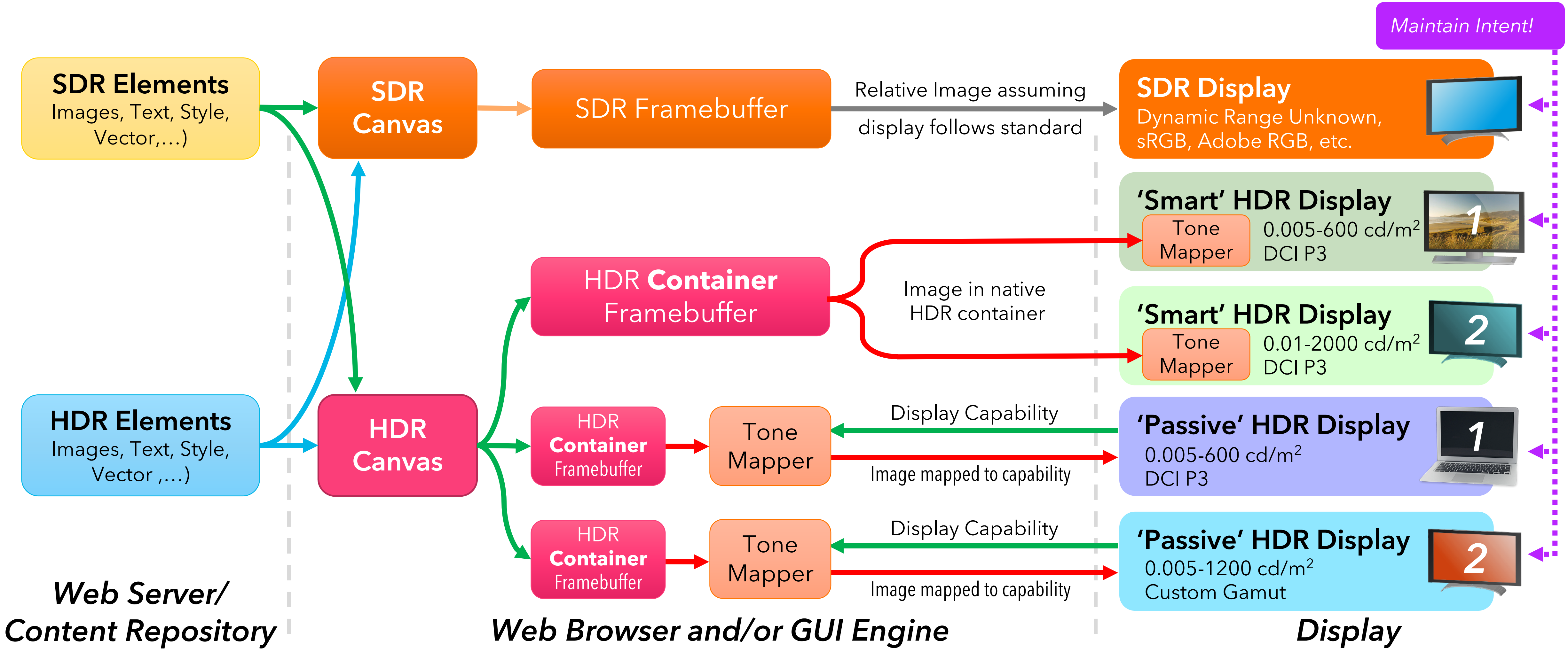
- Today, the **mastering properties of content element** such as color volume or viewing environment **are often unknown**
- **The encodings of the content elements can vary widely**
  - e.g., EOTF, absolute signal or not, color gamut,…
- **This makes mapping and compositing content from diverse sources challenging**
- Providing more **information about source & target display, content and environment** is beneficial as it can help **maintain the content's intent**
  - Metadata can likely help but requires implementation into the ecosystem e.g., SMPTE 2086, CTA 861, ITU-T Rec. H.273, EDID
- **How to do all this is an active area of research**

TONE- AND GAMUT MAPPING

Concept for Content Mapping



Pipeline Overview



CONCLUSION

Conclusion

- **Canvas compositing and rendering pipelines are more complex** than linear full screen rendering
  - Considers layout, color, shading, blending, etc. described in multiple source files
- Adding **HDR and Wide Color Gamut support complicates this process even further**
  - Ability to ingest mixed source elements e.g., provided in SDR and HDR for the same canvas
  - The final output must be compatible with different display capabilities (SDR or varying HDR)
- Display capabilities vary requiring **tone-mapping**.
  - Metadata e.g., describing properties of source content elements can help improve results
- **Backwards compatibility** must be maintained

- Independent of how we process the content for display, **the fundamental desire is to maintain the intent**
  - This Intent can be creative but can also be aimed at visual comfort.

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Standards Related to HDR

- **ARIB STD-B67** Essential Parameter Values for the Extended Image Dynamic Range Television (EIDRTV) System for Programme Production
- **CTA 861.3-A-2016** HDR Static Metadata Extensions
- **EBU Tech 3320** User Requirements for Video Monitors in Television Production. Version 4.1 (9/2019)
- **ETSI TS 103 433-1** High-Performance Single Layer High Dynamic Range (HDR) System for use in Consumer Electronics devices
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- **ITU-R Rec. BT.1886** Reference electro-optical transfer function for flat panel displays used in HDTV studio production. ITU-R. March 2011
- **ITU-R Rec. BT.2020-2** Parameter values for ultra-high definition television systems for production and international programme exchange. Oct. 2015
- **ITU-R Rec. BT.2035** A reference viewing environment for evaluation of HDTV program material or completed programmes
- **ITU-R Rec. BT.2100-2** Image parameter values for high dynamic range television for use in production and international programme exchange. July 2018
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- **ITU-R Rec. BT.2408-0** Operational practices in HDR television production. ITU-R. Oct. 2017.
- **ITU-T Rec. H.273** Coding-independent code points for video signal type identification, 2016
- **OpenEXR** High-dynamic-range scene-linear image data and associated metadata format. www.openexr.com
- **SMPTE ST 0196-2003** Motion-Picture Film - Indoor Theater and Review Room Projection - Screen Luminance & Viewing Conditions
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- **SMPTE RP 0431-2-2007** D-Cinema Quality - Reference Projector and Environment
- **SMPTE ST 2084:2014** High Dynamic Range Electro-Optical Transfer Function of Mastering Reference Displays. SMPTE 2014
- **SMPTE ST 2086:2018** Mastering Display Color Volume Metadata Supporting High Luminance and Wide Color Gamut Images
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