ICC HDR Stills Expert Day

Organised by ICC HDR working group with participation of ISO TC42 experts

TKP Tamachi Conference Center, Minato-ku, Tokyo

February 17, 2024

William Li, ICC co-chair, opened the event and introduced the agenda [see attached]. The purpose of the meeting was to invite experts to discuss issues and possible solutions for managing HDR workflows. He emphasised IP rules - same in principle as ISO, everyone should declare IP when discussing standards for publication.

Eric Walowit gave the TC42 perspective. This was an information sharing session, with no decisions; the purpose was to inform ICC of current perspectives in TC42.

ISO TC42 - HDR projects

Nicolas Bonnier described two current projects in TC42 [see attached]:

ISO 22028-5: HDR encoding for photography, supports Rec.2020 primaries, PQ or HLG transfer function, minimum 10 bits. Currently being revised.

ISO 21496-1 HDR gain map. The strategy of this approach is to store gain maps along with SDR assets, and apply the gain map to the SDR asset for better viewing on HDR displays.

Showed workflow for conversion and computation of gain map and alternate image. Gain map applied in linear RGB, map and alternate can be in different colour spaces.

HDRWG

Luke Wallis gave an HDRWG introduction [see attached]. This working group is considering how to address ICC limitations for HDR. First output was adoption of CICP tag, which was fundamental shift in ICC approach, defining the content source not the transform, and a shift from matching to optimisation. Needs implementation by CMM.

Gain map tag could potentially be added to ICC specification. Other things from 22028-5 that could be added to ICC are master display colour volume, content colour volume, colour light level.

An advantage of gain map is that is gives a way of showing image when display is not HDR-capable. Aesthetic dimension to gain map - artist conveys artistic intent. Noted that flag to indicate profile is embedded, cannot be reused - i.e. is image-specific - needs to be set in the profile.

HDR at W3C

Chris Lilley summarised work in W3C [see attached], especially in PNG and in CSS. Follows ISO 22028-5 in PNG. CSS4 is SDR only, ColourHDR discussing adding HLG, PG, ICtCp, Jzazbz, and proposal for dynamic headroom limit.

Chris Cameron discussed compositing issues. Frame buffer defined in screen colour space, compositing performed in that space. Screen col space defined in terms of primaries, transfer function and headroom, via EDID or ICC profile.

On the web, inputs converted to 2D canvas before drawing. New APIs add colour metadata and colour spaces. Need precedence rules for conversion to SDR. Linear better for compositing.

HDR in PDF

Leonard Rosenthol discussed HDR in PDF [see attached]. TC171 are reviewing the PDF imaging model. PDF is a compound format, with 11 colour spaces. Blend modes are similar to those used on web. Including support for AVIF and JPEG-XL. HDR could be added as a PDF colour space, including for blending.; or add new ImageXobj, overriding colour space. Blend modes are agnostic to file format, so it would be simpler to carry colour metadat in an ICC profile. Pages can be mixed, with vectors in SDR and images in HDR; compositor has to be able to understand diff spaces to be able to composite and render.

Considerations of White

Timo Kunkel discussed definitions of white [see attached]: they can be physical, perceptual, signal processing or display. Emphasised importance of adaptation, relative lightness and contrast. Need to bring together different streams of HDR: motion picture, stills, graphics, print.

ICC and ISO 21496-1

Yichuan Wang of Huawei asked questions about relationship between ICC.2 and ISO 21496-1 [see attached]. CICP tag better to achieve consistency for pre-gain map and post-gain map processing. Noted that linear needed for colour conversion. Conversion between YUV444 and YUV420 not needed as image has to be in RGB before conversion to PCS. Maybe no need for new specification, just documentation of best practices. Asked for gain map example profile on ICC site - noted that proposal not yet adopted in ICC. Can do HDR to SDR conversion in AToB tables; or provide HDR metadata for CMM to do conversion.

In ICC.2 can have HDR only, but we need to know more about what people are doing to move forward in ICC.

Noted that ICC not defining gain map, just trying to embrace existing methods.

Luke Wallis: gain map tag will be proposed for technical review in ICC within a few weeks, will include luma scaling. Initially in ICC.1, then ICC.2.

Some considered ICC redundant if primaries, transfer function and matric are in CICP. Advantage to having a single location, agnostic to file format etc. Need precedence rules - eg PNG says CICP takes precedence over transform in ICC profile. Gain map is linear so compatible with ICC PCS. Different decoders might give different results, but ICC transform is always the same.

Wallis stated that ICC is the best container for colorimetry and pixel colour management. It is not a problem if ICC is secondary in precedence, but he wanted to ensure consistency in implementation and that ICC is interpreted correctly. Also ICC is not format-specific.

ICC proposal is to start with source profile, apply the gain map, then apply the destination profile. If the destination is a file, need to know the encoding; or if a display, then eventually the display profile will be applied; or conversion to an intermediate space. In ICC workflows transforms are chained together, gain map is an intermediate stage. In CICP the post gain map tag will tell you the final output space. Currently CICP is required for HDR images in ICC, optional for SDR.

CICP is in ICC.1 4.4, not yet in ISO 15076. ICC will consider holding development of ISO 15076-2 to be able to potentially add HDR tags. Can't yet provide a sample profile as the specification is to be completed.

Conversion to SDR

Chris Cameron discussed conversion to SDR PCS [see attached]. HDR images that match on a reference display should match each other in SDR. He outlined a conversion algorithm based on Reinhard et al, provided a link to a test framework and images. Proposed as informative in TC42 ISO 22028-5. Scott Foshee invited Chris Lilley to make a liaison request to obtain TC42 documents, and will also make a more general case for sharing with relevant experts. Cameron showed conversion to multiple headrooms, interpolating between.

What should ICC role be? Could be providing examples, tutorials, demo implementation. Bonnier proposed a White Paper on order of operation; agreed with ICC example profiles and implementation. Max: also White Paper or specification on the relationship to the PCS, documentation of the transform and what the CMM should do. ICC.2 has extended range, could connect with CICP. Most implementations don't clip but permit out-of-range values, but ICC should clarify.

ICC and TC42 will continue work, no meeting needed before June.

ISO is asked to consider results of this meeting, and produce liaison statement to ICC with any action requests. ICC should meet to discuss. Also need to share ISO 22028-5 draft with ICC via liaison to ask for input and comment; similarly for TC171.

Scott Geffert invited TC42 to meet at Met, will follow up with Rosenthol (who is hosting June meeting at Adobe New York).

ICC HDR Stills Experts Day

Supporting ISO HDR Stills in ICC color managed workflows

Feb 19, 2024 - Tokyo

General Information

- **Introduction**
    - The ICC hosts the *ICC HDR Stills Experts Day* to collaborate with ISO TC42 HDR experts on how to best support ISO HDR Stills in ICC color managed workflows.
- **Goals**
    - Share the latest devolvements in ISO, ICC, W3C and PDF HDR working groups
    - Define how to build support for ISO HDR Stills in ICC color managed workflows
- **Targeted audience**
    - ICC members
    - ISO HDR experts
- **Date**
    - February 19, 2024
- **Location**
    - TKP Tamachi Conference Center
Tamachi Nikko Building B1/2F
5-29-14 Shiba
Minato-ku, Tokyo 108-0014 Japan
- **Registration**
    - https://www.color.org/events/hdr/HDR_Experts.xalter

Agenda

- Welcome - Wil Li
- Summary of all activities: top level overview from project leaders - 1 hour
  - ISO HDR - Nicolas Bonnier
  - ICC HDRWG - Luke Wallis
  - W3C & HDR - Chris Lilley
  - TC171 SC2 PDF - Leonard Rosenthol
  - QA

- Break

- Invited talk Timo Kunkel –Appearance, Conventions & Technological Considerations of White - 30 min talk + QA
- Baseline tone mapper for ISO 22028-5 images - Chris Cameron
- ICC and ISO 21496-1 - Yichuan Wang

- Lunch break

- Working sessions: HDR color management workflow - 2 to 3 hours
  - Building a profile for ISO HDR stills
  - Tone mapping ISO HDR images to SDR
  - HDR metadata, where does it live? How to deal with redundancy?
  - Workflows from capture through editing to publication and/or print
  - Future work: what else are we missing?

- Demos

ISO TC42 - HDR projects

ICC HDR Experts Day 2024

Nicolas Bonnier Feb 19, 2024

ISO HDR Stills File Formats

ISO HDR file format

Technical Specification: TS 22028-5

- *Photography and graphic technology — Extended colour encodings for digital image storage, manipulation and interchange — Part 5: High Dynamic Range and Wide Colour Gamut encoding for still images (HDR/WCG).*
  - Work conducted within the HDR Ad-Hoc Group of the ISO Technical Committee 42, Photography
- **Project Leaders:** Nicolas Bonnier & Paul Hubel
- **Timeline**: 2019-2023 **Published!**
- Goals
  - Provide requirements and guidelines for HDR/WCG colour encoding of still images.
  - Meet the industry need for a complete, fully documented, publicly available definition of a high dynamic range (HDR) and wide colour gamut (WCG) image encoding for digital still images.

TECHNICAL SPECIFICATION

ISO/DTS 22028-5

ISO/TC **42**

Secretariat: **ANSI**

Voting begins on:
2023-03-23

Voting terminates on:
2023-05-18

Photography and graphic technology — Extended colour encodings for digital image storage, manipulation and interchange —

Part 5:
High dynamic range and wide colour gamut encoding for still images (HDR/WCG)

Photographie et technologie graphique — Codages par couleurs étendues pour stockage, manipulation et échange d'image numérique —

Partie 5: Plage dynamique élevée et codage large de la gamme de couleurs pour les images fixes (HDR/WCG)

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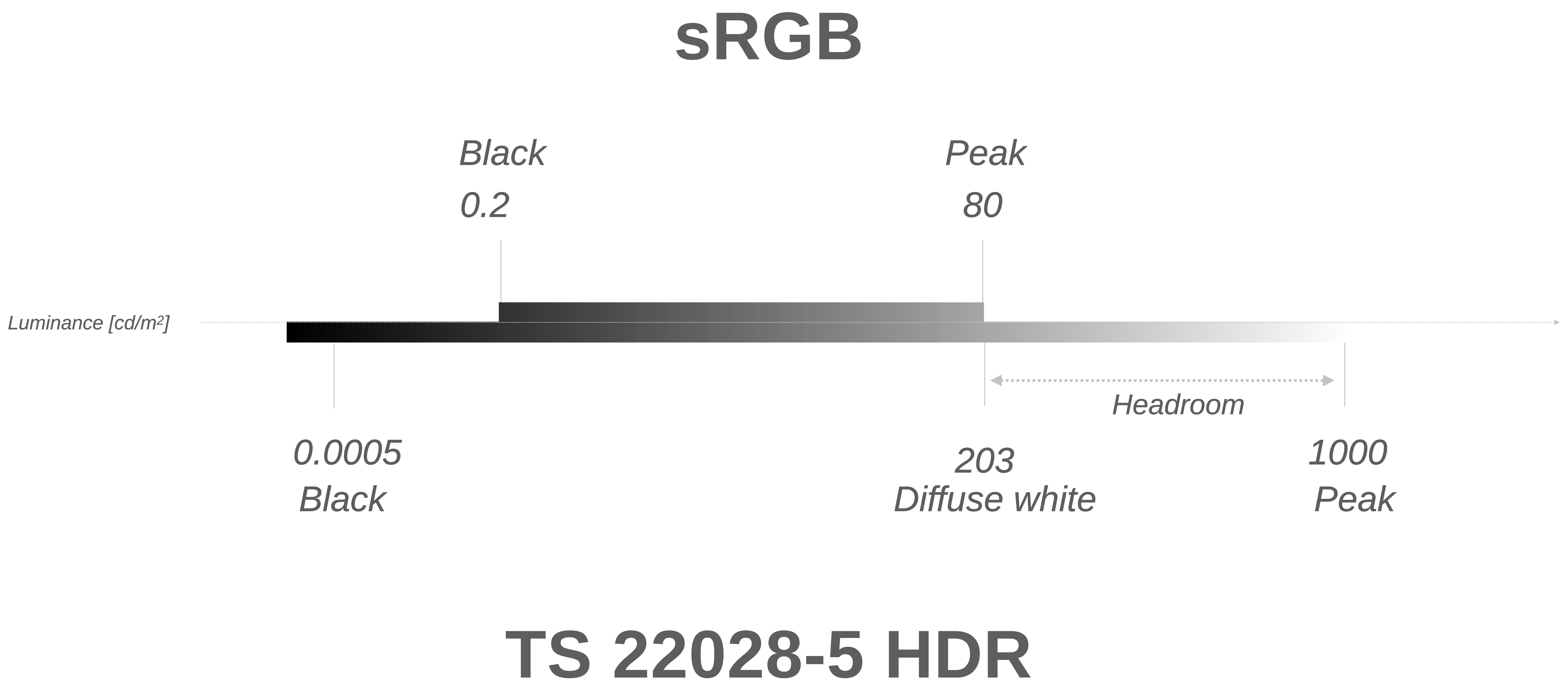
Reference number
ISO/DTS 22028-5:2023(E)

TS 22028-5 Key specs and metadata

Transfer functions	Shall use either the HLG transfer function or the PQ transfer function
Color encoding	Shall use ITU-R BT.2020/2100-2 colour primaries, RGB or YCbCr non constant luminance representations
Signal range	10bit, both narrow range and full range representations might be used
Metadata	Normative: Either CICP or an ICC Profile containing a cicpTag Optional: • Mastering Display Colour Volume (MDCV) • Content Colour Volume (CCV) metadata • Colour Light Level (CLL) • Diffuse white luminance: stores the luminance value of the reference nominal diffuse white, in cd/m2 • Scene referred: indicates that image is intended to represent estimated scene colorimetry

TS 22028-5 Reference display



TS 22028-5 Reference display and environment

Reference display

Parameter	Values
Default nominal peak luminance	1 000 cd/m2
Default black point	0.0005 cd/m^2
Default nominal diffuse white luminance	203 cd/m^2
Default reference color volume	ITU-R BT.2020-2 RGB

Reference environment

Parameter	Values
Colour temperature of surround and periphery	Neutral grey at D65
Luminance of surround	5 cd/m^2
Luminance of periphery	$\leq$ 5 cd/m^2
Spatial distribution of ambient lighting	No direct specular light sources shall be incident upon the eyes of the observer or the display.

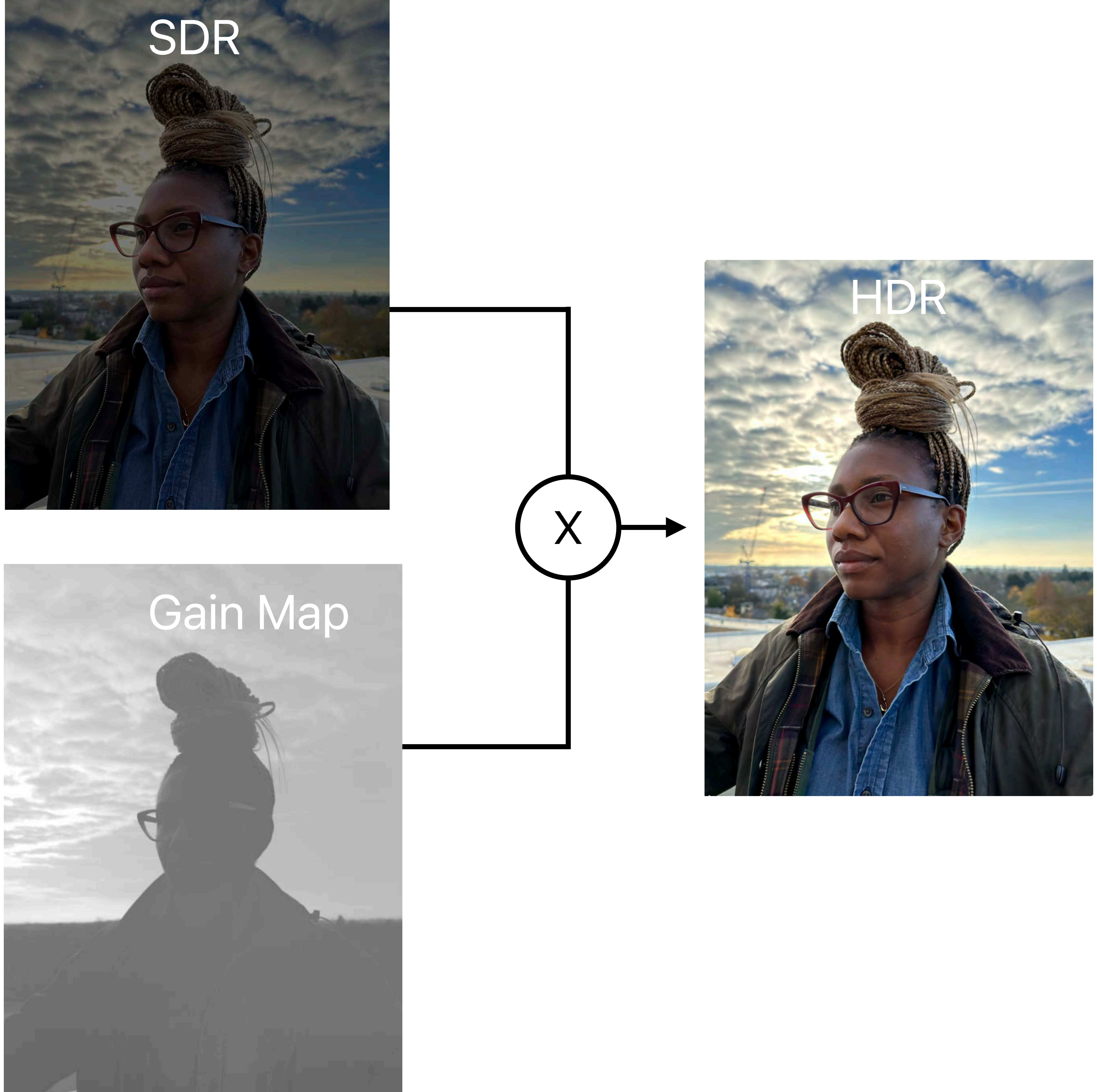
ISO HDR file format

Revision of TS 22028-5

- Goals
  - Revision and conversion to International Standard
  - Addition of default tone mapping in informative annex
- Timeline
  - Vote passed 2023-09-15
  - CD: 2024-07-01
  - DIS: 2024-11-01
  - Publication: 2025-07-01

ISO HDR Stills File Formats

Gain map stills



Flexible dynamic range

Tuesday 17 January Plenary

14:00 -15:00

Embedded Gain Maps for Adaptive Display of High Dynamic Range Images

Eric Chan, Paul M. Hubel, Garrett Johnson, and Thomas Knoll, with presentation by:
Eric Chan, *Fellow, Adobe Inc., and* **Paul M. Hubel**, *director of Image Quality in Software Engineering, Apple Inc.*

Images optimized for High Dynamic Range (HDR) displays have brighter highlights and more detailed shadows, resulting in an increased sense of realism and greater impact. However, a major issue with HDR content is the lack of consistency in appearance across different devices and viewing environments. There are several reasons, including varying capabilities of HDR displays and the different tone mapping methods implemented across software and platforms. Consequently, HDR content authors can neither control nor predict how their images will appear in other apps.

We present a flexible system that provides consistent and adaptive display of HDR images. Conceptually, the method combines both SDR and HDR renditions within a single image and interpolates between the two dynamically at display time. We compute a Gain Map that represents the difference between the two renditions. In the file, we store a Base rendition (either SDR or HDR), the Gain Map, and some associated metadata. At display time, we combine the Base image with a scaled version of the Gain Map, where the scale factor depends on the image metadata, the HDR capacity of the display, and the viewing environment.

Eric Chan is a Fellow at Adobe, where he develops software for editing photographs. Current projects include Photoshop, Lightroom, Camera Raw, and Digital Negative (DNG). When not writing software, Chan enjoys spending time at his other keyboard, the piano. He is an enthusiastic nature photographer and often combines his photo activities with travel and hiking.

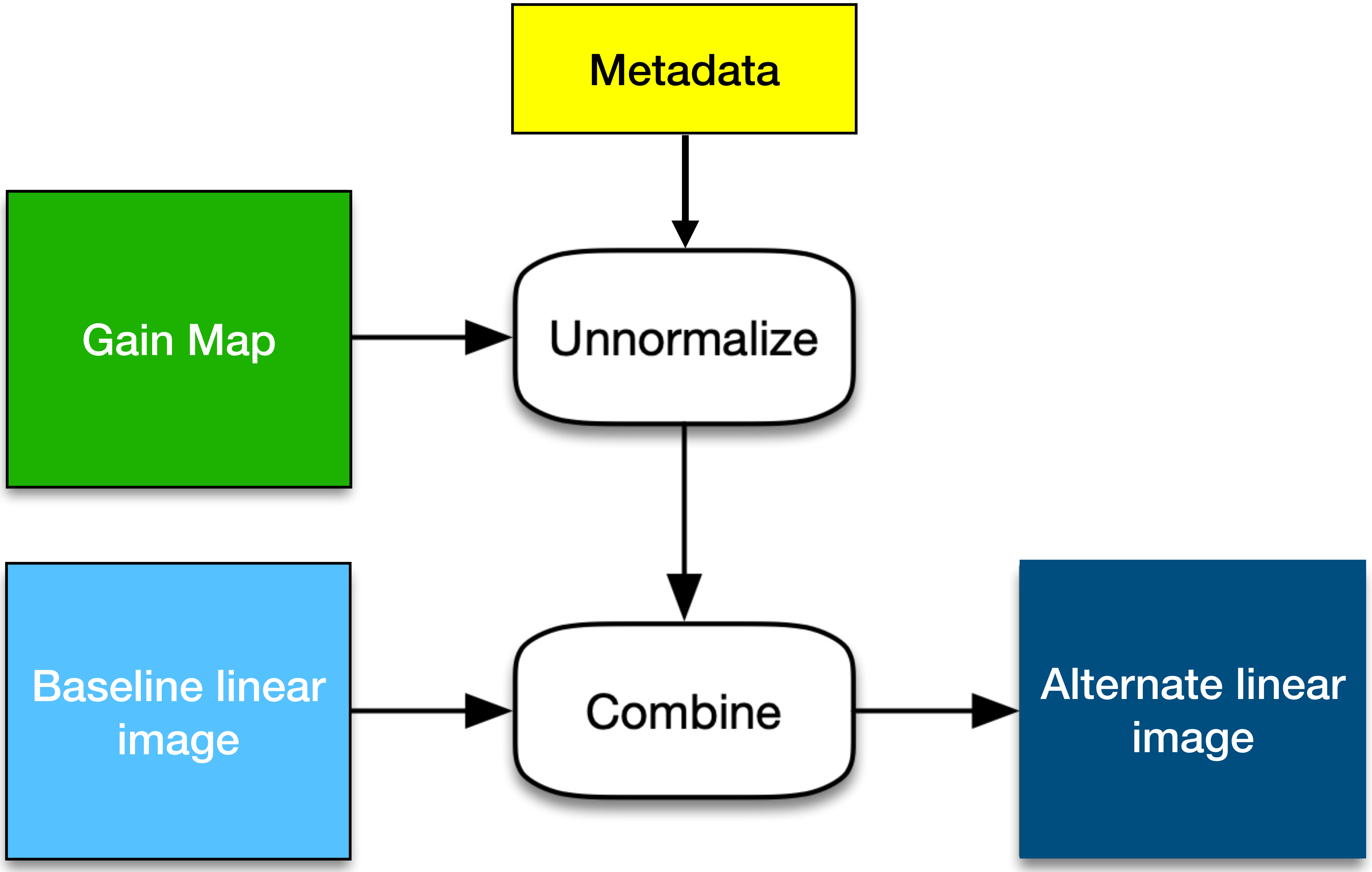
Paul M. Hubel is director of Image Quality in Software Engineering at Apple. He has worked on computational photography and image quality of photographic systems for many years on all aspects of the imaging chain, particularly for iPhone. He trained in optical engineering at University of Rochester, Oxford University, and MIT, and has more than 50 patents on color imaging and camera technology. Hubel is active on the ISO-TC42 committee Digital Photography, where this work is under discussion, and is currently a VP on the IS&T Board. Outside work he enjoys photography, travel, cycling, coffee roasting, and plays trumpet in several bay area ensembles.

Standardization | ISO HDR Gain Map

ISO/NP 21496-1 – Digital Photography -- Gain map metadata for image conversion -- Part 1: Dynamic Range Conversion

- Scope
  - This document defines a gain map used in HDR digital photography applications, for dynamic range conversion between image representations. This includes the definition of the gain map metadata and its attributes, how to apply a gain map, and how to specify the gain map and other associated metadata.
- Project Leaders: Nicolas Bonnier (Apple), Paul Hubel (Apple) and Scott Foshee (Adobe)
- Purpose and justification
  - High dynamic range (HDR) images, that have been produced for HDR displays, can provide a better user experience. One challenge is ensuring that there is no image quality regression when displaying an HDR image on standard dynamic range (SDR) displays.
  - This can be solved by creating a standardized solution that includes storing in the same file a baseline image and a gain map, to convert between HDR and SDR representation.
  - Compared with storing both the HDR and SDR representations, the benefit of this solution is the optimization of the file size, obtained by minimizing the amount of redundant data stored.
- Timeline
  - Initial introduction Fall 2022
  - New Work Item Proposal approved July 6, 2023
  - Circulation of 1st Working Draft to experts: 2023-10-06
  - Committee Draft consultation (if any): 2024-01-19
  - DIS submission*: 2025-01-19
  - Publication*: 2025-05-19

ISO 21496- 1| Gain map application



ISO 21496- 1| Gain map computation

ISO 21496- 1| Color conversion

ICC - HDR projects

ICC HDR Experts Day 2024

Luke Wallis, Feb 19, 2024

ICC HDR Working Group

Working group charter:

The HDR Working Group exists to promote the use of ICC color management in HDR imaging.

- Specifically, this group will:
  - Identify issues and limitations with the current implementation and use of color management in HDR imaging.
  - Develop proposals for how to include HDR in ICC workflows.
  - Prepare white papers and other educational materials to aid developers and users in the appropriate application of color management to HDR.
  - Propose revisions to ICC specifications where required to address the needs of HDR workflows.

v4 PQ and HLG profiles

Created by Lars Borg (Adobe)

Allow to convert HDR to SDR with hardcoded SDR reference white point

- Good first order approximation
- Main issues:
  - No tags to identify specific HDR format and relevant processing steps documented in HDR format specifications (ITU format conversion recommendations).
  - Anonymous sequence of conversion steps uncorrelated to specifications.
  - Single channel correction leading to hue shift

CICP tag

Significant shift in ICC profile concept

Uniquely identifies HDR standard file format.

- CMM needs to implement relative processing steps (no longer included in the profile)
- Other benefits:
  - Easy inclusion of specialized HW e.g. GPU builtin PQ EOTF to linearize signal
  - No need to update profiles to follow updates of ITU recommendations.
  - Choice of different tone mapping techniques depending on the tone mapping goal*

HDR Gain Maps

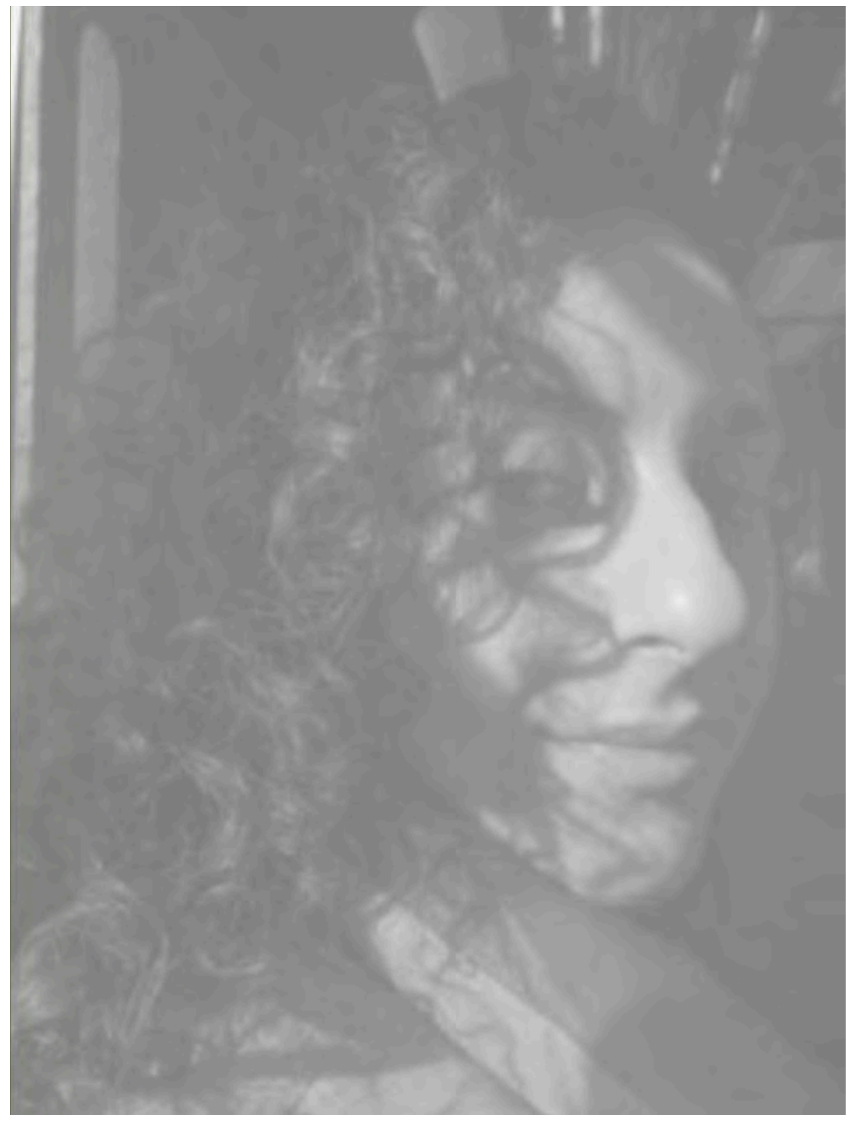
Gain Maps provide powerful, image specific HDR management

Significant use of system resources (memory, processing, power)

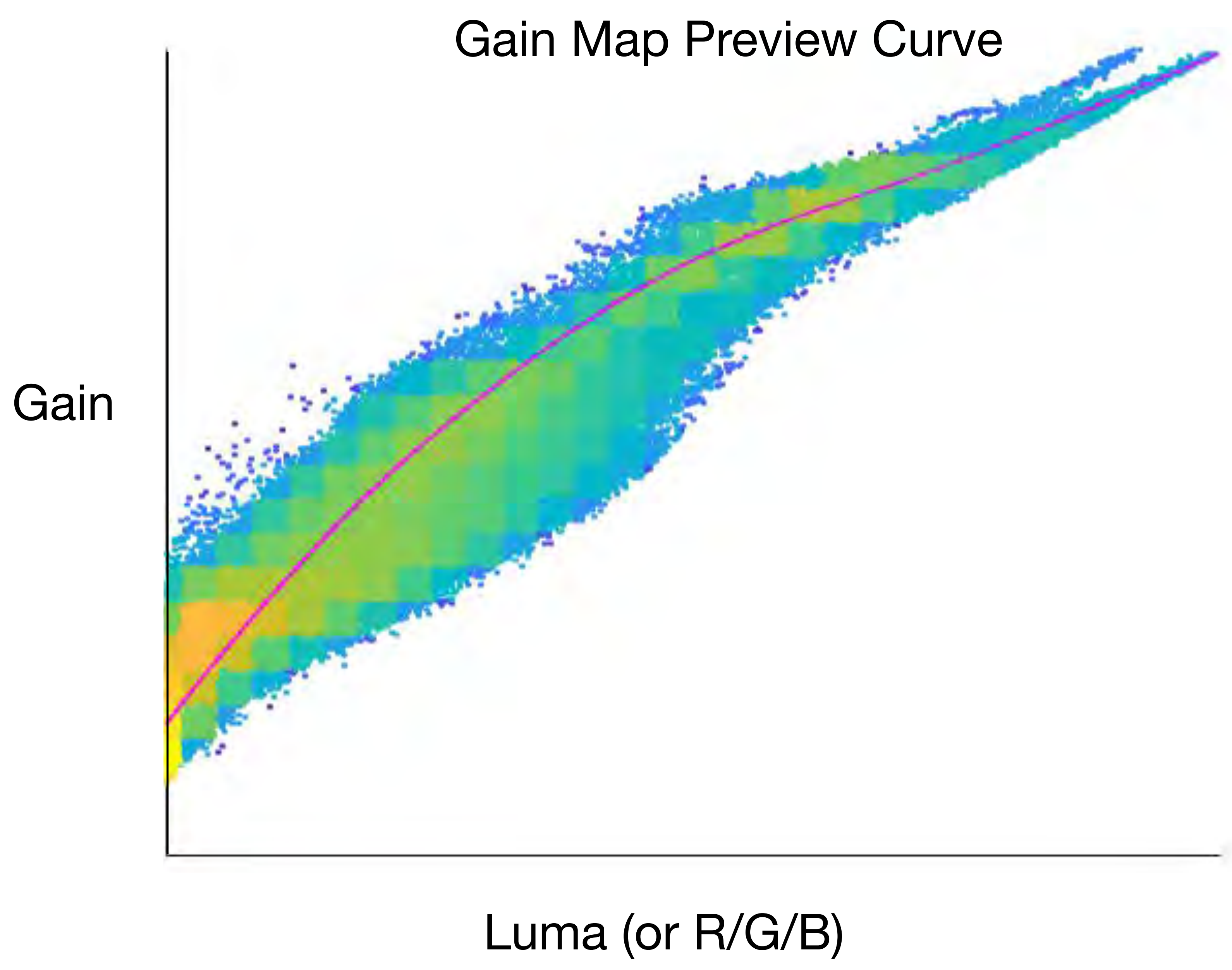
- Many situations when less expensive approximation of Gain Map usage is desired.
  - Proposed approximation: image specific, global tone mapping function calculated from Gain Map.

Gain Map Preview Curve

Gain Map Based Global Tone Mapping Function



Gain Map



Currently based on monochrome gain map, but expandable to RGB gain map

Gain Maps, Gain Map Preview Curves and ICC

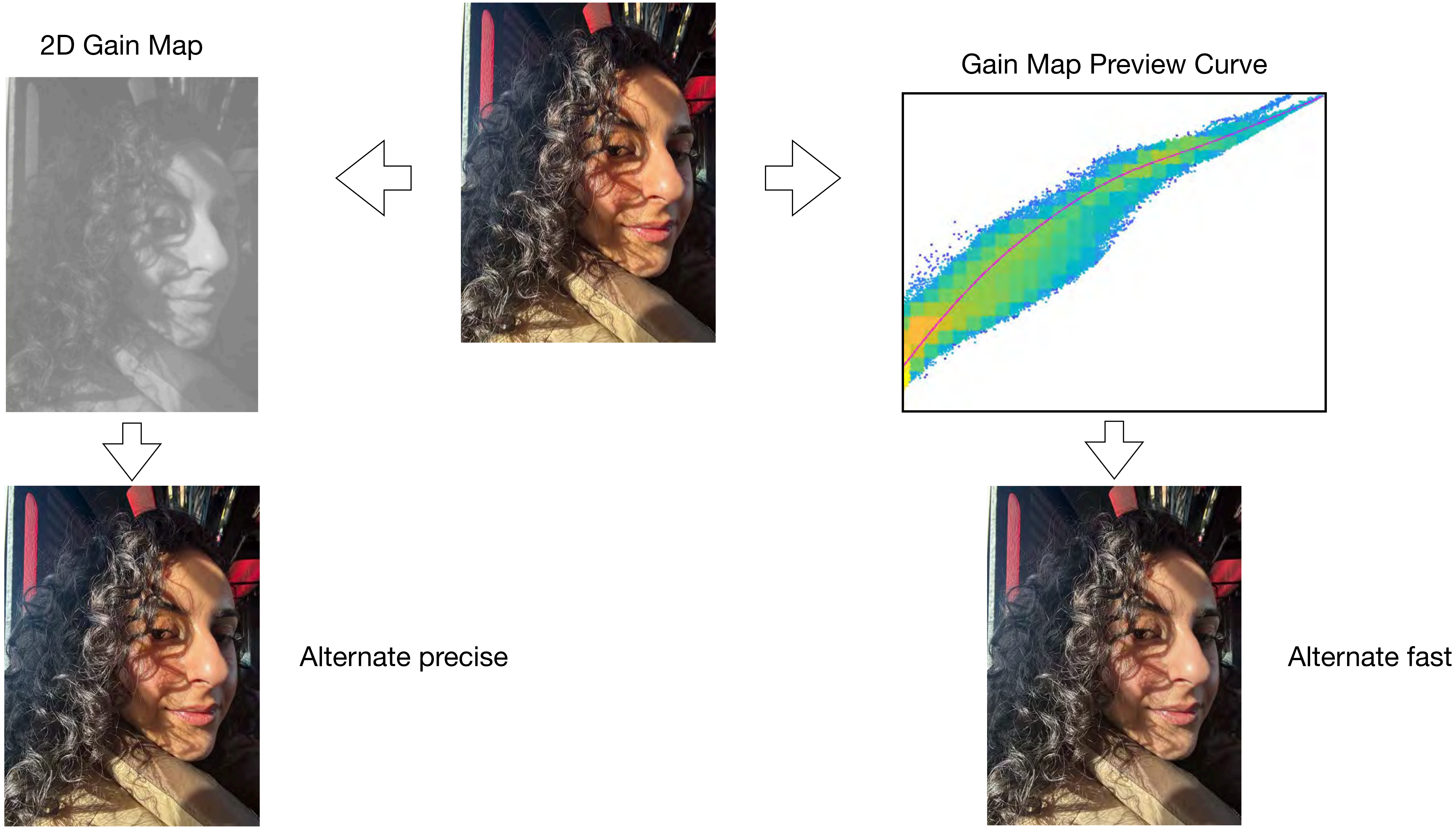
Expand ICC profile to include Gain Map Preview Curve

Gain Map metadata is shared with Gain Map Preview Curve

- Gain Map Preview Curve, same as Gain Map, can be used for tone mapping to specified target headroom.
- Standardized by ICC, Gain Map Preview Curve produces consistent results across different CMMs.
- ICC profile contains Gain Map and Gain Map Preview Curve metadata in a new Gain Map tag.

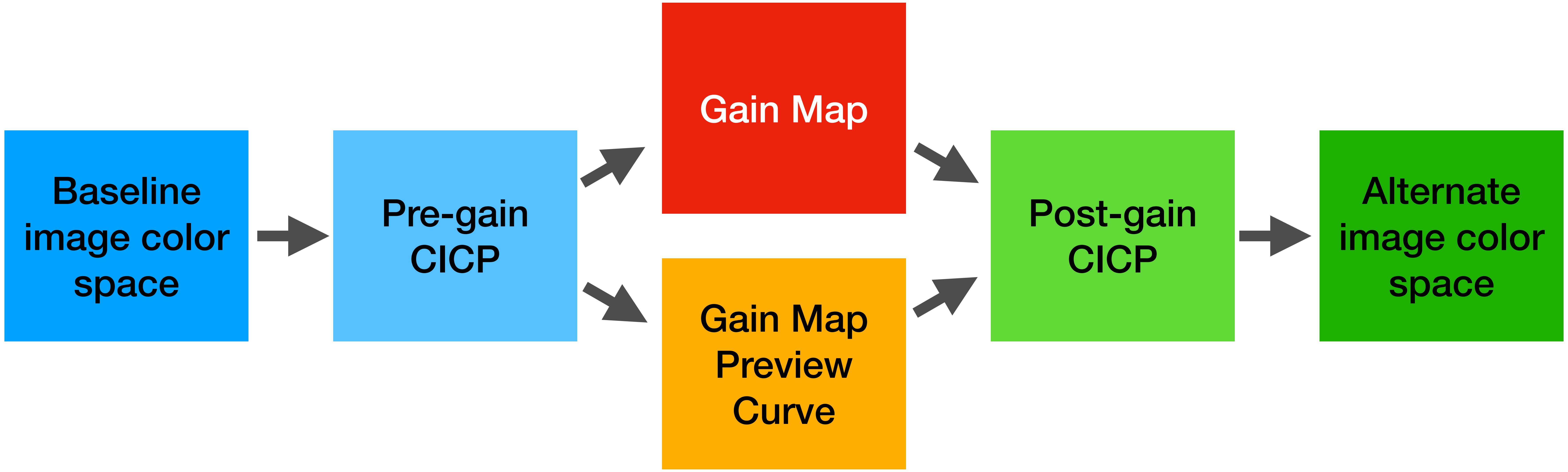
Converting Baseline to Alternate

ICC profile provides two options: Precise or Fast



Gain Map Tag Color Conversion Steps

Gain Map or Gain Map Preview Curve applied in a color space of choice



Gain Map Tag and Backward Compatibility

Is it possible to create v4 tags emulating Gain Map Preview Curve?

Multiple steps in lutAtoB tag are a good option

- v4 can only accommodate one target headroom.
- HDR to SDR should be sufficient for backward compatibility.

Other HDR related topics to be addressed by ICC

HDR Display Profile

HDR Display headroom characterization

- static value of headroom not sufficient to describe dynamic behavior of HDR displays

22028-5 Metadata in ICC profile

MDCV - Master Display Color Volume

CCV - Content Color Volume

CLL - Color Light Level

???

HDR at W3C

ICC HDR Stills Expert Day
Tokyo, Japan

19 February 2024
Chris Lilley, W3C

Overview

Workshop on WCG & HDR (2021)

Portable Network Graphics (PNG)

HTML Canvas

Cascading Style Sheets (CSS)

Selected workshop outcomes:

Formats for HDR images needed

HDR tone mapping

Prototyping HDR in Canvas

WCG Interoperability in CSS

Portable Network Graphics (PNG)

Clarification: ICC.1 v2 & v4

Standardized: Animated PNG

Added: EXIF

Portable Network Graphics (PNG)

Coding-independent code points (CICP)
(from ITU-T H.273)

BT.2100 HLG = 09/18/00/01
Display P3 = 11/13/00/01

Portable Network Graphics (PNG)

Mastering Display Color Volume (MDCV)
(from SMPTE ST 2086)

e.g. P3-D65 2k in BT.2100 PQ container

Portable Network Graphics (PNG)

Content Light Level Information (CLLI)
(from SMPTE ST-2067-21)

Maximum Frame Average Light Level (MaxFALL)
Maximum Content Light Level (MaxCLL)

HDR in HTML Canvas

(by Christopher Cameron)

Cascading Style Sheets

CSS Color 4

SDR only

Predefined RGB color spaces

CIE Lab & LCH, Oklab & Oklch

CSS Color 4

Color conversion

Color interpolation (any colorspace)

Media Queries 5

Color gamut (srgb | p3 | rec2020)

Dynamic range (standard | high)

CSS Color HDR

BT.2100 HLG, PQ & linear

IC_TC_P

$J_za_zb_z$ & $J_zC_zH_z$

CSS Color HDR

Dynamic-headroom-limit CSS property
(standard | high | constrained-high)

Continuously animatable

HDR in W3C – Chris Lilley

Text transcript

(title slide)

Hi, I'm Chris Lilley. I'm a Technical Director at the World Wide Web Consortium (W3C) and the W3C representative to the ICC. I am also co-editor of CSS Color 3,4,5 and editor of CSS Color HDR.

(slide 2, Overview)

Current activity on HDR at W3C was spearheaded by a workshop we did in 2021 on Wide Color Gamut and High Dynamic Range on the Web.

Around the same time, work was restarted on the image format Portable Network Graphics (PNG); there was a proposal to extend HTMl Canvas for HDR, and another for Cascading Style Sheets, which had already been extended to WCG starting in 2016.

(slide 3, Selected workshop outcomes)

The workshop report https://www.w3.org/Graphics/Color/Workshop/report.htm identified a number of next steps, including:

- the need for browsers to support ile formats for 2D image HDR distribution - further investigation of HDR tone mapping

- prototyping to proposal for HDR in Canvas

- improving WCG Interoperability for CSS

(slide 4, Portable Network Graphics)

The PNG specification, whose second edition was jointly published in 2003 by W3C and by ISO (as ISO/IEC 15948:2003), was in need of maintenance for clarification, corrections and errata (for example due to the age of the specification, it only allowed version 2 ICC profiles, although in practice implementations accepted v4 as well); there was also a desire to incorporate the widely implemented, but unofficial, extensions for Animated PNG, to add EXIF to the main specification (it had been loosely defined in an extensions document) and as already said,to extend PNG to support HDR imagery.

Compatibility with existing images and decoders was seen as critical.

(slide 5, PNG)

Labelling of HDR content was done by referring to Coding Independent Code Points, defined in the freely available specification ITU-T H.273 which is widely used for video content and also in still image or image-sequence formats such as AVIF and JPEG-XL.

Numerical codes identify the primary and white chromaticities, the transfer function, the matrix to convert to RGB (if applicable) and whether the data is narrow-range or full-range. For example, Hybrid Log Gamma BT.2100 content uses the (decimal) values 9 for chromaticities (same for PQ and for BT.2020 SDR), 18 for the HLG transfer function, 00 to indicate the data is already RGB, and in this case 01 to indicate full-range data.

The same signalling method can identify some SDR formats; for example Display P3. In contrast to ICC profiles, only a select number of formats can be labelled; for example ProPhoto RGB cannot be so described. However, the labelling is very compact, with only four data bytes.

Chrome and Safari already implement CICP in PNG and other image formats; Firefox supports it in AVIF and is expected to add PNG support soon.

(slide 6, PNG)

It's common for image and video content not to use the entire theoretical color volume. Not just for artistic reasons, but also because the delivery method might mandate a larger color space.

Calculating the actual frame-by-frame or scene-by scene color usage is computationally expensive and not necessarily desirable if that would cause gamut or tone mapping to vary.

A useful and content-independent upper bound can be established simply by recording the characteristics (chromaticities, minimum and maximum luminance) of the reference display used for content creation or final grading. This is specified by SMPTE ST 2086,a specification which (following a request from W3C) is now freely available.

For example, content is often graded on a display with DCI P3 primaries, a D65 white point, with a maximum peak luminance of 2,000 cd/m^2 and a minimum black luminance of 0.02 cd/m.

It is then delivered as BT.2100 PQ, which has a significantly wider color gamut and a theoretical peak luminance of 10,000 cd/m^2.

PNG Third Edition enables MDCV to be recorded, adding only 24 data bytes and fitting into existing content workflows.

(slide 7, PNG)

Consistent tone mapping is aided by summary information on content luminance levels. It would not be practical, particularly for animations or for streaming content, to analyze this in real time.

SMPTE ST-2067-21 defines two metrics: the mean luminance of the brightest frame, and the luminance of the brightest pixel (in practice, typically filtered to remove outliers).

PNG Third Edition enables CLLI to be recorded, adding only 8 data bytes.

(slide 8, HDR in HTML Canvas)

This will be covered by Christopher Cameron in a separate presentation.

(slide 9, Cascading Style Sheets)

Turning now from image formats to CSS, which is used to describe the color and formatting of web pages.

(slide 10, CSS Color 4)

The early web was a firmly sRGB-only environment.

In 2016, with the widespread availability of WCG screens on laptops, tablets and phones, CSS Color 4 defined how to use WCG colors in CSS. The focus was (deliberately) on standard dynamic range and media white-relative colorimetry.

In addition to sRGB it also added Display P3, ProPhoto RGB, BT.2020, and CIE XYZ (with either D50 or D65 white points).

To permit color manipulation in a perceptually uniform space, CIE Lab and LCH(ab) were added and then, later, Oklab and Oklch which have improved hue linearity and hue uniformity, avoiding the need to use computationally complex ΔE2000

(slide 11, CSS Color 4)

In addition to defining these various color models, sample code was provided for color conversion.

In the case of differing white points, the linear Bradford CAT is used, as with ICC. Color interpolation is also defined between any two colors; the color definitions and the color space used for interpolation need not be the same.

Special attention is given to interpolating in polar spaces with near-neutrals, whose hue is ill-conditioned.

CSS Images 4 uses this to specify the color space used for color gradient interpolation.

(slide 12, Media Queries 5)

Conditional logic allows broad categories of display device to be distinguished: standard, wide, and ultrawide gamuts, and standard or high dynamic range.

(slide 13, CSS Color HDR)

When defining CSS Color 4 as SDR-only, it was necessary to verify that later expansion to HDR was possible, in other words, to check we were not painting ourselves into a corner.

I wrote an unofficial draft which proposed the use of BT.2100 (both RGB forms, and also ICtCp as a perceptually uniform space).

Jzazbz and the corresponding polar form, JzCzHz, were also defined. ICtCp could be used for color mixing and distance estimation (ΔEITP)

This draft was recently adopted by the CSS Working Group, and a linear-light form of BT.2100 was also added at that time.

It is too early to see browser implementations, although all these color spaces are implemented

in the JavaScript library color.js https://colorjs.io/

(last slide 14, CSS Color HDR)

Even more recently (last week), the CSS WG adopted a proposal by Christopher Cameron to define a property to limit the degree of HDR on a per-page or even per-element basis.

The constrained-high value is defined to be "enough HDR" to allow comfortable viewing of SDR and HDR content side by side, for example in an image gallery.

For privacy reasons the exact number of stops of HDR headroom is not exposed to the platform (otherwise a web page could track, for example, when a user moves outdoors) but the implementation has access to this internally, so that the values may be smoothly animated.

For example, in an image gallery, hovering over an image or displaying it larger could smoothly bring it to full HDR.

Thank you for your attention.

HDR in PDF

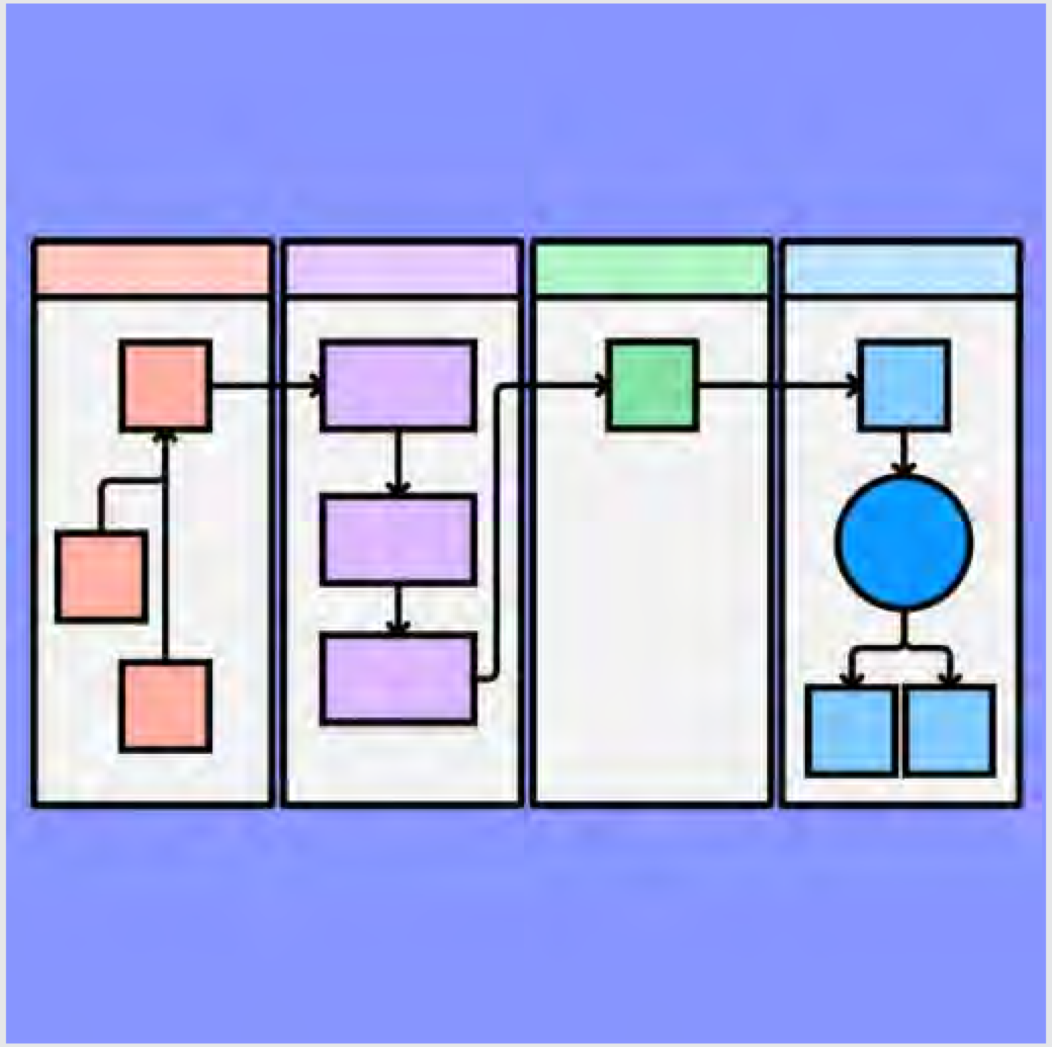
Leonard Rosenthol, PDF Architect, Adobe

What is “unique” about PDF?

- **Compound document format**
  - Text, Vectors, & Raster images
  - Annotations
  - Video & 3D
- **11 Colorspaces**
  - 3 device dependent
  - 4 device independent
  - 4 special
- **Complex Transparency**
  - Simple alpha channel or mask on all objects (or groups of objects)
  - Blending Modes
  - Blending Groups

PDF is part of workflows

- Exchange
- Reuse
- Archiving
- Printing



Initial focus of TC 171/SC 2

- Raster images
  - Required to support new image formats (AVIF & JPEG XL)
  - Required by PDF/R (PDF for Raster imaging as used by TWAIN & scanning)
  - Align with work of TC 42 & ICC
- Text & Vectors
  - Ensure that colors “match” associated images

HDR is “sort of” like a colorspace

- Need to know if a given image in HDR or SDR
  - “source colourspace”
- Need to know whether the final output device is HDR or SDR
  - “destination colourspace”
  - potentially related to OutputIntent?
- Need to know what do with transparency blending
  - “blending colourspace”

Option 1: Create a new colourspace

- Most logical
  - Can be used anywhere/everywhere one can be used
  - Doesn’t help for OutputIntent (but would for blending space)
- But not backwards compatible
  - (since existing viewers won’t know what to do)

Option 2: New “HDR” key

- Add to Image XObj, Transparency & Page Groups & OutputIntent
  - When present, overrides the ColorSpace/CS entries or DestOutputProfile
- Older (non-compliant) processors fall back to standard colourspace

Format for HDR data

- Somewhat dependent on the results of the HDR Experts Day
- We expect to store CICP & MDCV (Mastering Display Color Volume) data

- Options
  - Small binary blobs, which would be new to PDF and not a native concept
  - Arrays of integers (most logical, but takes up more space)
  - HexString of values (relatively equivalent, but weird)

Embedded HDR data inside an Image XObj?

- Newer formats we are discussing support native HDR
- HDR data can be encoded into JPEG 1 (aka DCTFilter) images

- Need to determine whether to
  - copy values out?
  - Read the internal data always?
  - Add some keys to specify which way (ala “SMaskInData”)?

PQ vs. HLG

- Do we want to support both models or only one?
  - Both means more work on the processor/renderer
  - Only one means that the creator may have to transcode

- Do we want to support different options for raw PDF data vs. embedded in images?
  - We might want to allow for less modifications when embedding new formats

Thank you!


thank you
thank you
thank you
thank you
thank you
thank you
thank you
thank you

Let’s Discuss

Dolby

Appearance, Conventions & Technological Considerations of White

—

Timo Kunkel, PhD

Office of the CTO

Dolby Laboratories, Inc.

Contact: *timo.kunkel@dolby.com*

What is White?

White = [255,255,255]

Convention to describe

- The brightest 'color' a system can process…
- In context of an encoding scheme (e.g. 8-bit integer, gamma encoded, sRGB)
- Relative in luminance

To know the appearance, other system properties need to be known!

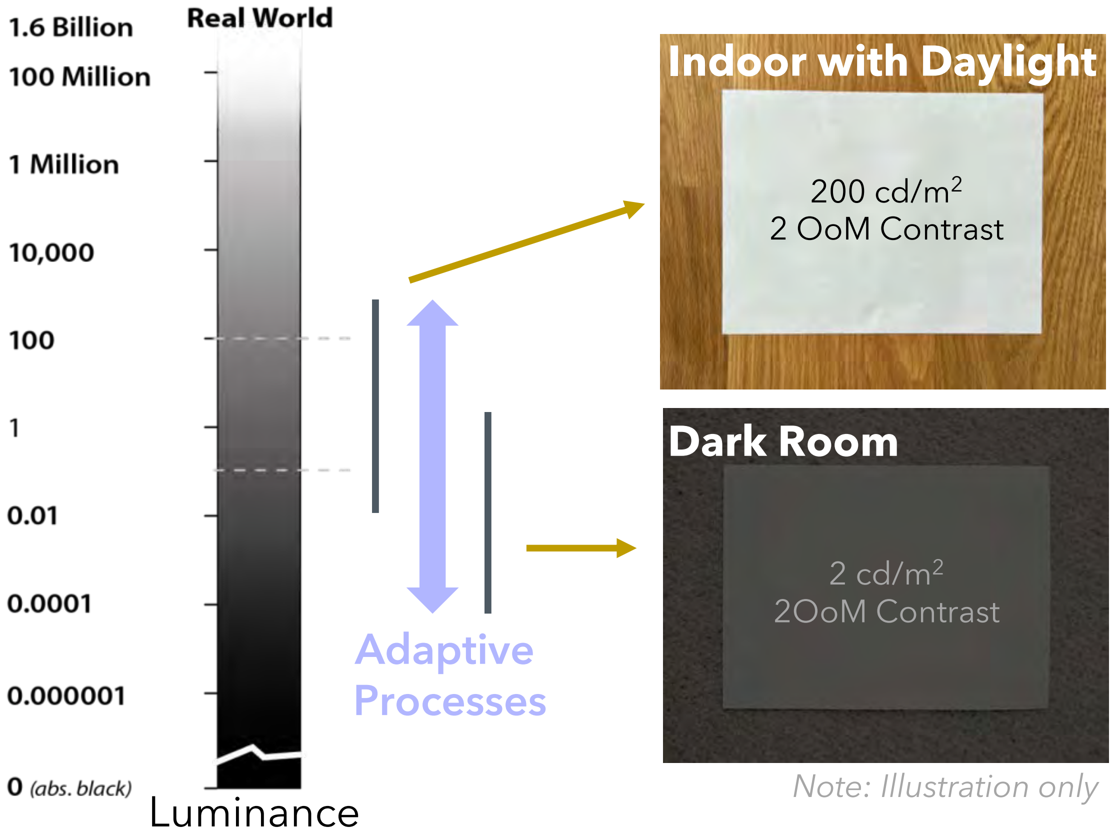
Why do We Need to Differentiate Whites?

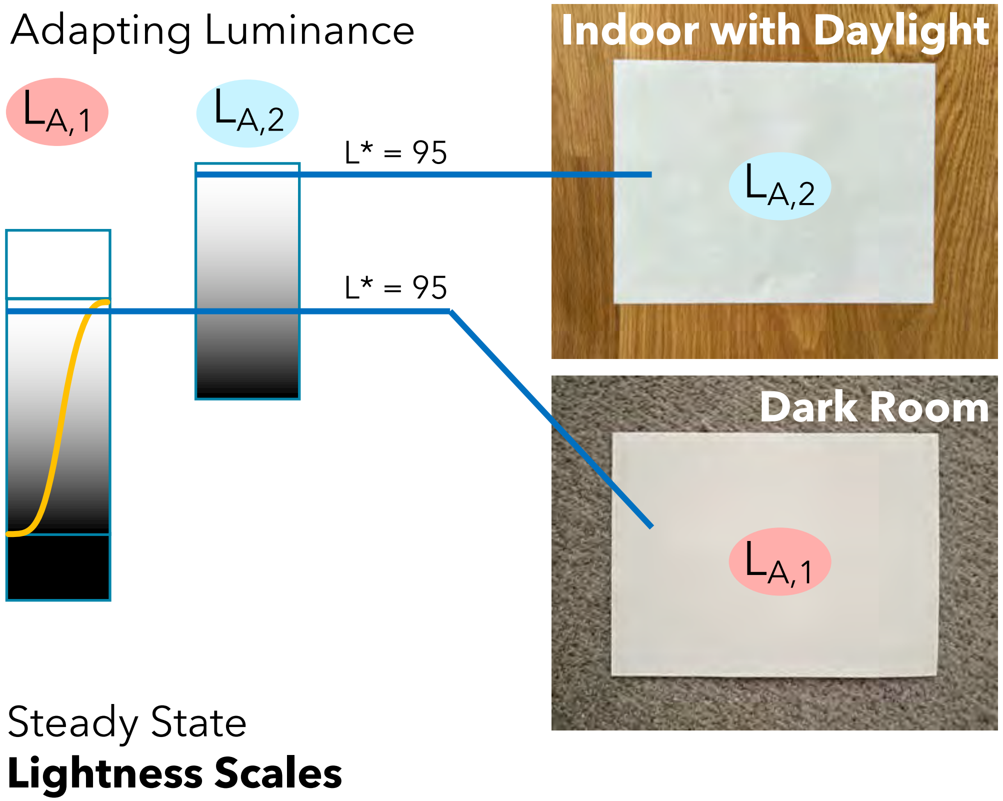
Ultimate goal of imaging systems:

- The composition of content should **maintain intent, consistency & fidelity**
- Keep track of **how different ‘whites’ appear when processed through the imaging pipeline**
  - **Multiple pipeline stages** can change a white’s properties:
  - Processing, multiple mapping steps, composition, hardware capabilities, etc.
- Also: Human Communication: White (and color in general) is a perceptual concept
  - But we commonly attribute whiteness to physical properties as well!

Consider many **behavior, appearance, context** & **convention-**based definitions of white

Luminance vs. Lightness



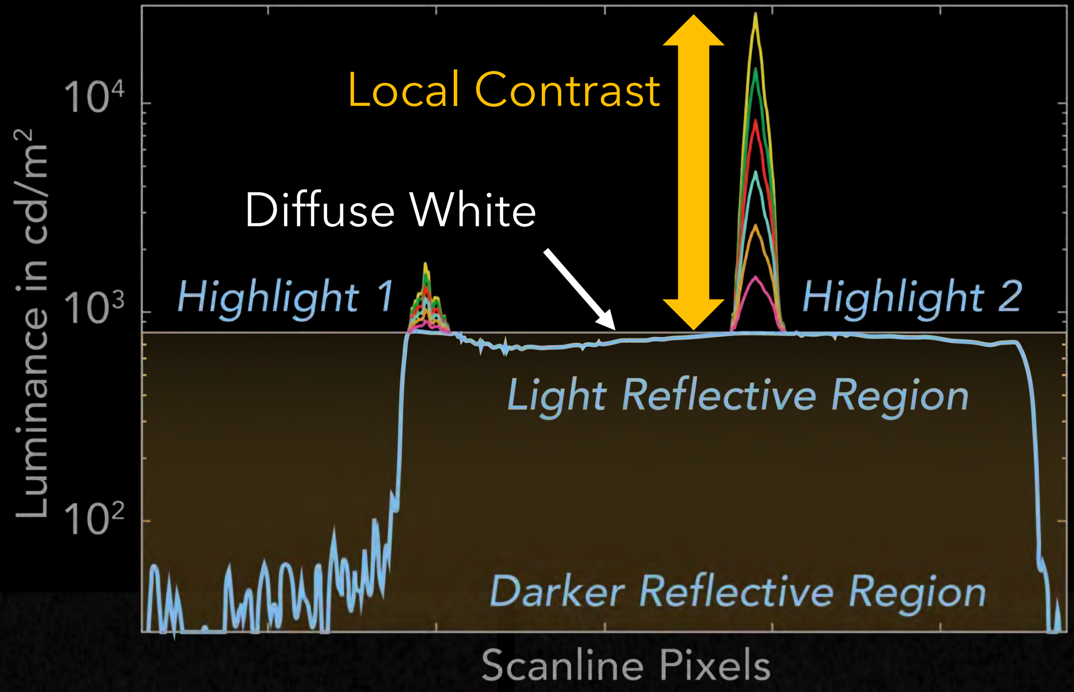


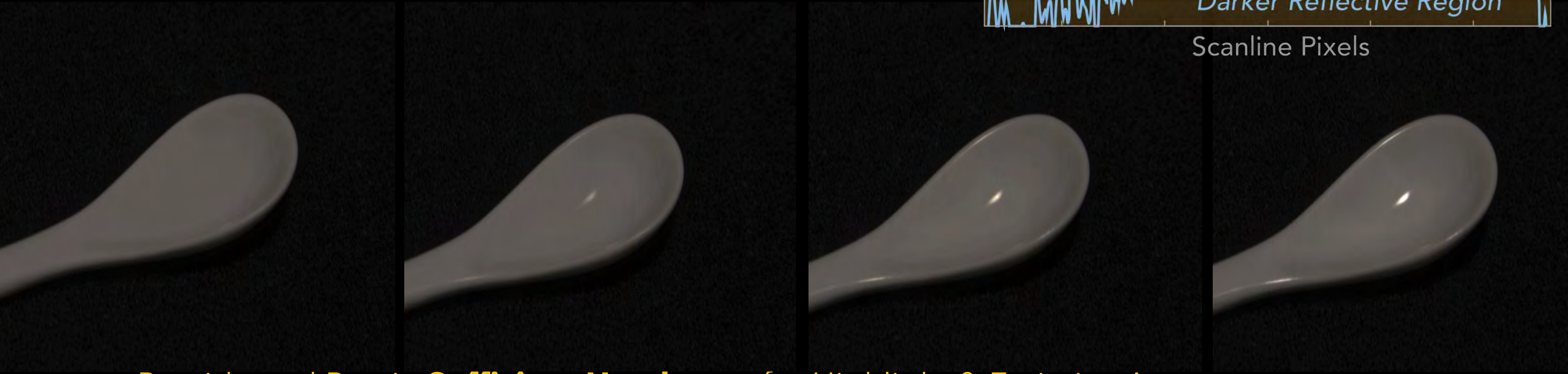
- Absolute **luminance** ≠ **appearance**!
- Adaptive processes **align visual sensitivity** to **environment**
- Significantly impacts how colors & imagery appear, e.g., **what appears white**…

Diffuse vs Emissive & Specular Highlights

- Luminance & perceptual differences between **emissives** & **diffuse white**

Material Properties





Provide and Retain **Sufficient Headroom** for Highlight & Emissive Appearance

Image Context

- **Realism, Aesthetics, Fantasy, …**
- Aesthetics, Value, …

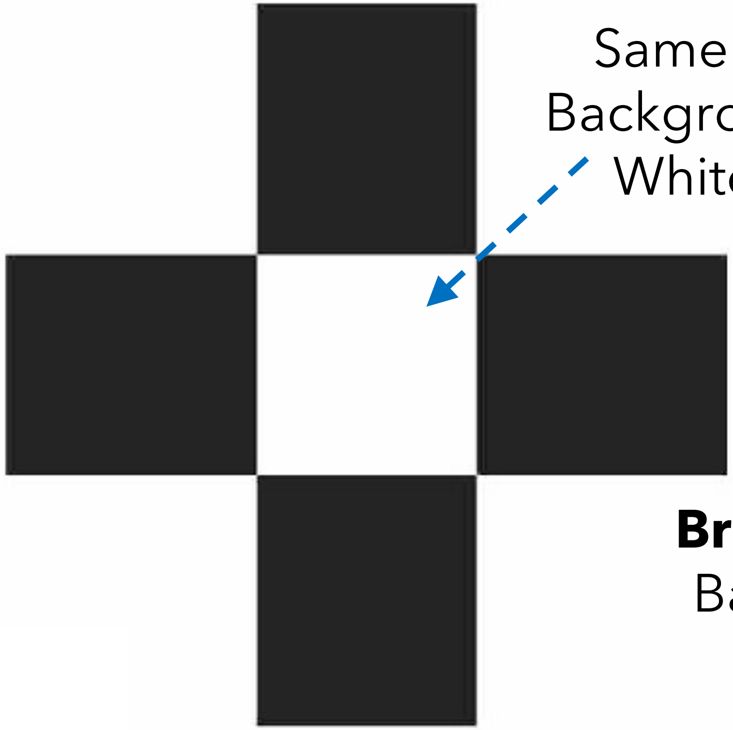
References:

L. B. Wolff (1994): ‘**Relative brightness of specular and diffuse reflection’,** Optical Engineering 33(1), https://doi.org/10.1117/12.149144

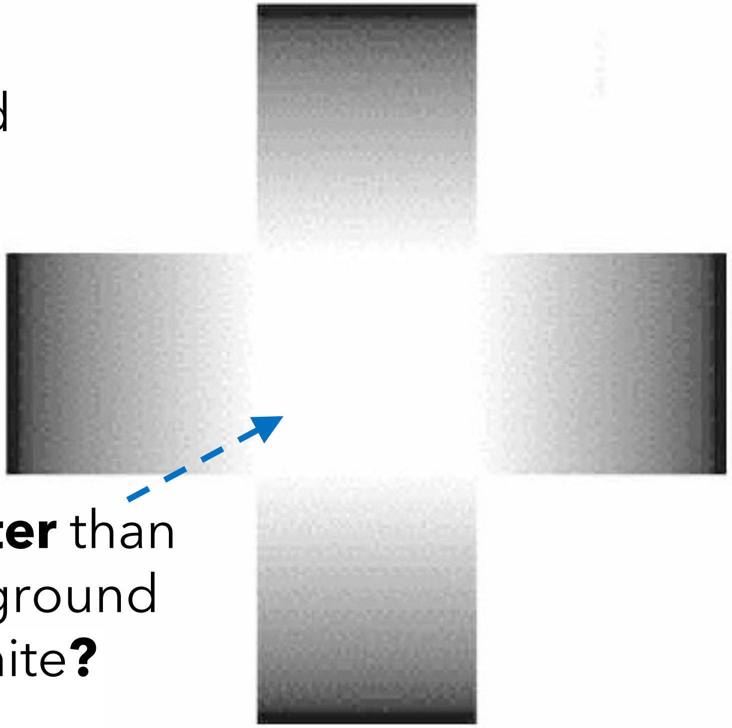
Source: Zavagno & Caputo, The glare effect and the perception of luminosity, Perception 2001, (30) pp 209-222.

Glare Effect Causing Changes in Apparent Brightness

Glowing Grey?

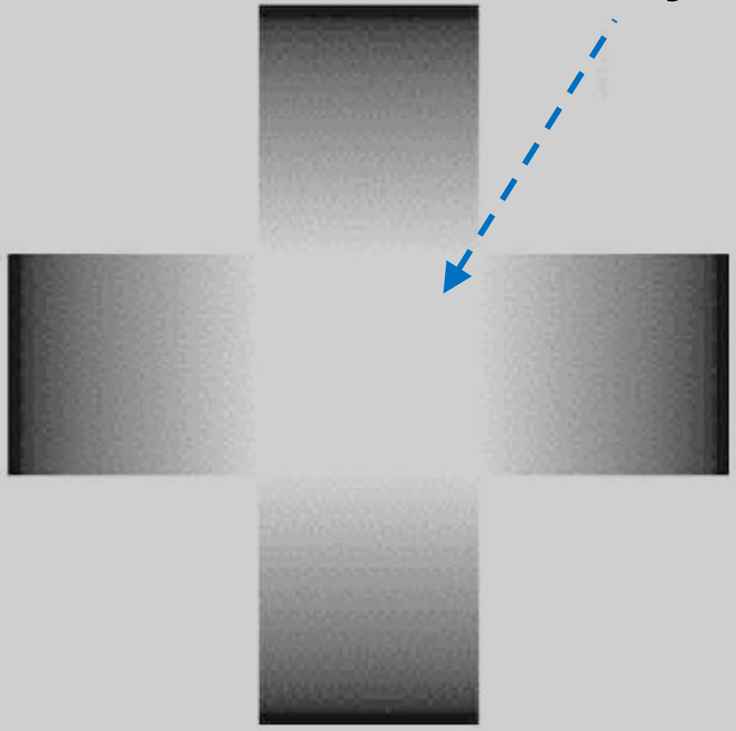


Same as Background White!



Brighter than Background White**?**

A Light Source?



Whites in Content & Content Manipulation

Modern Imaging Technologies *(e.g. Processing, Color Science, Display Technology…)*

- Offer more **advanced means to depict realistic imagery**
- Require **more challenging signal processing & Hardware**

This **can lead to perceptual artifacts** for the **final image appearance**

- Pixel TMO
- Spatial Compositing
- Adding Whites based on Conventions
- Ambient Mapping
- Temporal Mapping

Whites in Content & Content Manipulation

1. **Different TMO have different results**
- Global vs. Local TMOs
- TMO is achromatic
  - Chroma gets mapped back ad-hoc
- Multiple TMOs in succession (w/o knowledge of each other)

2. **Spatial Compositing**
- Images are spatially placed without prior knowledge

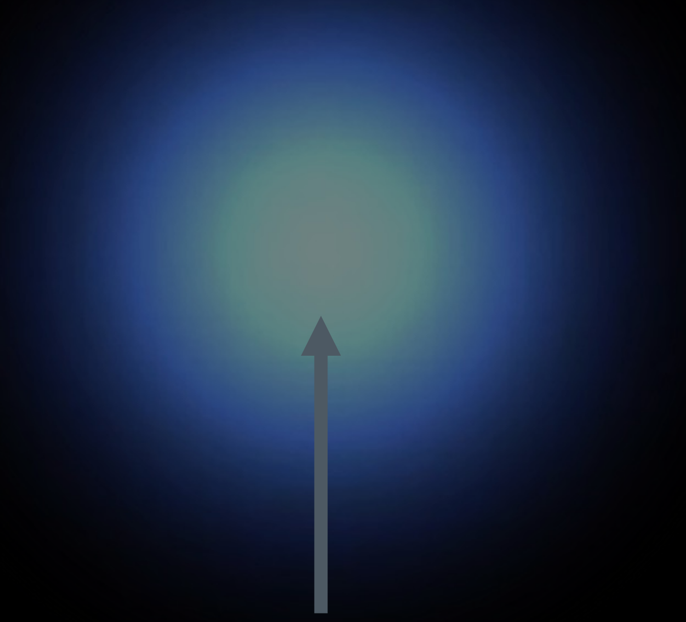
3. **Whites based on conventions**
- Graphics and Reference Whites might not fit into appearance context

4. **Ambient & Temporal mapping adds complexity**
- **Ambient mapper** can…
  - Lift reflective white
  - Clip or significantly compress highlights
- **Temporal mapping** can…
  - Change appearance too fast or too slow

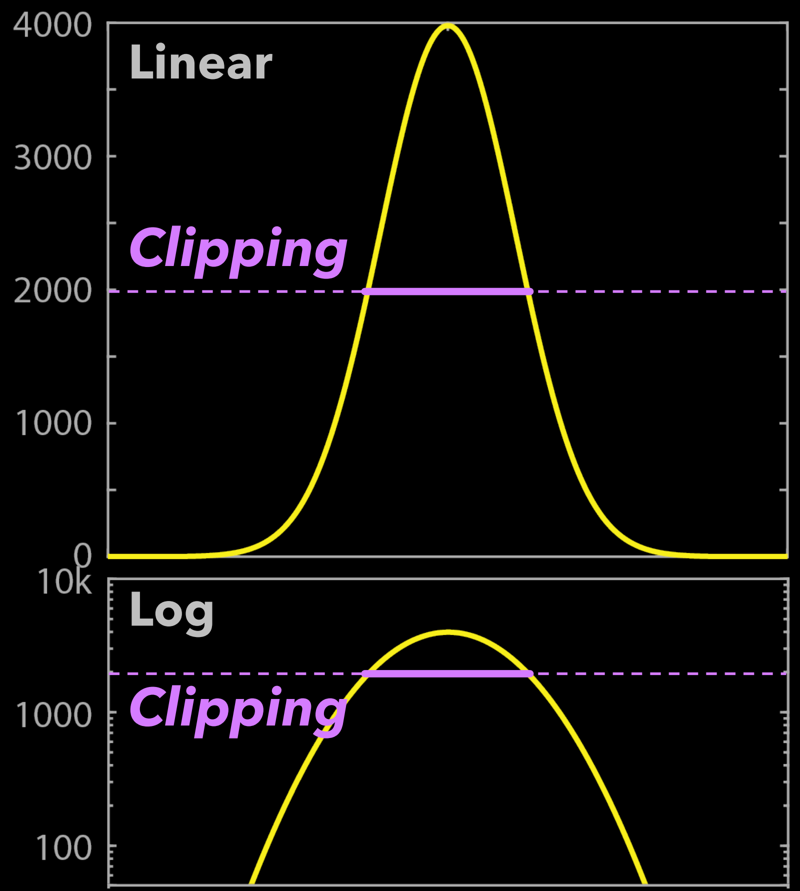
Distortions/Clipping

PSF of a Light
Source or Highlight

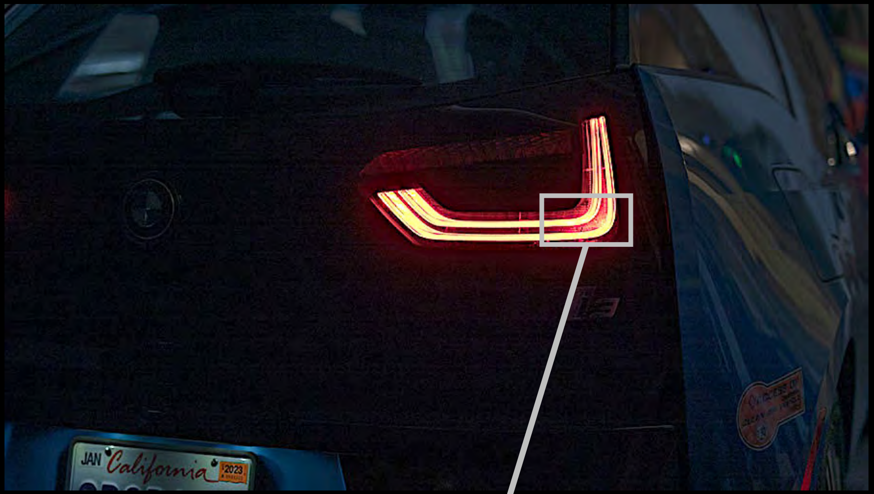
Discontinuous
Gradient Field
(from capture or mapping)



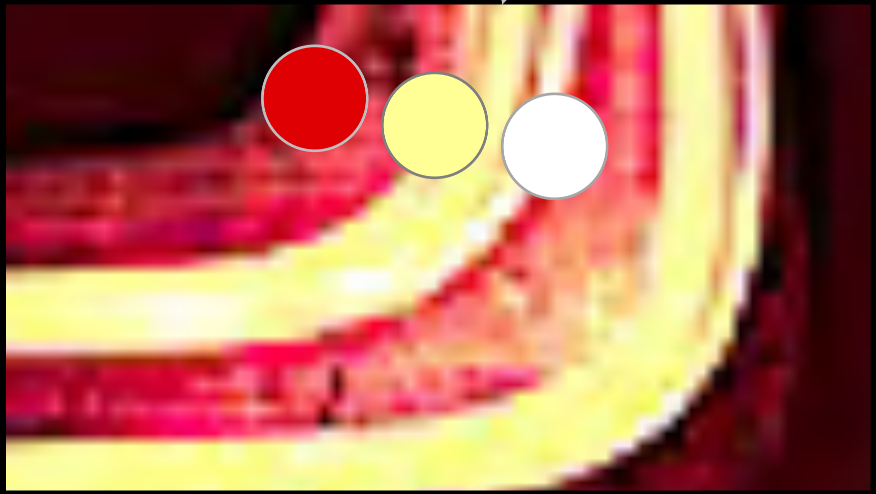
Potentially Undesired
White-point Shift



Color Distortions



Insufficient Chromatic Headroom



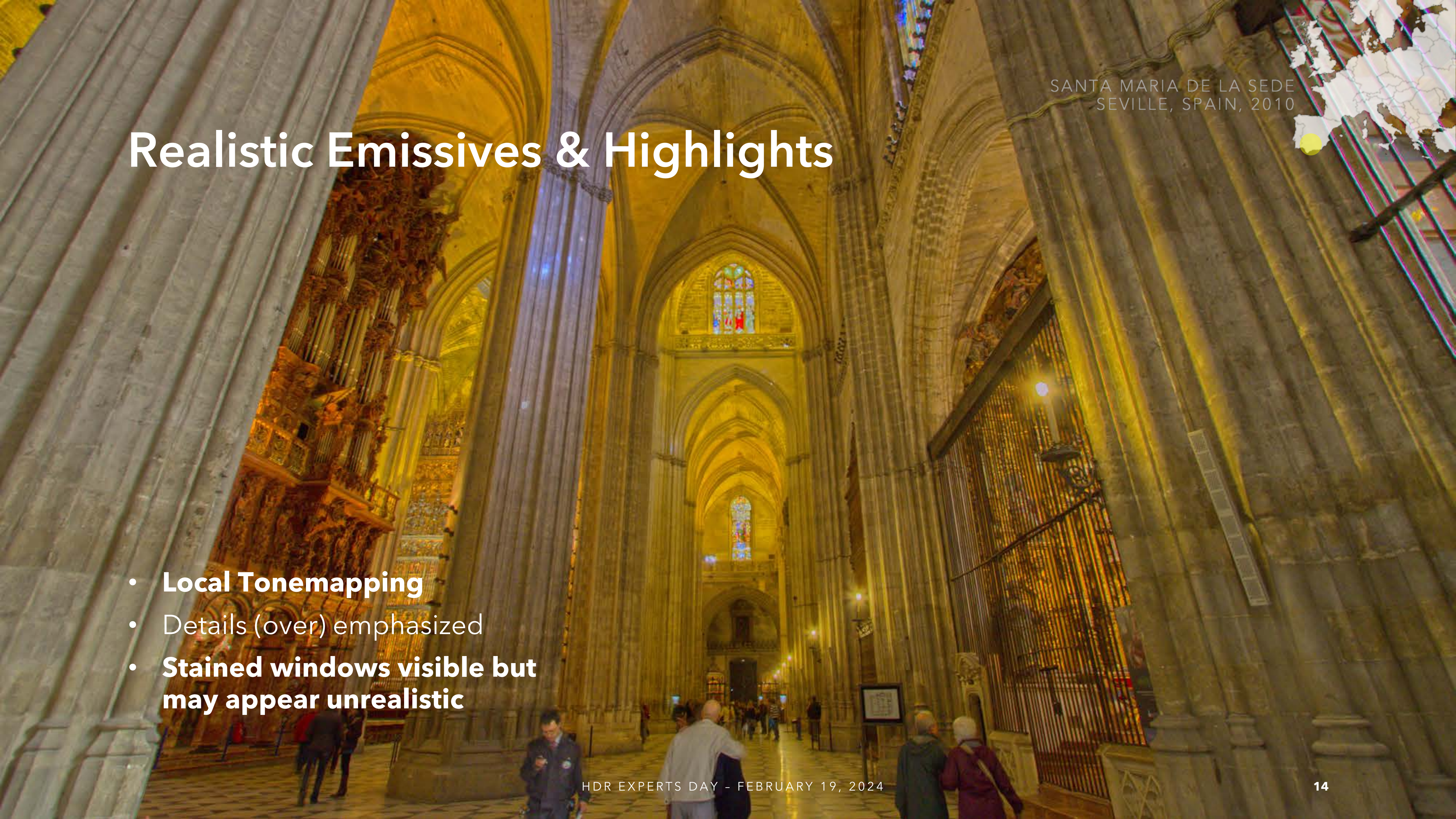
Clipping to Yellow & White

Tone Mapping Options

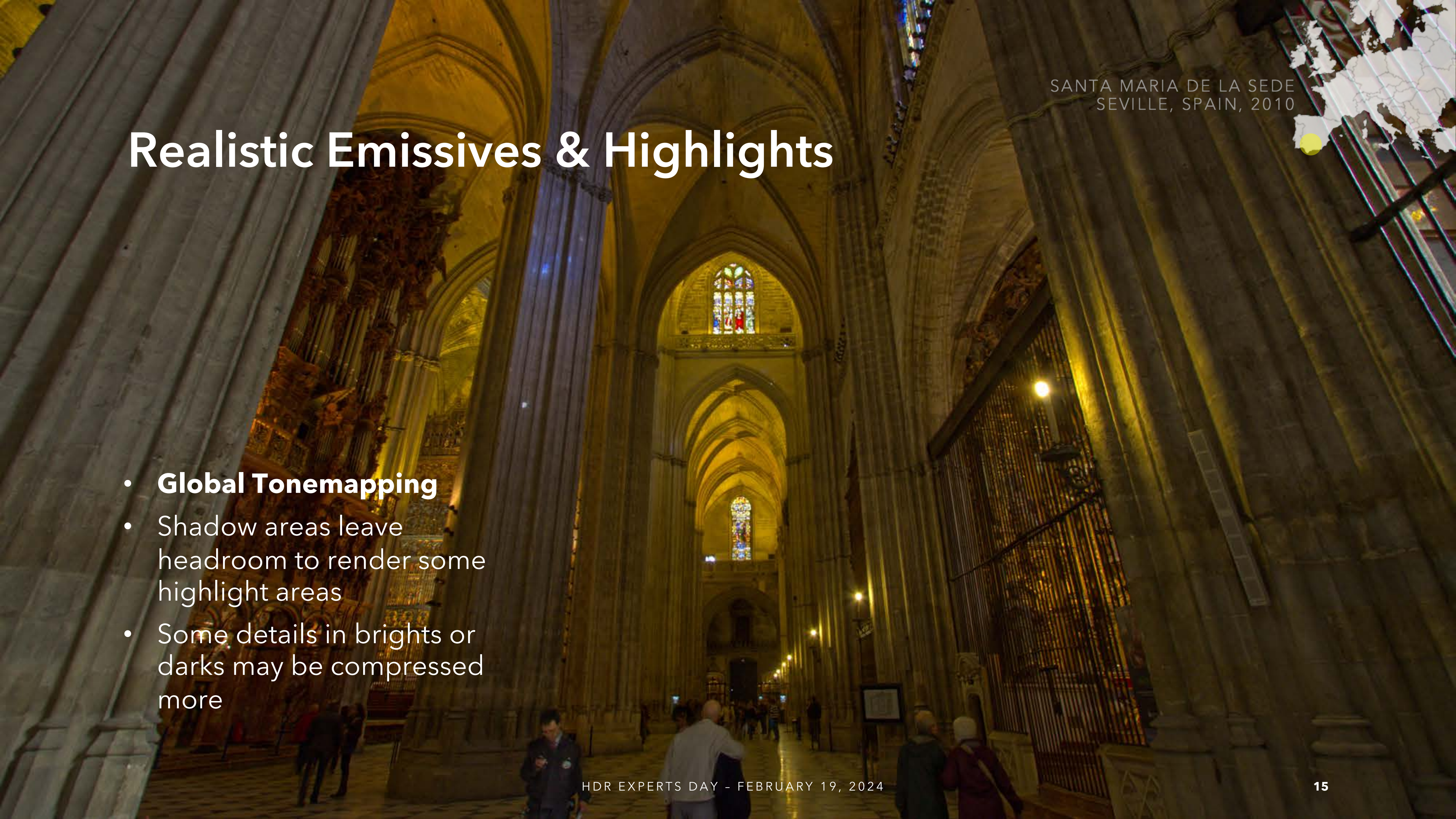
TMOs Differ in their Outcome

- TMOs behave differently
- The **choice of TMO might vary** depending on source and target scenario.

Realistic Emissives & Highlights



- **Local Tonemapping**
- Details (over) emphasized
- **Stained windows visible but may appear unrealistic**

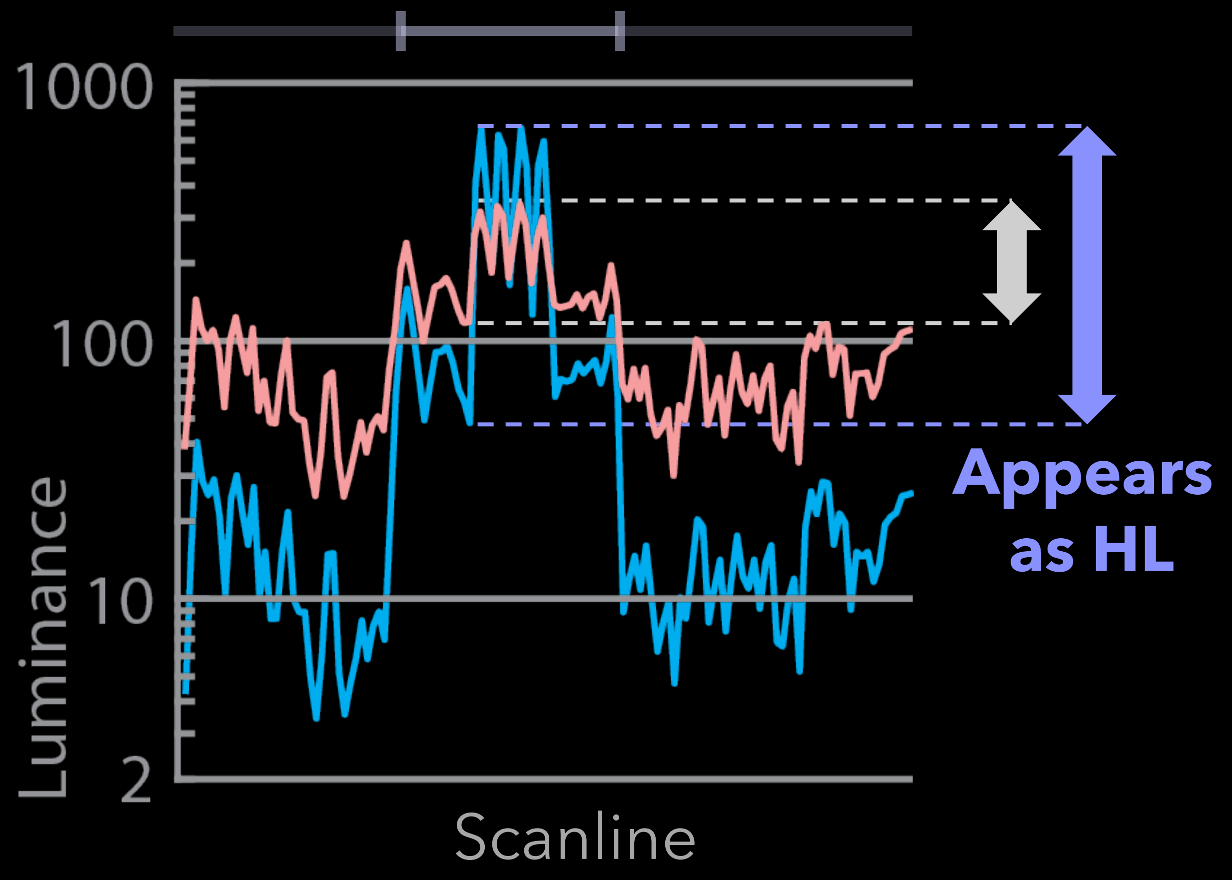


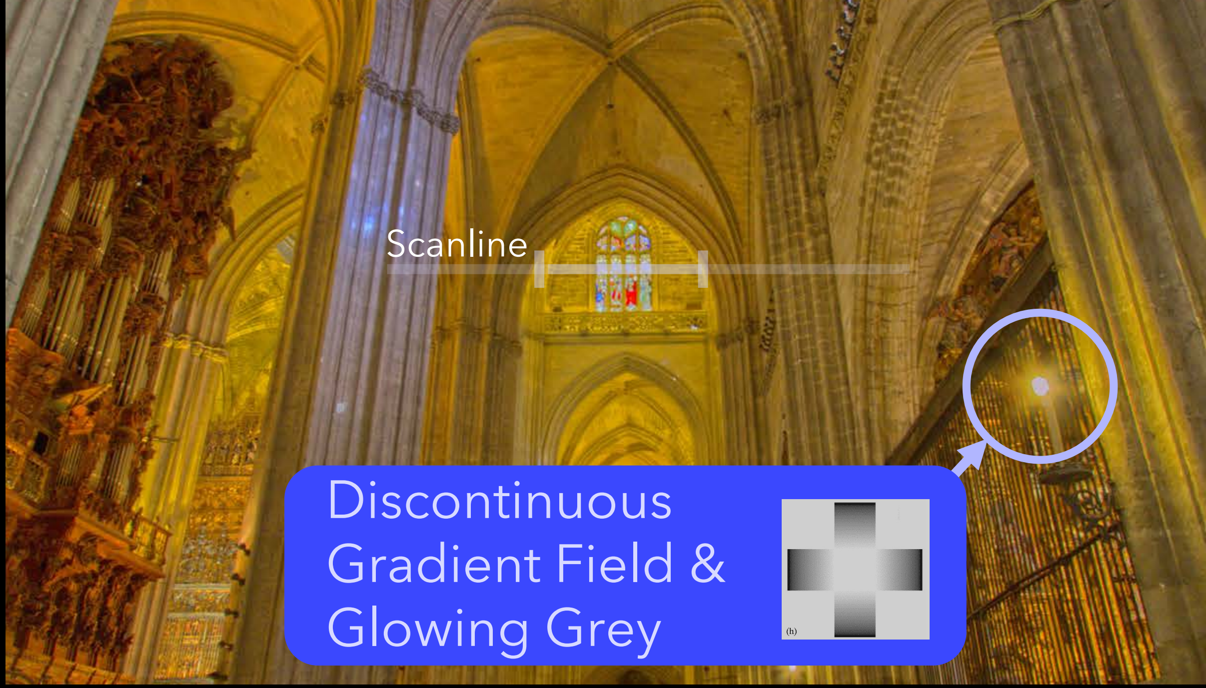
SANTA MARIA DE LA SEDE
SEVILLE, SPAIN, 2010

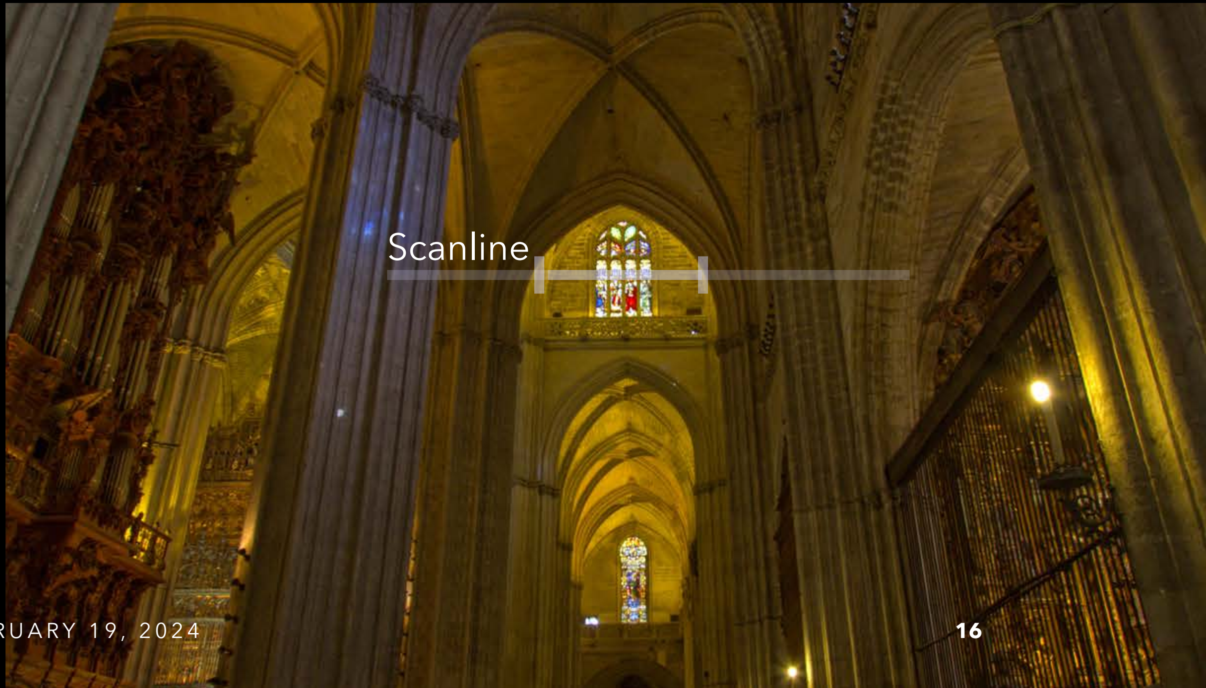
Realistic Emissives & Highlights

- **Global Tonemapping**
- Shadow areas leave headroom to render some highlight areas
- Some details in brights or darks may be compressed more

Local LS & Highlight Contrast







Provide Sufficient Headroom for Highlight & Emissive Appearance

Whites set by Conventions & Technology

- **Peak White:** highest luminance capability of a display for a **small display area**
- **Full-Screen White**: Peak white capability of a display with **all pixels @ 100% intensity**
- **Nominal Peak White:** Peak defined in context of encoding or theoretical display (e.g. SDR, some HDR proposals)
- **EOTF Interpretation:** Relative & Absolute Signals on Displays
- **Reference White**: E.g. 203 cd/m^2 from ITU-R Rec. BT.2100 *(conversion - HLG & PQ)*
  - Can also be called **Interoperability White**
  - Is in some cases also defined as **diffuse white**
- **Graphics White**: Intensity Level for **white GUI elements** (text, lines, etc.)

Consider:

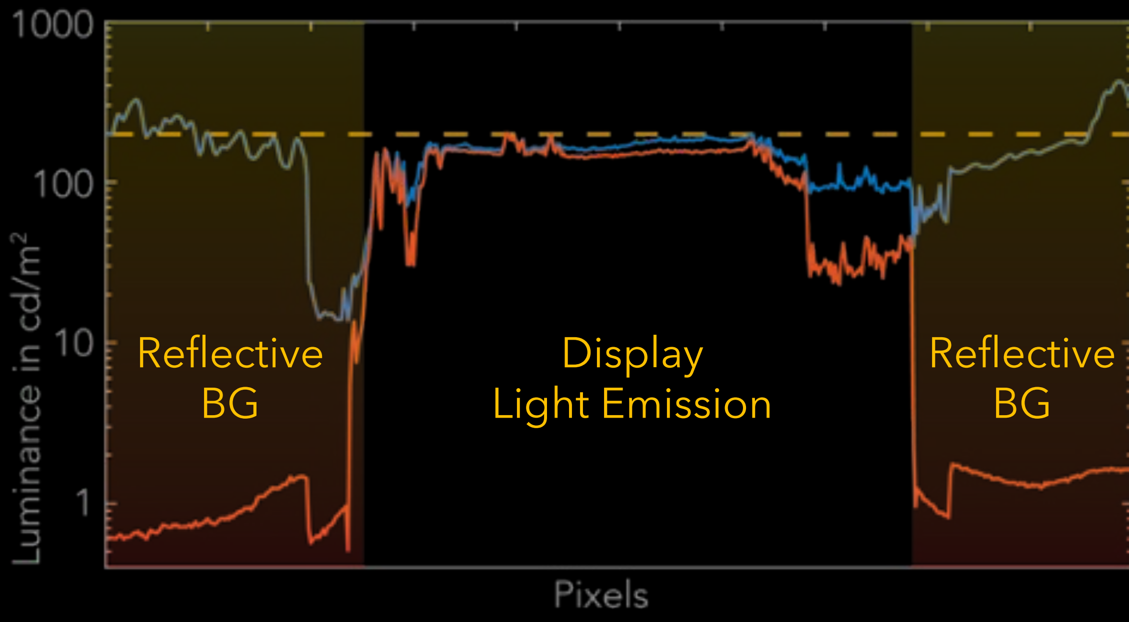
- **Even though all are <u>called 'white'</u>, it is not guaranteed that they <u>appear</u> white**
- **The appearance of white depends on the image/scene context**

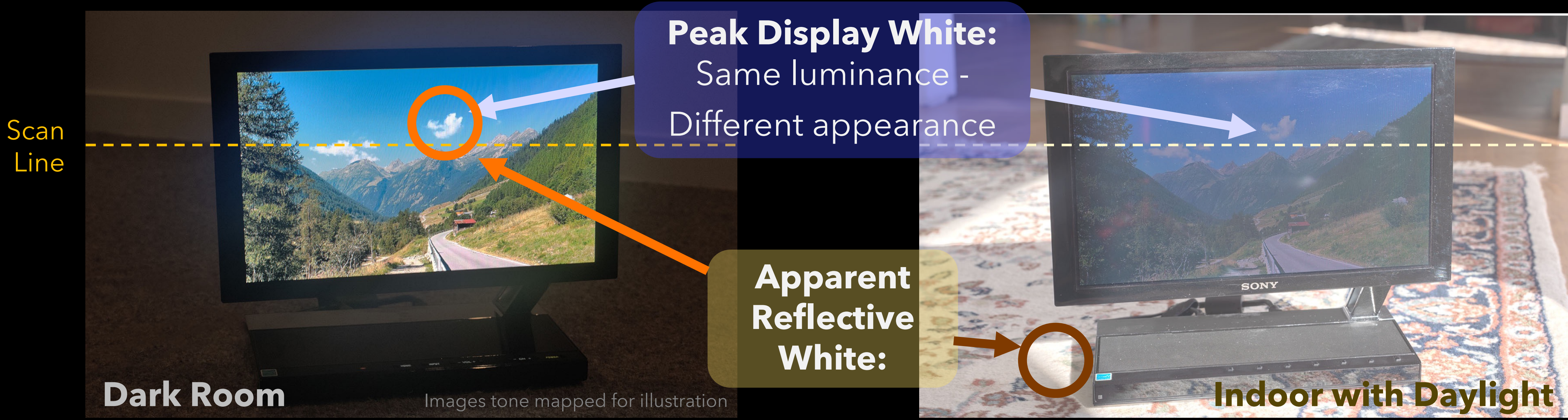
Absolute Emission & Relative Ambient Reflections

Displays emit an absolute luminance 'window'

- E.g. defines physical peak luminance
- Appearance can only be manipulated in bounds

Display is part of viewing environment

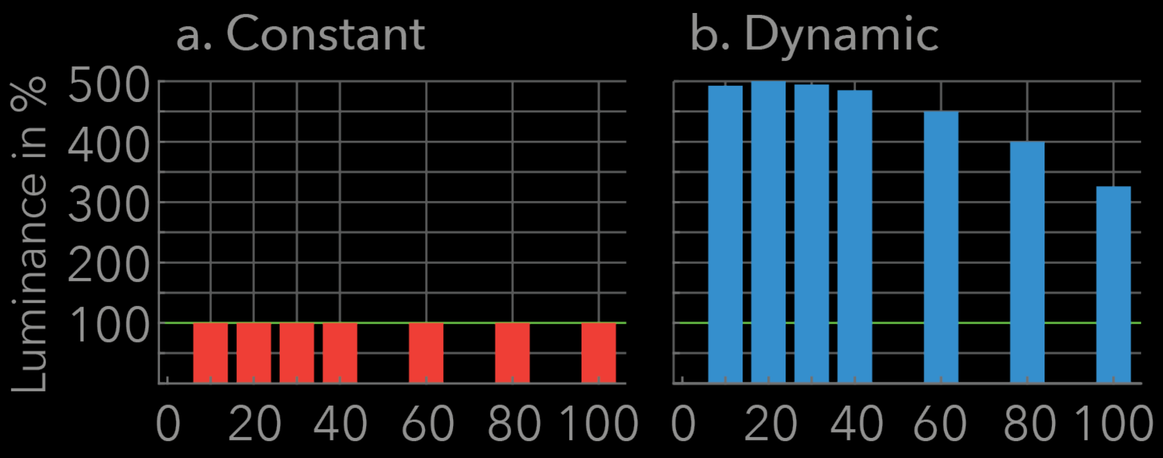


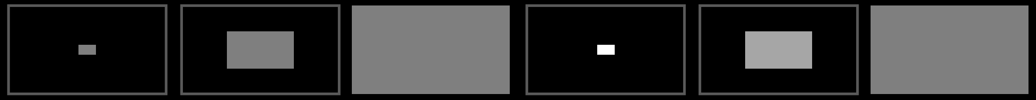


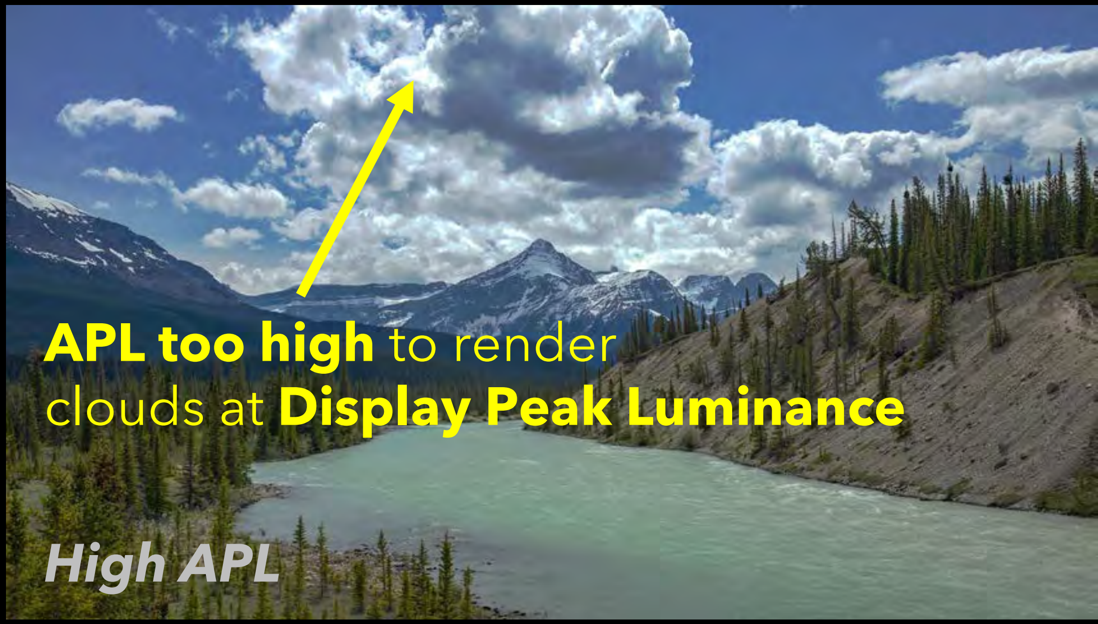
Power & Thermal Budgeting

- Displays change peak white dynamically
- Small features can be brighter
- Full screen is significantly dimmer

⇢ **APL vs Peak Luminance**







EOTF Interpretation by Displays

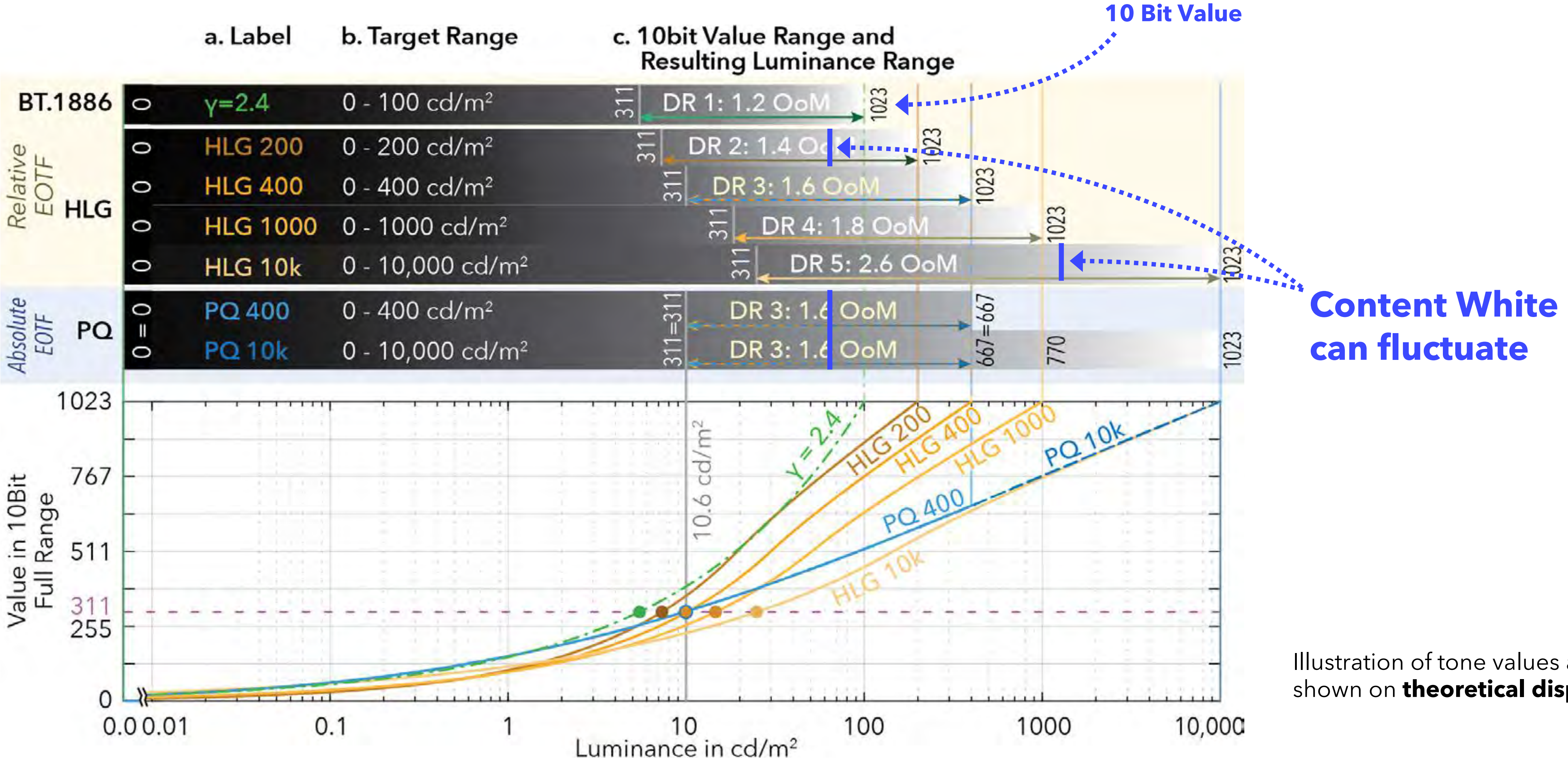


Illustration of tone values as shown on **theoretical display**

Reflective vs. Reference/Graphics White

Tone-mapped to SDR for this presentation

Adapted to
Lighter ambient

4000 cd/m² peak
Could be higher if display is capable

300 cd/m² diffuse

CC: 203 cd/m² ?

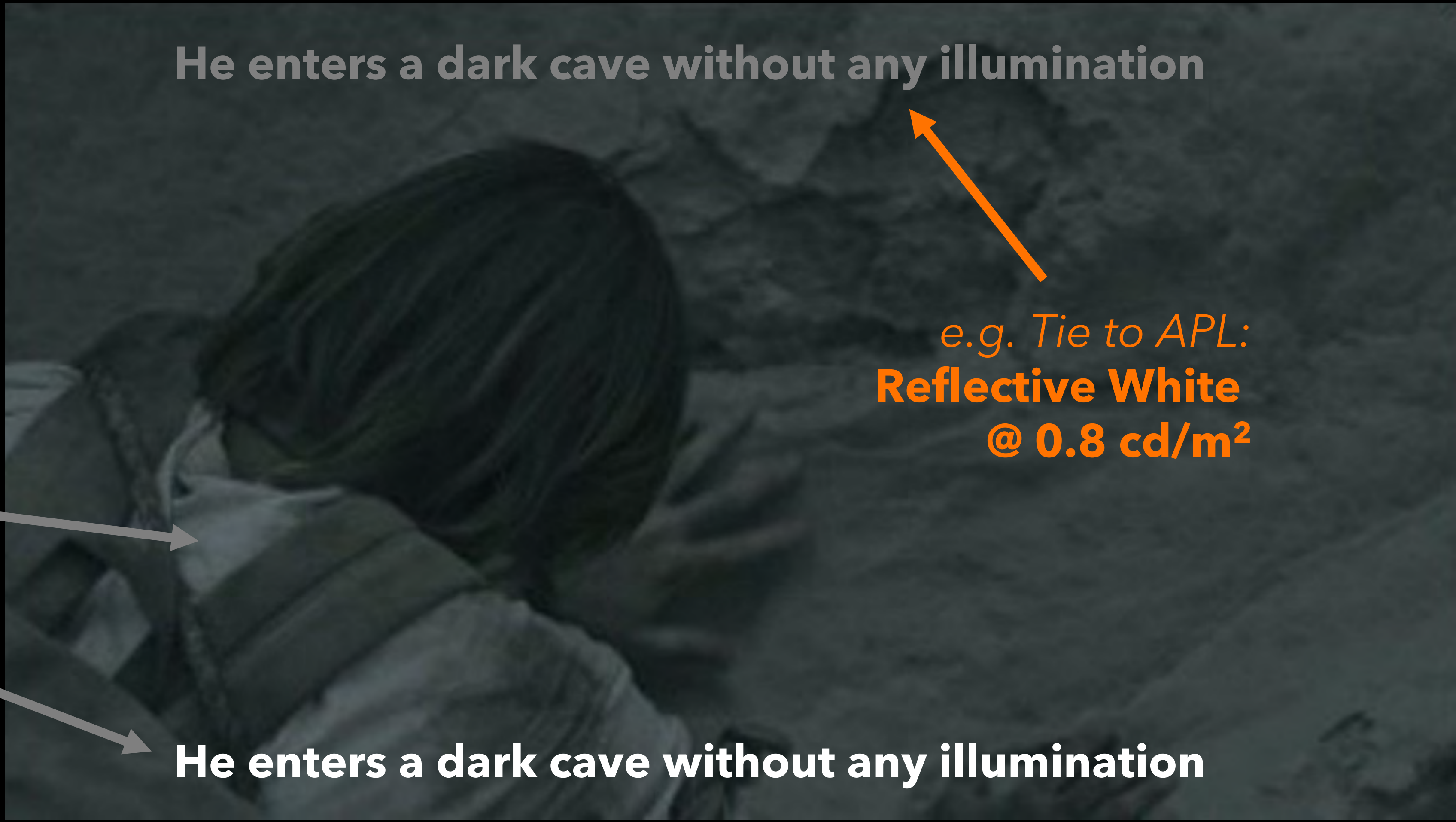
Reflective vs. Reference/Graphics White

Tone-mapped to SDR for this presentation

Change of
Adaptation Level:
Adapted to
Darker ambient

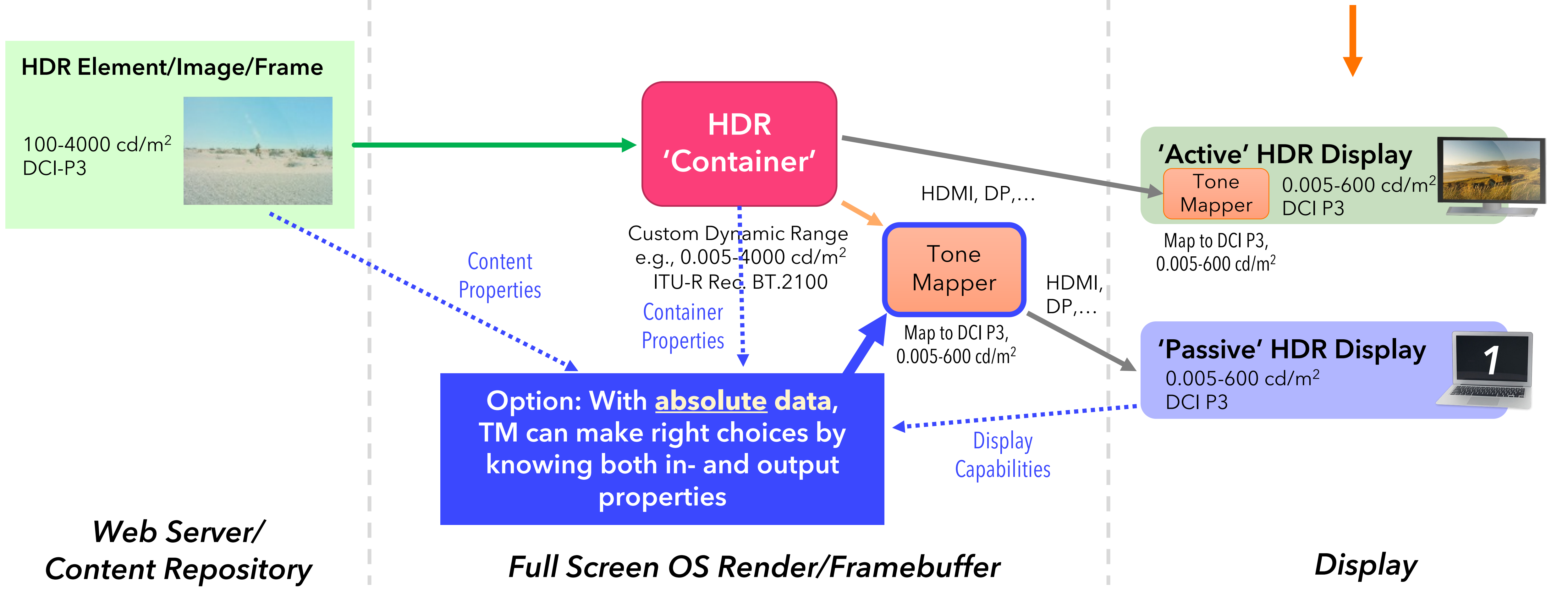
1 cd/m²
peak & diffuse

CC at **Reference White:**
203 cd/m² !



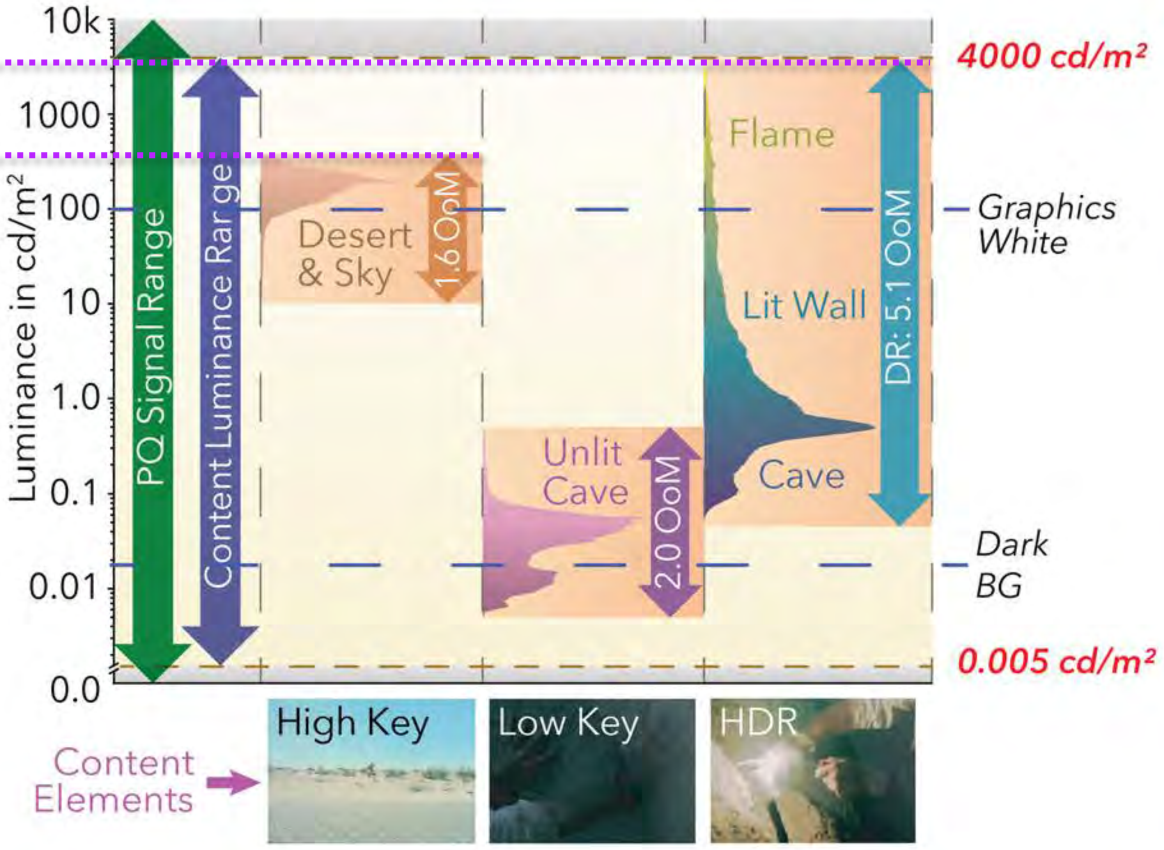
‘Traditional’ Fullscreen HDR

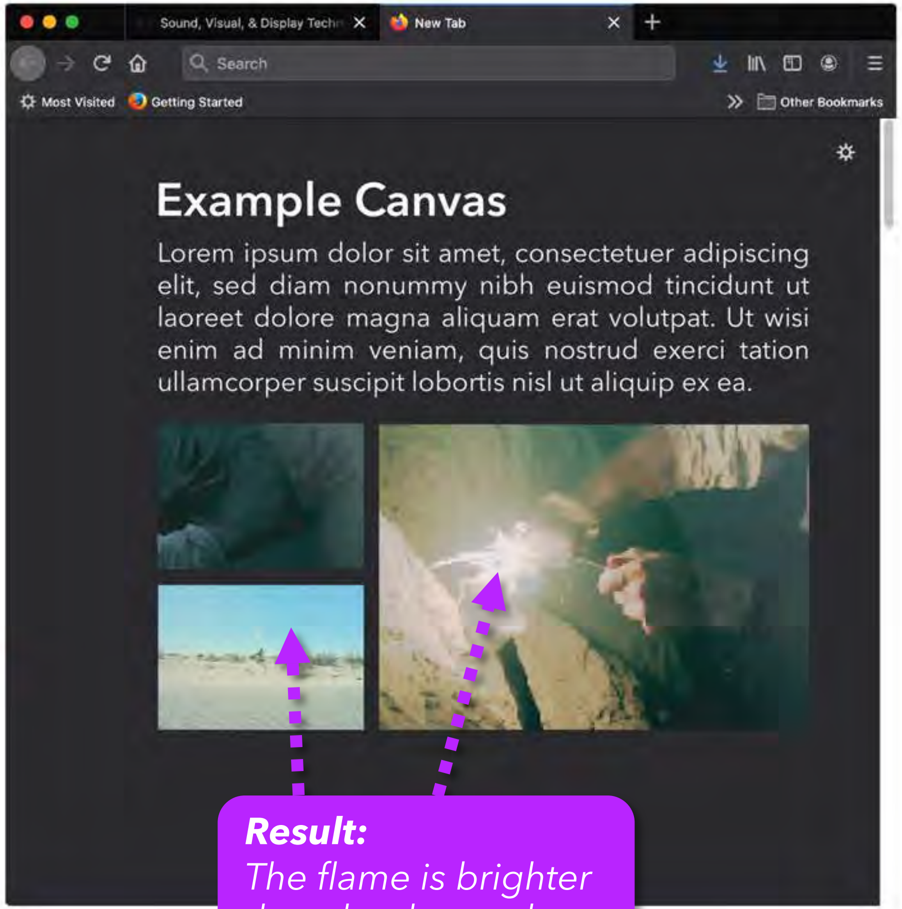
Display Capabilities are often communicated.
We need to assure this remains the case!



Spatial Compositing - No Mapping

Luminance Contrast between images **is different**



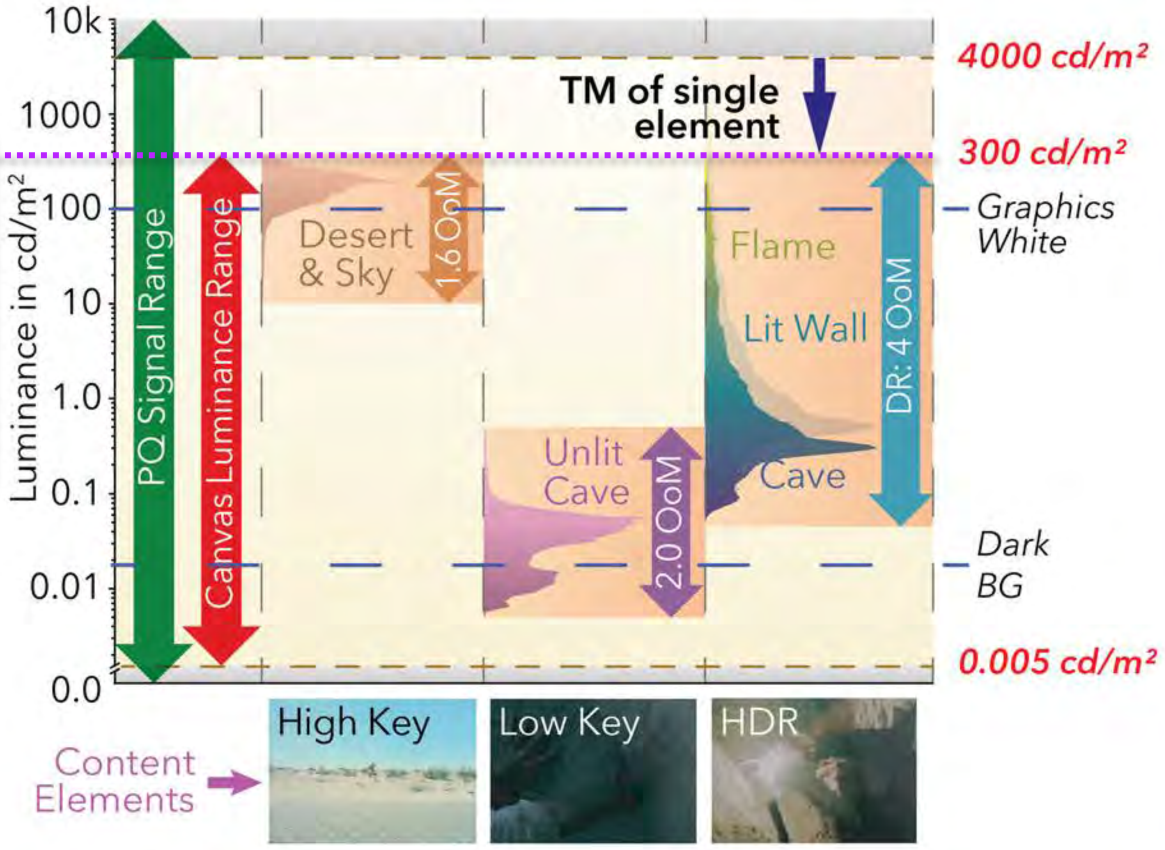


Result:
The flame is brighter than the desert sky

Mapping of Individual Elements Before Compositing

NO MORE Luminance contrast between images

Result:
The desert image appears brighter



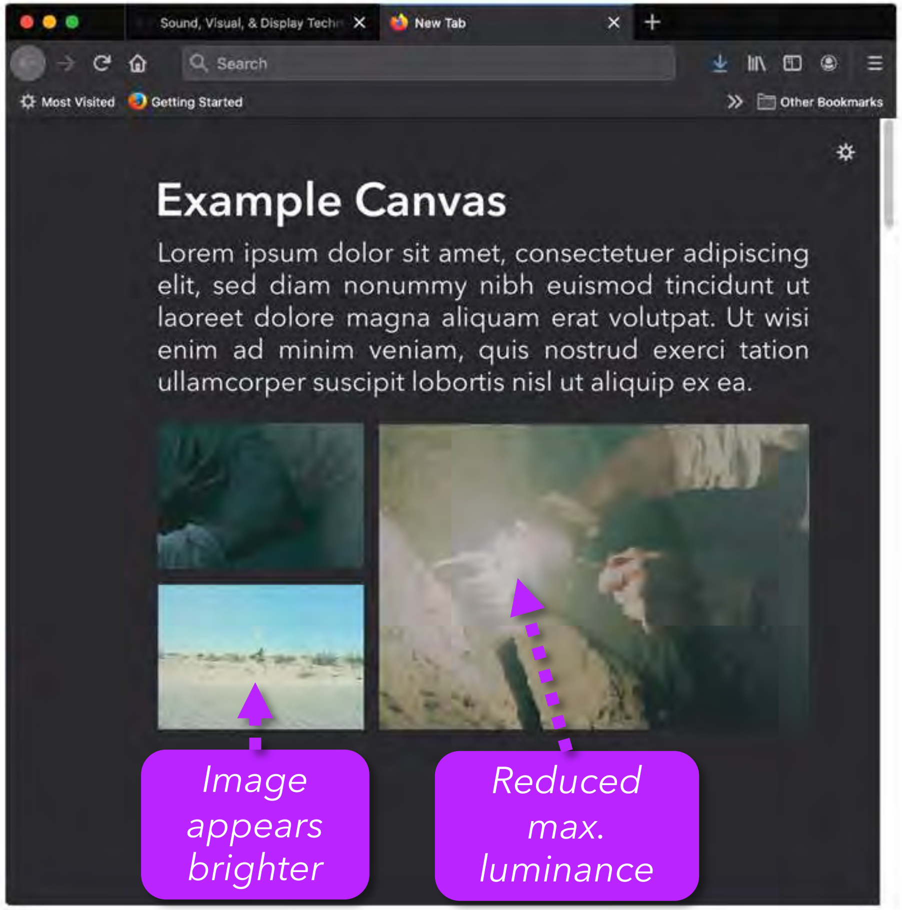


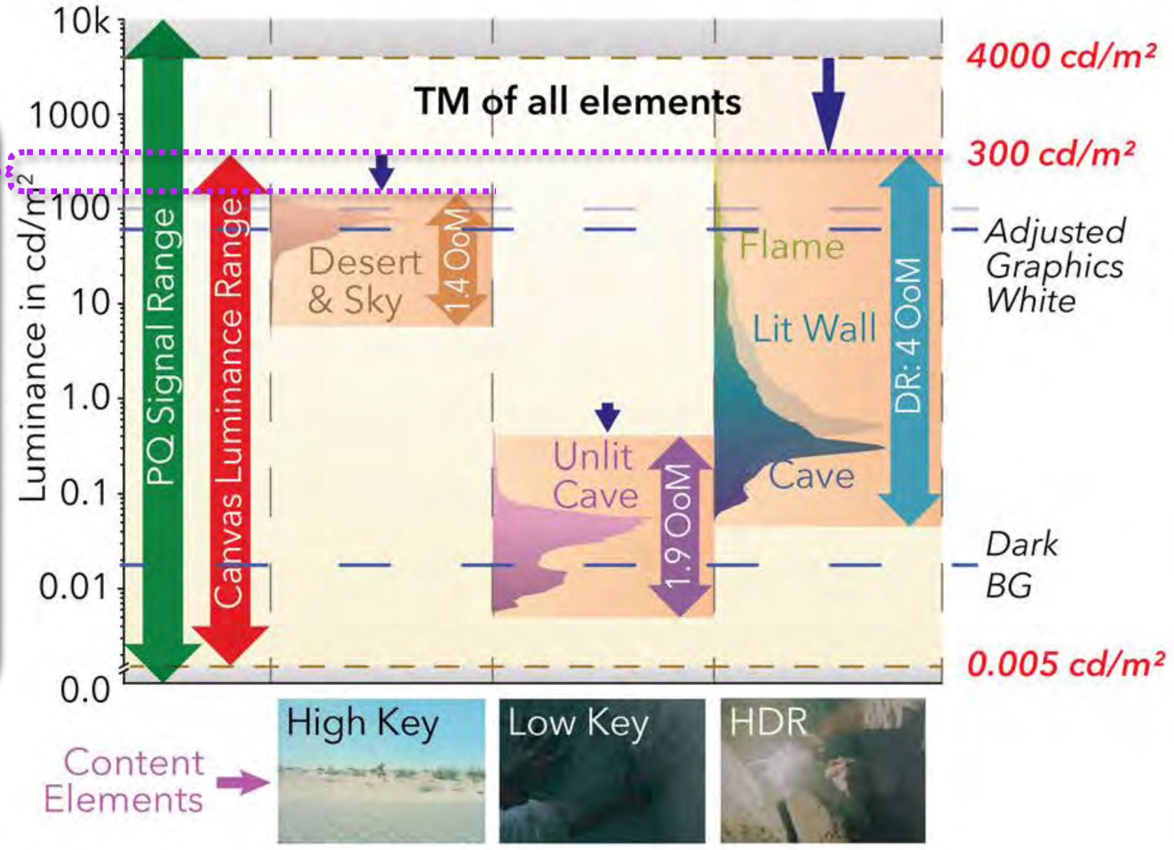
Image appears brighter

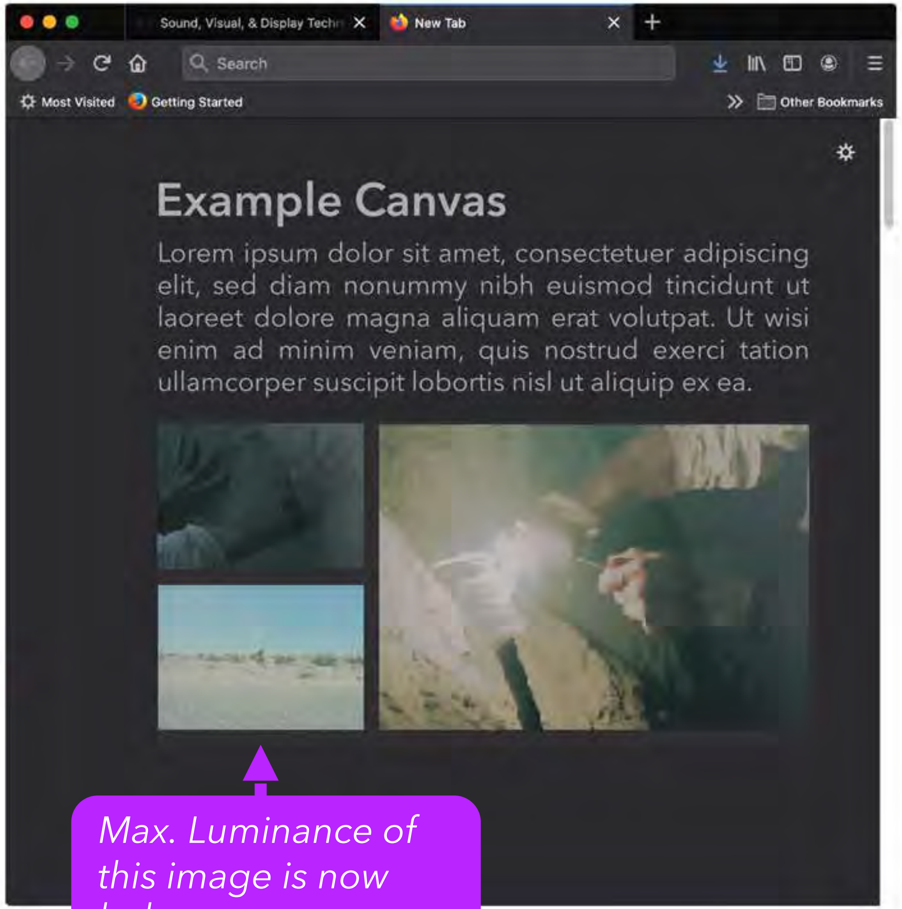
Reduced max. luminance

Mapping of Whole Canvas After Compositing

Luminance contrast between images is compressed

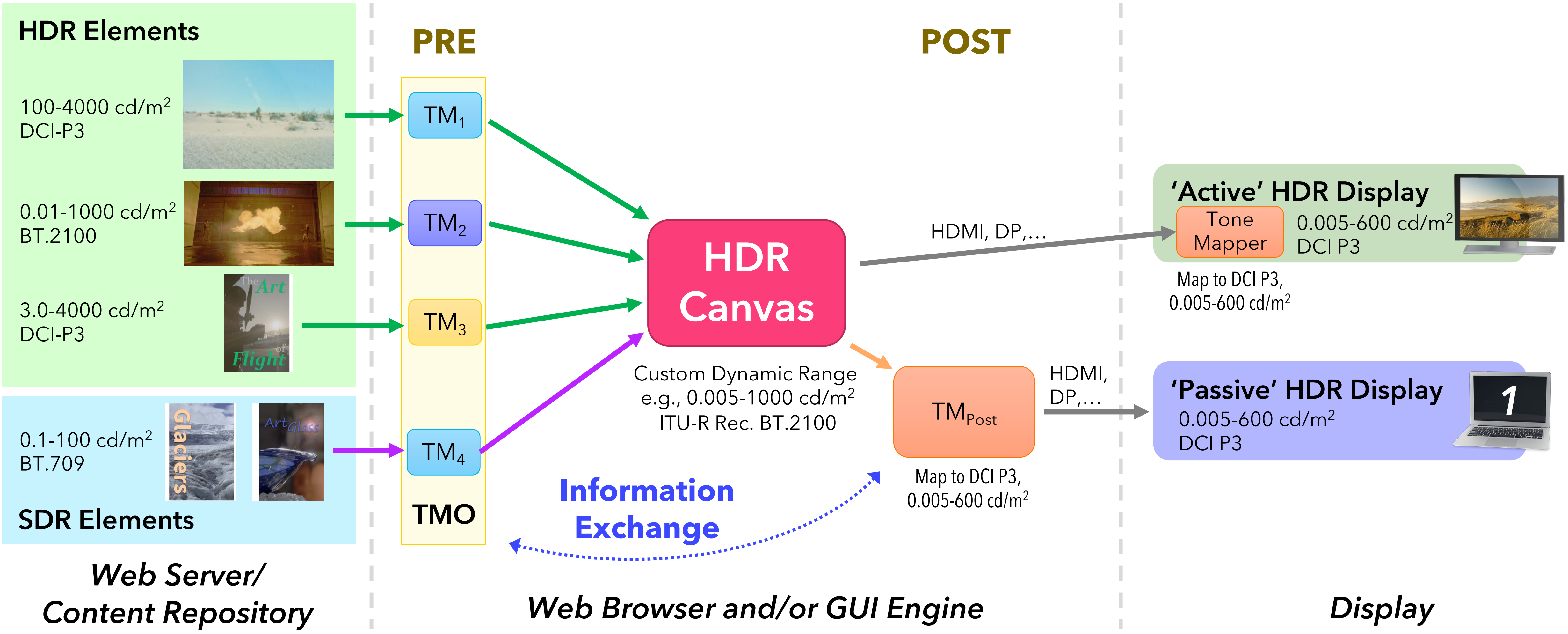
Result:
The whole canvas is mapped while maintain the local contrast cohesiveness



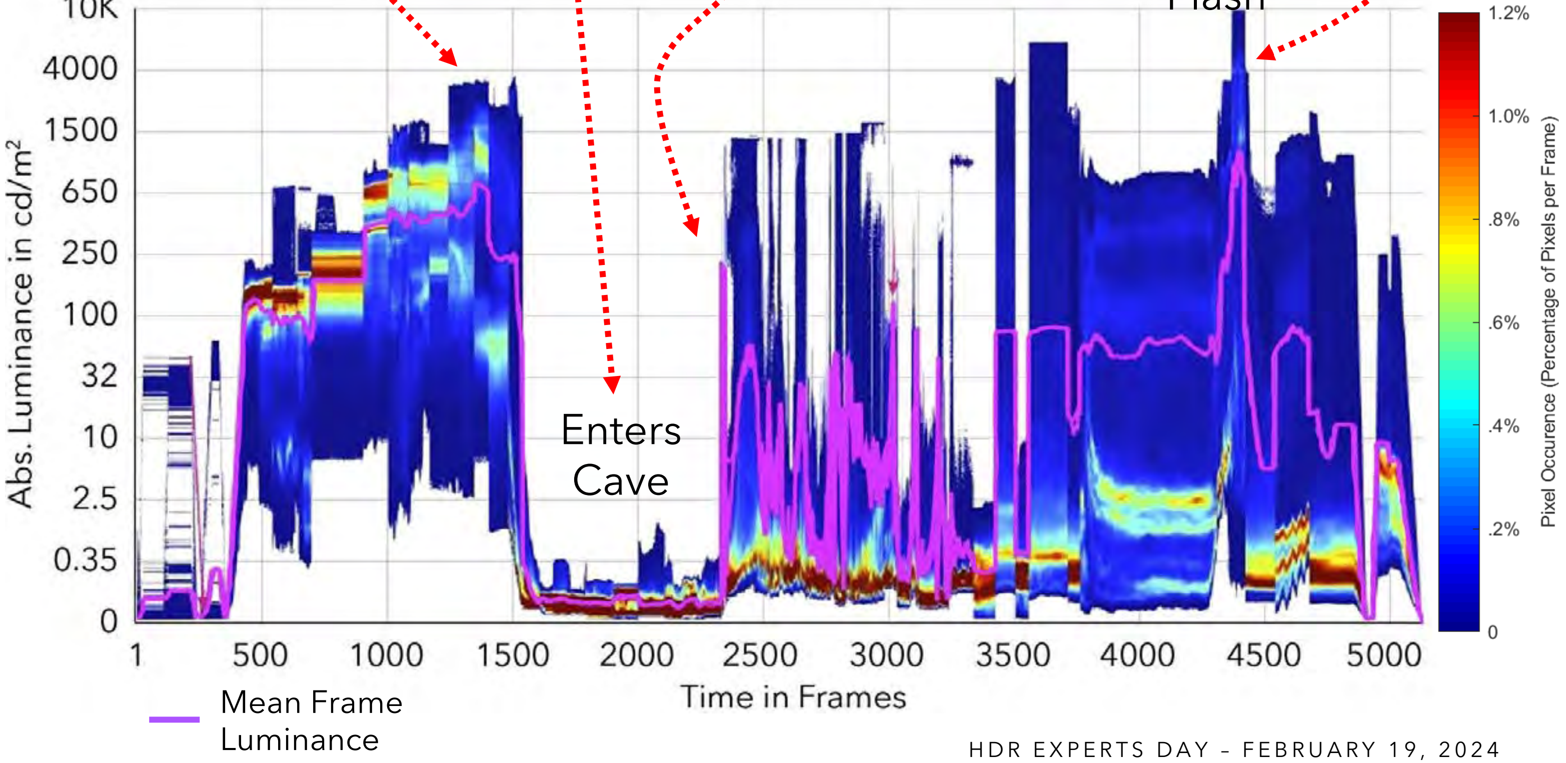


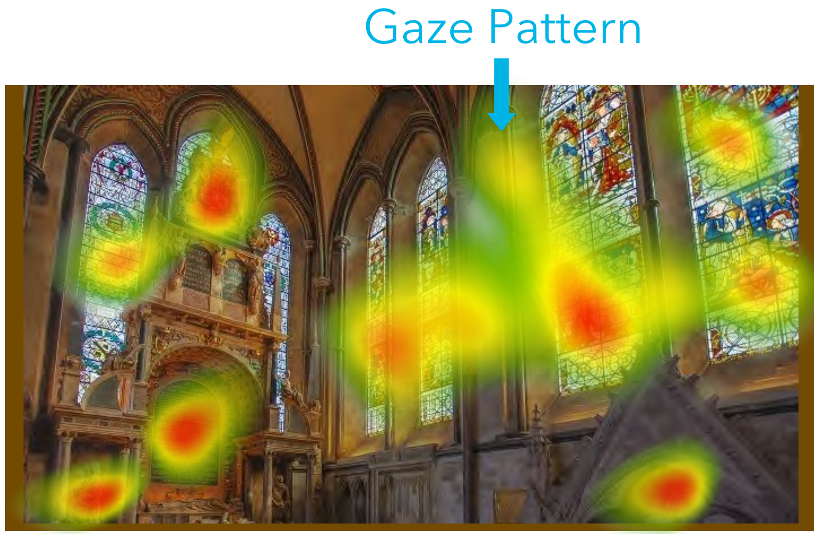
Max. Luminance of this image is now <u>below</u> canvas max.

Design Pre & Post Mapping ‘Infrastructure’



Temporal Progression





Still Image

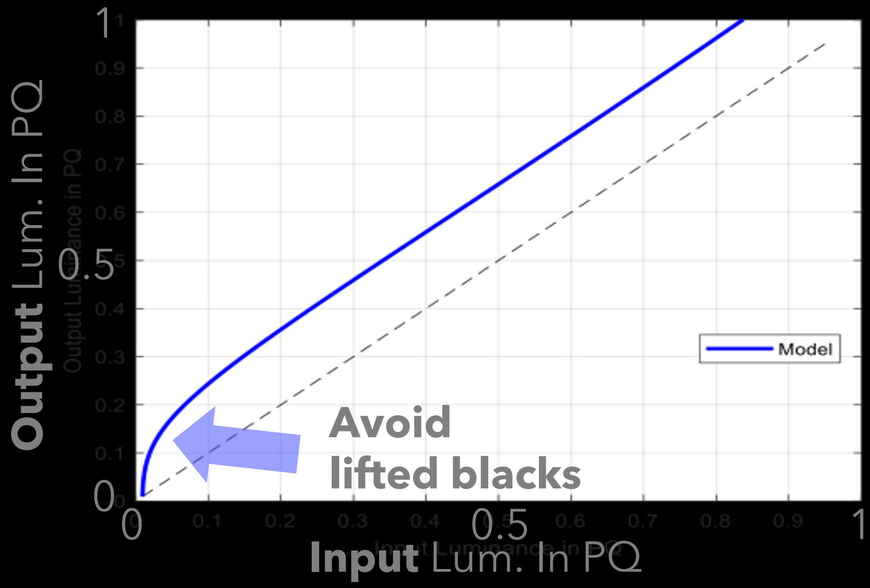
Transitioning Between Scene Luminance Brackets:

- Sharp Scene Cuts *(current)*
- Temporal dampening TMO
- Adaptation time-course Mapping
- Support from Dynamic Metadata

Typical Ambient Light Problem

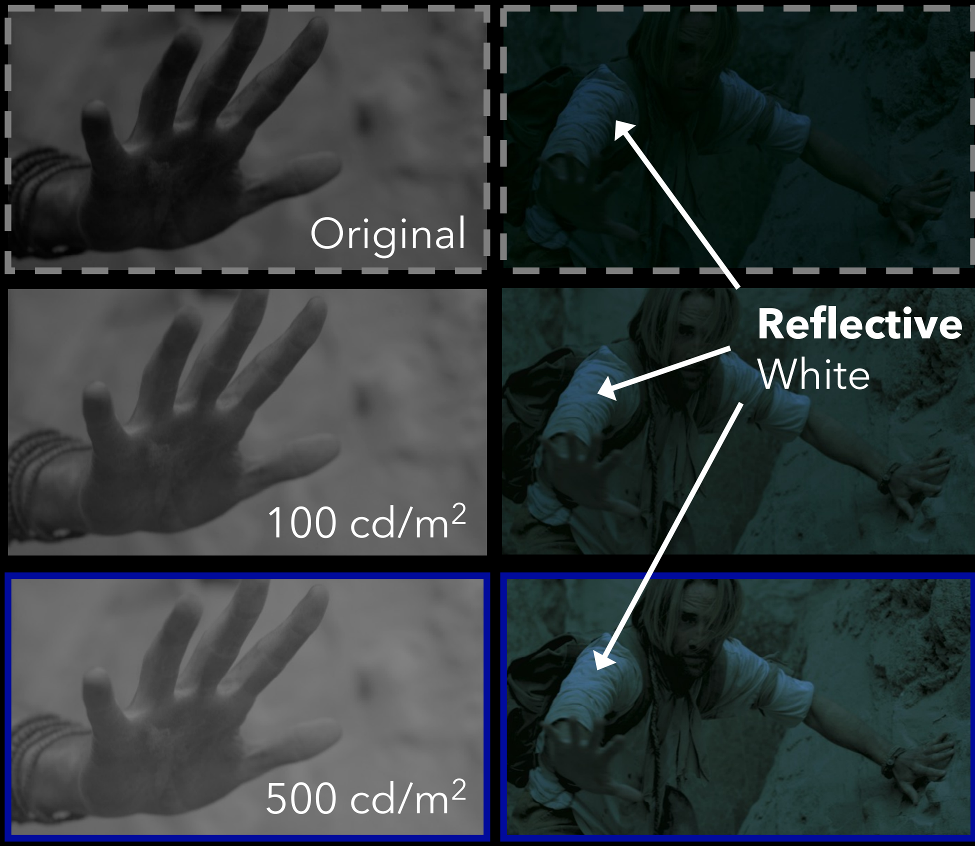
Ambient Compensation

- Beneficial with varying Ambient Illumination
- Increased Ambient Light Level both **raises blacks** & the **adaptation level**
- Can be compensated with **ambient light control** algorithm *(bound by physical display limits)*



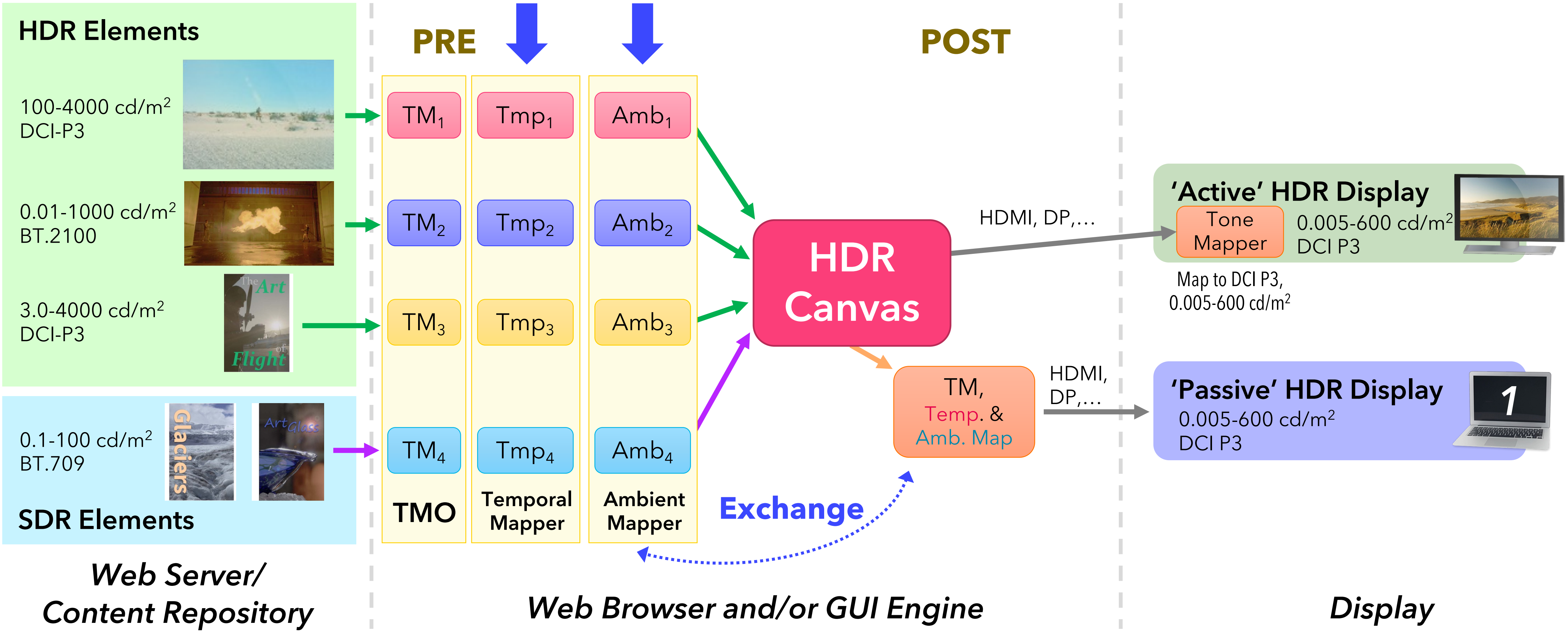
- Due to this compensation, the ***Absolute Level*** of **Reflective White** Changes

Images with Ambient Compensation



Source: Jaclyn Pytlarz, SMPTE Conference 2023

Allow Independent Algorithms for Temporal & Ambient



More ‘Whites’?

Physical Realm

- Peak white (measurement in scene/env.)
- Reflective white (measurement in scene/env.)
- **Color Temperature (based on CT or CCT)**

Perceptual Realm

- Light Sources (appearance)
- Highlights (appearance)
- Reflective white (lightness scales)
- Adapting white (lightness scales)
- Glare Induced White
- **White Point (CIE Ill. A, D_{50}, D_{65} ,…)**
- **Super White (fluorescent/phosphorescent)**

Signal Processing (conventions)

- Datatype (e.g. 8Bit max.)
- Nominal Peak White
- Reference white
- Graphics white
- **Super White (full & head/narrow range issues)**

Electronic Displays (hardware limits)

- Display Peak
- Power & Thermal Managed White (APL, Distribution, Time)

Print/Hardcopy

- **Reflectance**,…

Summary

- **White appearance** depends on the **state of adaptation** & **spatial surround**
- What **appears as light source or highlight** depends on the **contrast to its surround**
- **Displays** are **emissive**, **limited in capabilities** & have **complex modulation behavior**
- **Conventions for white:** Either adjust the **luminance of those whites** or **adjust the content itself** to match perceptually

When implementing tone mapping operators, allow **options** for

- **Information exchange** between mapping nodes
- **Absolute** luminance & color addressing
- **Choice** of TMO, temporal and ambient mapping algorithm

THANK YOU!

Contact: timo.kunkel@dolby.com

Acknowledgement: Scott Daly, Shane Ruggieri & Jaclyn Pytlartz

ISO/TC 42/WG 23 "Joint ISO/TC 42 - ISO/TC 130 - CIE WG: Extended colour encodings for digital image storage, manipulation and interchange"
Convenorship: **ANSI**
Convenor: **Foshee Scott Dr**

ICC and ISO 21496-1

Document type	Related content	Document date	Expected action
Project / Other	Project: ISO/WD 21496-1	2023-12-15	**INFO**

ICC and ISO 21496-1

• ICC and ISO

In 2003 the **ICC** entered into a "Co-operative Agreement between **ISO/TC130** and the International Color Consortium" which established the detailed procedures whereby **ISO/TC130** (Graphic technology) and the International Color Consortium (ICC) will cooperate to continue the development of a series of ISO standards based on the work of the ICC, including the ICC Profile Specification.

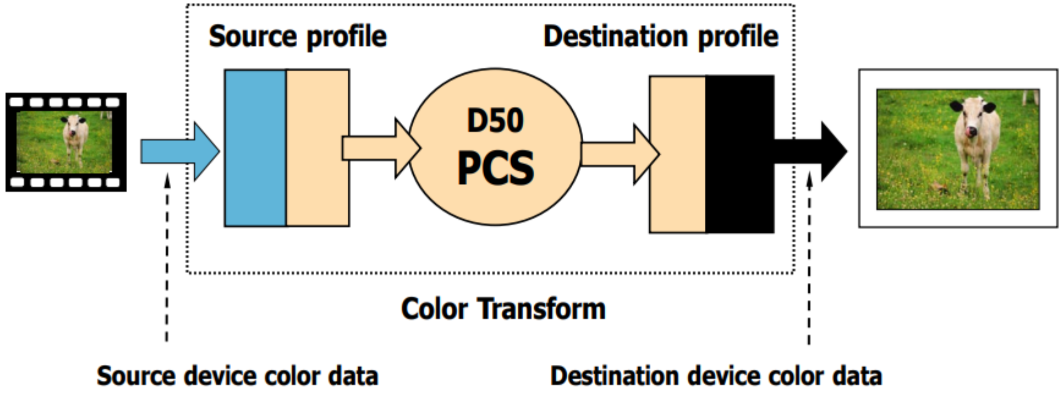
ICC.1:2004-08	<->	ISO 15076-1:2005 Image technology colour management - Architecture, profile format ,and data structure
ICC.1:2010	<->	ISO 15076-1:2010
ICC.2:2023	<->	ISO 20677:2019

Compared with ICC.1, ICC.2 has many extensions enabled for **HDR/WCG workflows.**

Now **ISO/TC42** is developing a standard ISO 21496-1 Digital photography - Gain map metadata for image conversion –Part 1: Dynamic range conversion, which defines a gain map used in **HDR digital photography applications**, for dynamic range conversion between image representations. This includes the definition of the gain map metadata and its attributes, how to apply a gain map, and how to specify the gain map and other associated metadata.

ISO/TC 42/WG 23 Joint **ISO/TC 42 - ISO/TC 130** - CIE WG: Extended colour encodings for digital image storage, manipulation and interchange

- ICC and ISO



Cite:https://www.color.org/info_profiles2.xalter
Fundamentals_of_ICC_Color_Management

ICC
Image technology colour management — Architecture, profile format, and data structure
support CMM workflows

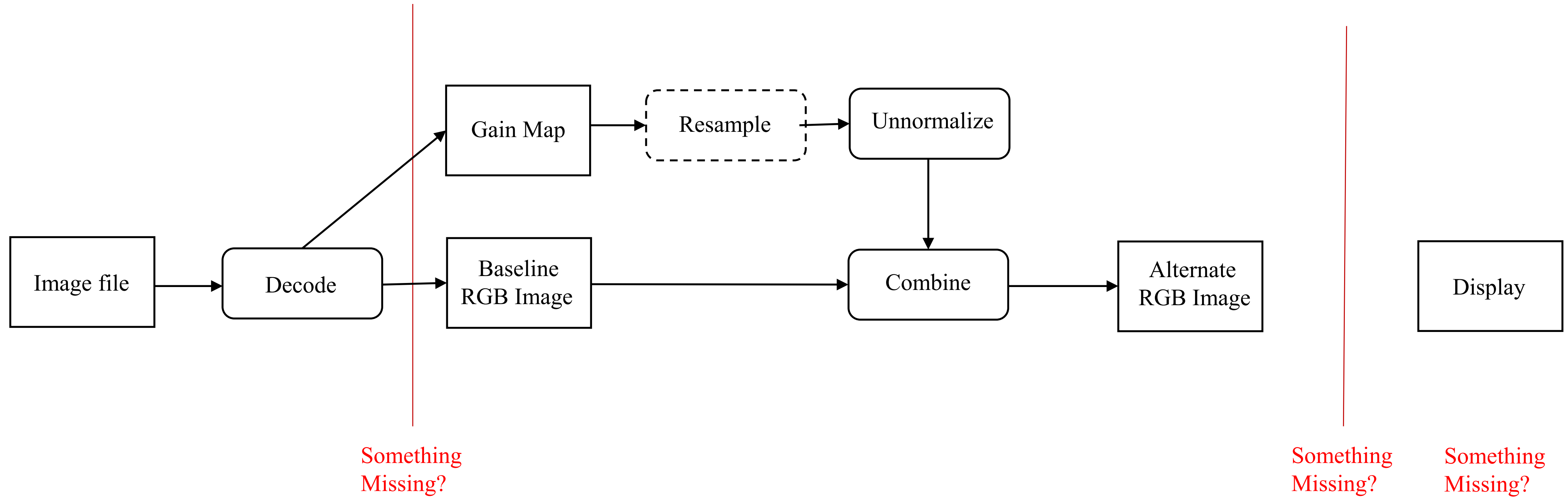
ICC is more close to the definition of workflow or Architecture

ISO/TC 42/WG 23
Extended colour encodings for digital image storage, manipulation and interchange

ISO 21496-1 Gain map metadata for image conversion

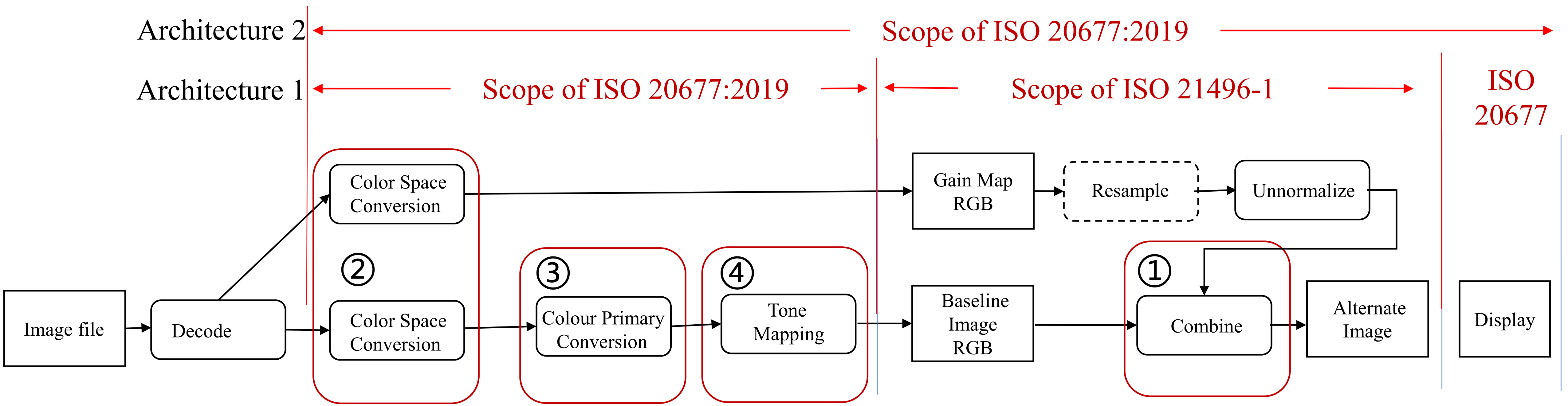
The problem is ISO 21496-1 also include how to do image conversion with Gain map Metadata and have its own workflow, which may have different Architecture with ICC.

• Current workflow of ISO 21496-1



- The combination is performed in RGB
- Except for **color primary**, the color space of gain map and baseline image could be different from the application space, so **color space conversion** is necessary.
- **A (inverse) tone mapping function** to baseline image could efficiently reduce the energy of gain map.
- After combination, the alternate linear image shall be converted to or from the format such as PQ/HLG/Gamma.

- Our proposed workflow of ISO 21496-1 and ISO 20677:2019



① Support combining baseline image and gain map in RGB, using linear, and may also PQ/HLG/Gamma for application space .

② Support color space conversion. Eg. Decoded Gain map & baseline image are YUV, gain map application space is RGB. YUV->RGB.

③ Support color primary conversion. Eg. Baseline image is BT709, alternate image and gain map application space is BT2020. BT709->BT2020.

④ Support (inverse) tone mapping for baseline image.

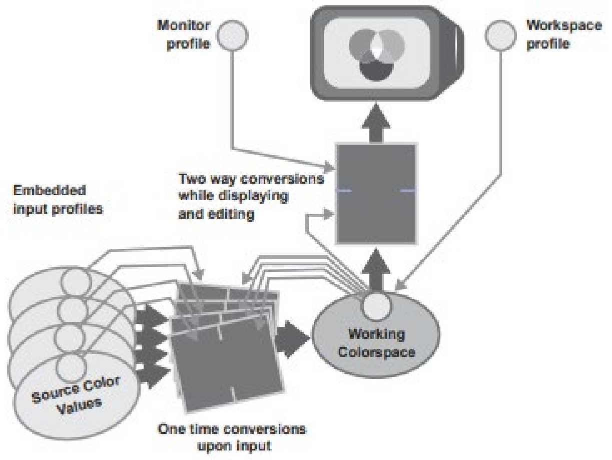
The relationship between ISO 20677:2019 and ISO 21496-1

Architecture 1: Refer ISO 20677:2019 in ISO 21496-1

- **Option 1: combination is done in working color space according to the ICC profile in baseline image (compulsory) and gain map (optional)**
  - ➢ All the required steps or functions in ISO 21496-1 could be achieved by creating and utilizing ICC profiles defined in ISO 20677:2019, no modification needed.
  - ➢ Adding unambiguous instructions to indicate how to refer ISO 20677:2019 in the processing pipeline of ISO 21496-1 is enough, which saves the time cost a lot.
- **Option 2:** only one ICC profile for alternate image
  - ➢ All color space/primary conversion of ISO 21496-1 should be defined in ISO 21496-1

- For faster implementation and higher efficiency, we request that the optimal method of combining this two is **option 1 in Architecture 1.**

Similar to: Compound multi-pictures in workflow



Cite:https://www.color.org/info_profiles2.xalter
Why Color Management?

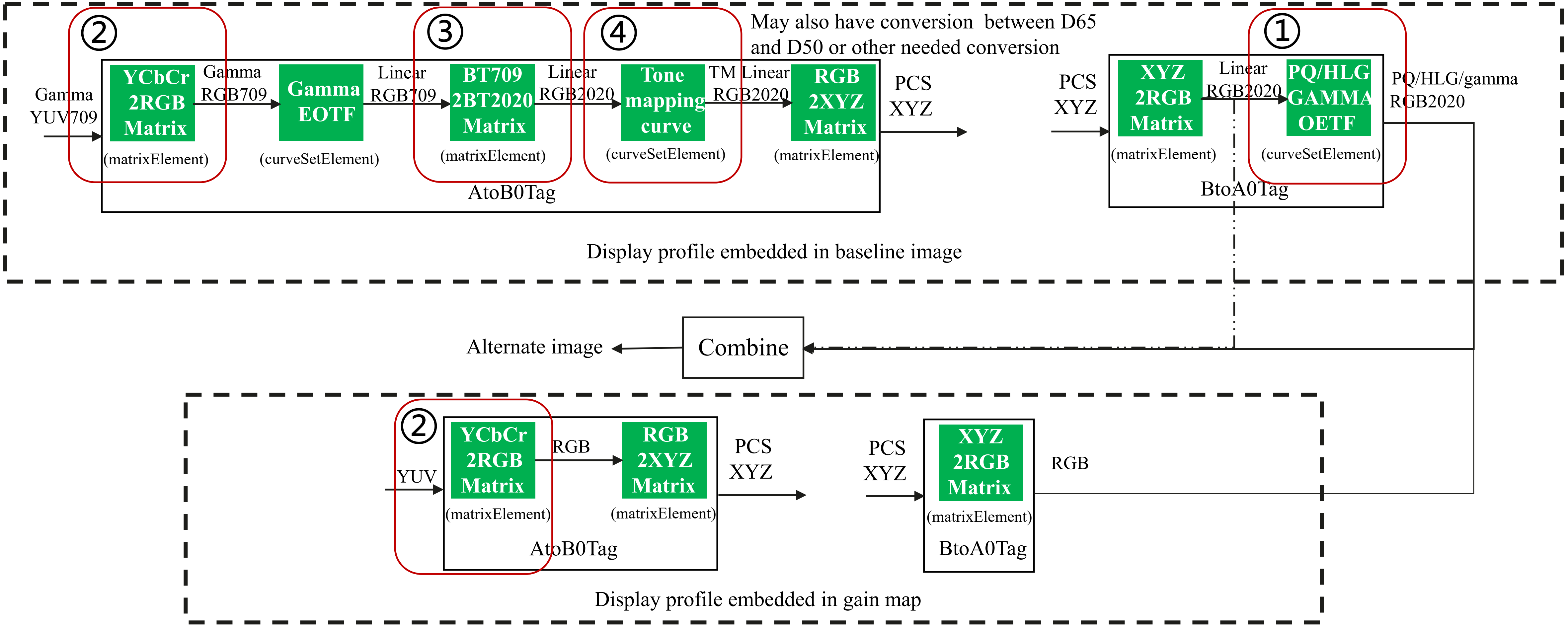
Architecture 2: Integrate ISO 21496-1 into ISO 20677:2019

- **Detail is after the description of Architecture 1**

Architecture 1: Proposed Method for referencing ISO 20677:2019 in ISO 21496-1

Option 1 (Method 1): one ICC for each picture (baseline and gain map), combination is done in working color space

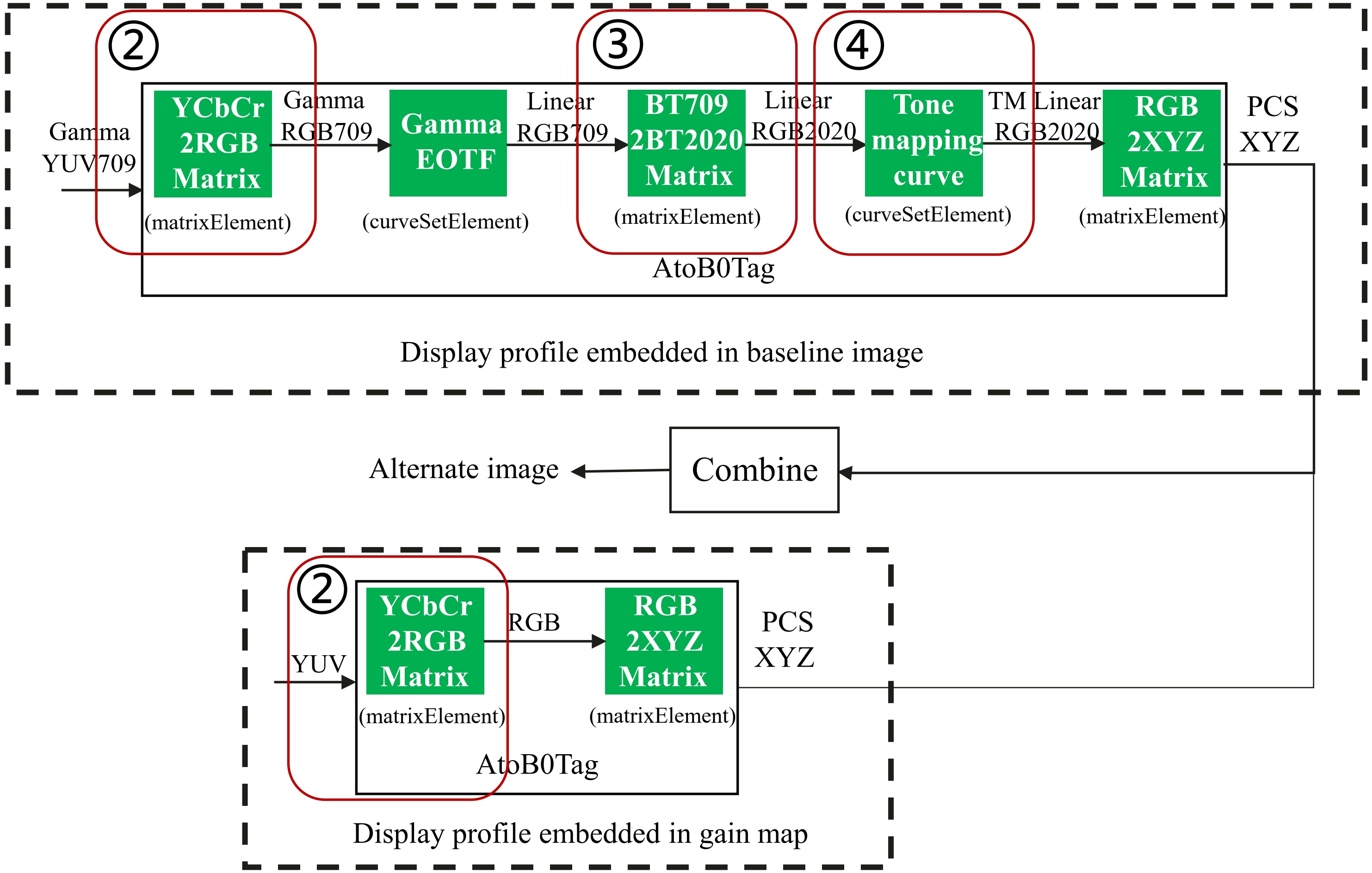
Add a cicpTag in the ICC-profile to indicate the format of alternate image.



Architecture 1: Proposed Method for referencing ISO 20677:2019 in ISO 21496-1

How about applying gain map in PCSXYZ or CIEXYZ space?

Option 1 (Method 2): one ICC for each picture (baseline and gain map), combination is done in working color space

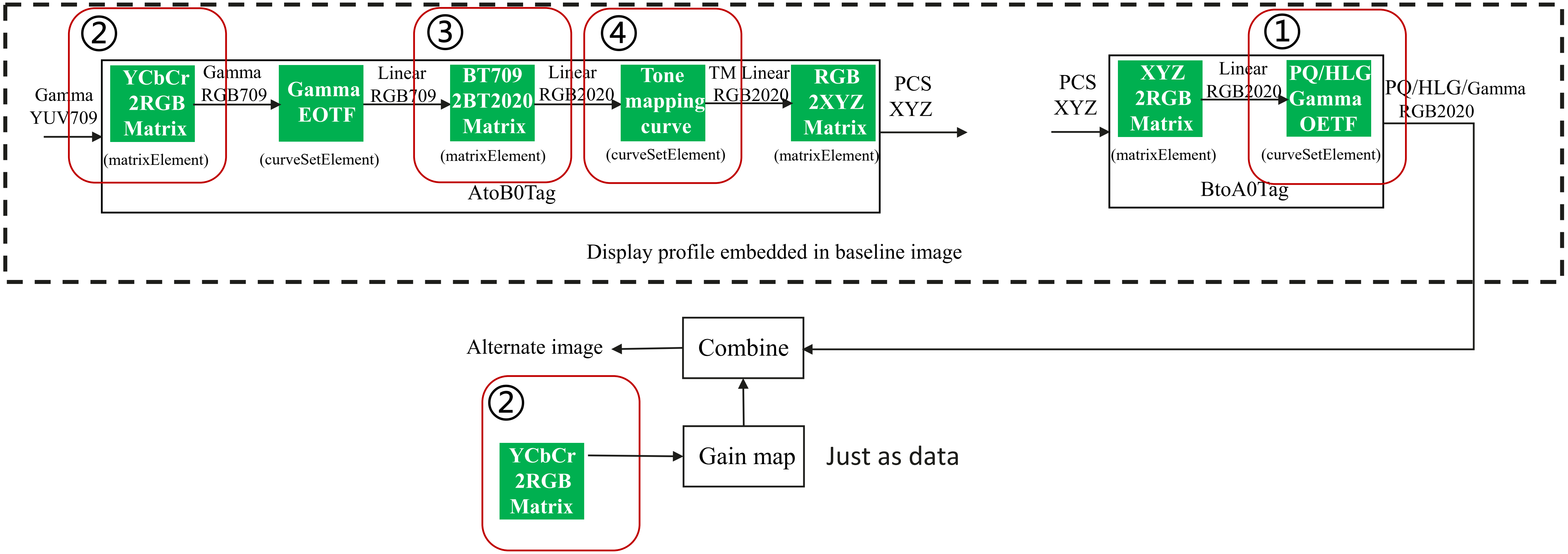


- XYZ color space is a more common color representation method, which is **independent of the characteristics of the device** and **closer to the perception of the human visual system.**

Architecture 1: Proposed Method for referencing ISO 20677:2019 in ISO 21496-1

How about taking gain map format as the default sRGB? Nearly all systems can do the YUV2RGB conversion correctly

Option 1 (Method 3): only one ICC for baseline image, combination is done in working color space



- **Gain map does not include and utilize ICC profile, it is just regarded as some kind of image data with default sRGB format.**

Solution for issue ①（Transfer Curves)

- CurveSetElement(ISO 20677:2019 11.2.2)

The Curve Set element encodes multiple one-dimensional curves. The encoding is shown in Table 107. The sampledClaculatorCurve curve type allows for the encoding of 1-dimensional curves as an arbitrary function using an embedded element of type calculatorElement. This allows for more optimal implementation as the embedded calculator element can be applied at transform setup to populate a sampled 1-dimensional lookup table that is then used for performing curve transforms. The encoding of a sampledClaculatorCurve is shown in Table 109.

Table 107 — curveSetElement encoding

Byte position	Field length (bytes)	Content	Encoded as...
0...3	4	'cvst' (63767374h) type signature	
4...7	4	Reserved, shall be 0	
8...9	2	Number of input channels (P)	uInt16Number
10...11	2	Number of output channels (Q)	uInt16Number
12..11+8P	8P	Curve positions (offset and size)	positionNumber[...]
12+8P to end		Data	

Table 109 – sampledCalculatorCurve encoding

Byte Position	Field Length (bytes)	Content	Encoded as...
0..3	4	'clcf' (636c6366h) type signature	
4..7	4	Reserved, must be set to 0	
8..12	4	Recommended number of interpolation samples for the curve (R)	uInt32Number
12..15	4	Starting input range value of curve (S)	float32Number
16..19	4	Ending input range value of curve (E)	float32Number
20.21	2	Lookup Extension type (L)	uInt16Number
22.23	2	Reserved, must be set to 0	
16+20..end		Curve Definition	calculatorElement

In our case, take **PQ OETF** as an example, the input P and output channels are all set to **3,** which means that the PQ transfer curves shall be applied to R,G,B channels separately. PQ curve is defined according to ITU-R BT.2100 by embedded **calculator element** as:

$$L_{PQ} = \left(\frac{c1+c2L^{m1}}{1+c3Y^{m1}}\right)^{m2}$$

*where m1= 2610/16384,m2=2523/4096*128,c1=3424/4096,c2=2413/4096*32,c3=2392/4096*32*

The curves shall be defined between **0(S) and 1(E)** , with Lookup Extension type(L) set to 0 for clipping abnormal value.

Solution for issue ② （Color Space Conversion）

- matrixElement(ISO 20677:2019 11.2.10)

The matrix is organized as an array of P x Q elements, where P is the number of input channels to the matrix, and Q is the number of output channels. The matrix element encoding is shown in Table 120.

array = [e_{11}, e_{12}, ..., e_{1P}, e_{21}, e_{22}, ..., e_{2P}, ..., e_{Q1}, e_{Q2}, ..., e_{QP}, e_1, e_2, ..., e_Q]

$$\begin{bmatrix} Y_1 \\ Y_2 \\ \cdots \\ Y_Q \end{bmatrix} = \begin{bmatrix} e_{11} & e_{12} & \cdots & e_{1P} \\ e_{21} & e_{22} & \cdots & e_{2P} \\ \cdots & \cdots & \cdots & \cdots \\ e_{Q1} & e_{Q2} & & e_{QP} \end{bmatrix} \cdot \begin{bmatrix} X_1 \\ X_2 \\ \cdots \\ X_P \end{bmatrix} + \begin{bmatrix} e_1 \\ e_2 \\ \cdots \\ e_Q \end{bmatrix}$$

Table 120 — Matrix Element encoding

Byte position	Field length (bytes)	Content	Encoded as...
0..3	4	'matf' (6D617466h) type signature	
4..7	4	Reserved, shall be 0	
8..9	2	Number of input channels (P)	uInt16Number
10..11	2	Number of output channels (Q)	uInt16Number
12..end	4x(P+1)xQ	Matrix elements	float32Number[...]

In our case, take **YUVtoRGB2020** as an example, the input P and output channels Q are all set to **3**, the total transfer can be expressed as:

$$\begin{matrix} R \\ G \\ B \end{matrix} = \begin{bmatrix} 1.0000 & -0.0000 & 1.4746 \\ 1.0000 & -0.1645 & 0.5713 \\ 1.0000 & 1.8814 & -0.0001 \end{bmatrix} * \begin{matrix} Y \\ U \\ V \end{matrix} + \begin{matrix} 0 \\ 0 \\ 0 \end{matrix}$$

So the array could be written as $array = [1.0000, -0.0000, 1.4746, 1.0000, -0.1645, 0.5713, 1.0000, 1.8814, -0.0001, 0, 0, 0]$

Solution for issue ③ （Color Primary Conversion）

- matrixElement(ISO 20677:2019 11.2.10)

The matrix is organized as an array of P x Q elements, where P is the number of input channels to the matrix, and Q is the number of output channels. The matrix element encoding is shown in Table 120.

array = $[e_{11}, e_{12}, \ldots, e_{1P}, e_{21}, e_{22}, \ldots, e_{2P}, \ldots, e_{Q1}, e_{Q2}, \ldots, e_{QP}, e_1, e_2, \ldots, e_Q]$

$$\begin{bmatrix} Y_1 \\ Y_2 \\ \ldots \\ Y_Q \end{bmatrix} = \begin{bmatrix} e_{11} & e_{12} & \ldots & e_{1P} \\ e_{21} & e_{22} & \ldots & e_{2P} \\ \ldots & \ldots & \ldots & \ldots \\ e_{Q1} & e_{Q2} & & e_{QP} \end{bmatrix} \cdot \begin{bmatrix} X_1 \\ X_2 \\ \ldots \\ X_P \end{bmatrix} + \begin{bmatrix} e_1 \\ e_2 \\ \ldots \\ e_Q \end{bmatrix}$$

Table 120 — Matrix Element encoding

Byte position	Field length (bytes)	Content	Encoded as...
0..3	4	'matf' (6D617466h) type signature	
4..7	4	Reserved, shall be 0	
8..9	2	Number of input channels (P)	uInt16Number
10..11	2	Number of output channels (Q)	uInt16Number
12..end	4x(P+1)xQ	Matrix elements	float32Number[...]

In our case, take **RGB709toRGB2020** as an example, the input P and output channels Q are all set to **3**, the total transfer can be expressed as:

$$\begin{matrix} R2020 \\ G2020 \\ B2020 \end{matrix} = \begin{bmatrix} 0.6274 & 0.3293 & 0.0433 \\ 0.0691 & 0.9195 & 0.0114 \\ 0.0164 & 0.0880 & 0.8956 \end{bmatrix} * \begin{matrix} R709 \\ G709 \\ B709 \end{matrix} + \begin{matrix} 0 \\ 0 \\ 0 \end{matrix}$$

So the array could be written as $array = [0.6274, 0.3293, 0.0433, 0.0691, 0.9195, 0.0114, 0.0164, 0.0880, 0.8956, 0, 0, 0]$

Solution for issue ④ （Tone mapping)

- CurveSetElement(ISO 20677:2019 11.2.2)

The Curve Set element encodes multiple one-dimensional curves. The encoding is shown in Table 107. The sampledClaculatorCurve curve type allows for the encoding of 1-dimensional curves as an arbitrary function using an embedded element of type calculatorElement. This allows for more optimal implementation as the embedded calculator element can be applied at transform setup to populate a sampled 1-dimensional lookup table that is then used for performing curve transforms. The encoding of a sampledClaculatorCurve is shown in Table 109.

Table 107 — curveSetElement encoding

Byte position	Field length (bytes)	Content	Encoded as...
0...3	4	'cvst' (63767374h) type signature	
4...7	4	Reserved, shall be 0	
8...9	2	Number of input channels (P)	uInt16Number
10...11	2	Number of output channels (Q)	uInt16Number
12..11+8P	8P	Curve positions (offset and size)	positionNumber[...]
12+8P to end		Data	

Table 109 – sampledCalculatorCurve encoding

Byte Position	Field Length (bytes)	Content	Encoded as...
0..3	4	'clcf' (636c6366h) type signature	
4..7	4	Reserved, must be set to 0	
8..12	4	Recommended number of interpolation samples for the curve (R)	uInt32Number
12..15	4	Starting input range value of curve (S)	float32Number
16..19	4	Ending input range value of curve (E)	float32Number
20.21	2	Lookup Extension type (L)	uInt16Number
22.23	2	Reserved, must be set to 0	
16+20..end		Curve Definition	calculatorElement

In our case, take **Reinhard tone mapping** as an example, the input P and output channels are all set to **3,** which means that we have three one-dimensional curves(R,G,B separately). All the three curves apply Reinhard tone mapping function defined by embedded **calculator element** as:

$$L_{TM} = \frac{L * (1 + \frac{L}{L_{white}^2})}{1 + L}$$

The curves could be defined between **0(S) and 1(E)** , with Lookup Extension type(L) set to 1 for avoiding clipping.

Draft Modifications for Architecture 1 Option 1 in ISO 21496-1 (Preferred)

1. 3.2 baseline image
data structure that contains pixels and image-related data, and is stored in the file as the main image with ICC profile
The baseline image data in RGB or XYZ is then derived using the ICC profile.
Note: ICC profile contains the color conversion and tone conversion information.

2. 3.3 gain map
data structure that contains local quotients used for conversion between two image representations with or without ICC profile
Note: ICC profile contains the color conversion information, The gain map data in RGB or XYZ is derived using the ICC profile. If no ICC profile exist, the gain map use default sRGB for the potential color conversion.

The relationship between ISO 20677:2019 and ISO 21496-1

Architecture 1: Refer ISO 20677:2019 in ISO 21496-1

Architecture 2: Integrate ISO 21496-1 into ISO 20677:2019

- add new mechanism into AtoBx or some other tag with coordinate, store gain map as a lut or somewhere, using coordinate to seek for the value.
- add new mechanism into AtoBx with an opening design with only label and offset to gain map data to allow citing other image conversion standard.
- Extend the abstract profile or adding a special profile with an opening design.

- Need massive amendment on ISO 20677:2019 , how to and when can support current structure of ISO 21496-1(two images, baseline image and gain map) in ISO 20677:2019 is not clear.

Architecture 2: Integrate ISO 21496-1 into ISO 20677:2019

The following methods can be used separately or together

- add new coordinate mechanism into AtoBx or some other tag or tag type, store gain map as a lut or somewhere, using coordinate to seek for the value.
  - **Examples of things that cannot be done by a profile:**
    - — Conditional rendering intent selection
    - — Spatial operations
    - — Variable transforms
    - — Channel preservation

Cite:https://www.color.org/info_profiles2.xalter
Fundamentals_of_ICC_Color_Management

- add new mechanism into AtoBx or some other tag with an opening design with only label and offset to gain map data to allow citing other image conversion standard.

➢ Extend the Tag type, with one additional tag Type with label 'gain' that can be registered by other standard.
➢ The input and output colour space should refer to ISO 21496-1.

- Extend the abstract profile or adding a special profile with an opening design.

➢ Extend abstract profile with one additional tag with label 'extn' that can be registered by other standard. With tag Type of 'gain' as using ISO 21496-1.
➢ Extend the Tag type, with one additional tag Type with label 'gain' that can be registered by ISO 21496-1.
➢ Some constraints should be added in ISO 21496-1 on the usage of PCS to PCS.
➢ PCS range conversions tag should be set accordingly
➢ Some flag in profile header should be added to indicate the usage of abstract profile.

Use of alternate HDR to SDR conversions can be complished using an abstract profile containing a passthrough (identity) colorimetric transform, an HDR to SDR tag transform, and the use of extended-range PCS is flagged in the abstract profile header. The abstract profile's HDR to SDR transform will be applied when it is placed between an extended-range PCS source profile and a non-extended range PCS profile – thus allowing overrides of HDR to SDR transforms to be performed.

Cite: ICCMax Spec

8.9 Abstract profile

In addition to the tags listed in 8.2 an abstract profile shall contain one or more of the following tags: AToB0Tag (see 9.2.1), DToB0Tag (see 9.2.76).

This profile represents an abstract transform and does not represent any device model. Colour transformations using abstract profiles are performed from PCS to PCS. Abstract profiles cannot be embedded in images.

Draft Modifications for Architecture 2

- In ISO 21496-1
  - Adding Annex E
  - The tag type of gain map application is ‘gain’.
  - (optional) Add all the gainmap metadata into the structure of this type.
  - Set the Added flag in the profile header to notify that the gain map application should be used, for example flag is 1 means using Abstract Profile with ‘extn’ tag who have the type of ‘gain’.

- In amendment of ISO 20677:2019
  - Adding The tag type of ‘gain’, the structure of this type is the same as in ISO 21496-1 Annex E, the procedure is as in ISO 21496-1.
  - Adding The additional tag with label ‘extn’, with one of the tag type as ‘gain’.
  - Adding The additional tag to Abstract Profile.
  - Modified the constrain on Abstract Profile to allow embedded in image.
  - Adding some flag in the profile header to notify that the Abstract Profile should be used, for example flag is 1 means using Abstract Profile with ‘extn’ tag who have the type of ‘gain’.

Need massive amendment on ICC, how and when to support current structure of ISO 21496-1(two images, baseline image and gain map) in ISO 20677:2019 is not clear.

Summary

Architecture 1: Refer ISO 20677:2019 in ISO 21496-1

- **Option 1: combination is done in working color space according to the ICC profile in baseline image (compulsory) and gain map (optional)**

Thank You!

ISO/ICC HDR Still Image Day!
Conversion to SDR (& more!)
Proposed ISO 22028-5 Annex

Christopher Cameron
2024-02-19

Agenda

Scope & Motivation

When does an image include a mapping to SDR?

What to do when an image does not include a mapping?

What about HDR headrooms?

Part 1: Scope

Scope of annex

Provide guidance for how to convert an ISO 22028-5 image to an SDR image.

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An image that can be used in the existing extensive (primary ICC profile based) SDR color management ecosystem.

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SDR color management ecosystem is built around conversion from and to a “profile connection space” (PCS), usually XYZD50 (or Lab).

Scope of annex

Provide guidance for how to convert an ISO 22028-5 image to ~~an SDR image.~~

~~An image that can be used in the existing extensive (primary ICC profile based) SDR color management ecosystem.~~

~~SDR color management ecosystem is built around conversion from and to~~ a "profile connection space" (PCS), usually XYZD50 (or Lab).

Scope of annex

Provide guidance for how to convert an ISO 22028-5 image to XYZD50.

Scope of annex

Provide guidance for how to convert an ISO 22028-5 image to XYZD50.

Explicitly do not handle gamut mapping from Rec2020/ISO 22028-5 gamut to more narrow gamuts. The existing SDR CMS ecosystem covers this.

Motivation

Was I subtle about this?

Part 2:
When does an image include a mapping to SDR?

When does an image include a mapping to SDR?

Gainmap images

ICC Profiles

Gainmap images

SDR rendition is the rendition with HDR headroom of 1 (0 stops)

ICC profiles

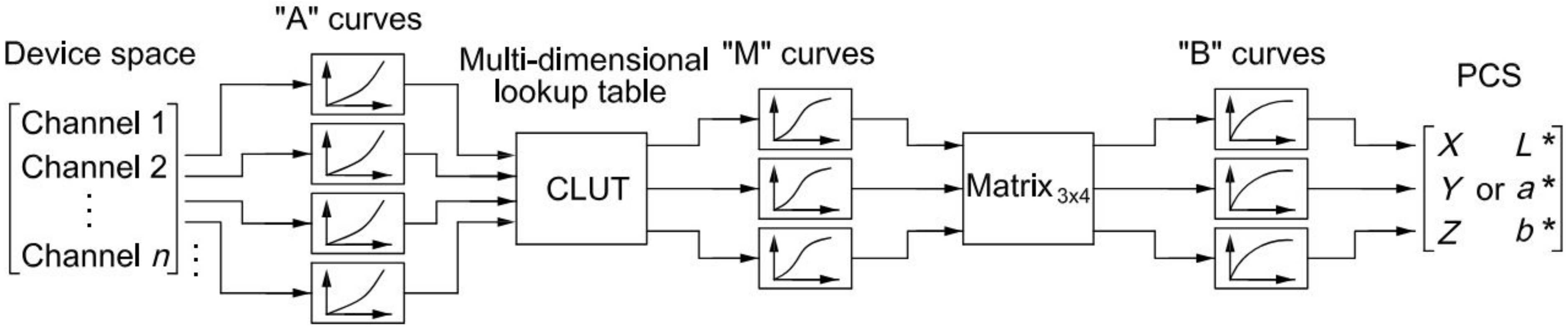
An ICC profile provides a (or several) mapping to XYZD50. So…

“If the image includes an ICC profile, then that ICC profile must specify a CICP tag that specifies primaries of 9 (Rec2020) and transfer characteristics of 16 (PQ) or 18 (HLG).

If that ICC profile includes a transformation to an SDR profile connection space (e.g, XYZ or Lab), then that transformation is to be used.”

ICC.1:2022, Figure 3

ICC profiles allow for image creators to have express their artistic intent.



e) Using a lutAToBType model

Part 3: When the image doesn’t specify an SDR mapping…

What to do when an image has no SDR rendition?

The image could have provided a gainmap … but didn’t

The image could have provided a global tone mapper … but didn’t

Now what?

What to do when an image has no SDR rendition?

Define a mapping to the SDR PCS (e.g, XYZD50 or Lab)

Part A: Goals/Constraints

Part B: Tone mapping algorithm outline

Part C: Details

Part 3a: Goals/Constraints

Goals / Constraints

Quality & Simplicity

Goals / Constraints: Simplicity

1. Global tone mapping
   - Not local tone mapping
2. Independent of image content
   - Only ISO 22028-5 metadata
3. No iterative numerical methods
   - A “reasonable” fragment shader
4. Unified between HLG and PQ
   - HLG and PQ encodings of an HDR image produce the same SDR image
5. Target Rec2020 Linear RGB
   - Specify conversion from there to PCS

ISO 22028-5 HDR Metadata

- Content color volume (CCV)
- Nominal diffuse white level (NDWL)
- Content light level info (CLLI)
- Mastering display color volume (MDCV)
- Reference viewing environment (REVE)

Goals / Constraints: Quality

1. Do not shift chromaticity
   - Do not cause “cyan sky” problem
2. Do not excessively darken the image
   - Image should look good on black and white (e.g, printed) backgrounds
3. Do not destroy highlights

Example: 1. Shifting chromaticity (HDR source)

Creator's custom SDR grading

Reinhard using YRGB then clamping

Example: 2. Excessive Darkening (HDR source)

Creator's custom SDR grading

ITU-R BT.2446 Method A

Example: 3A: Destroying highlights ([HDR source]())

Creator's custom SDR grading

ITU-R BT.2408 Annex 5

Reinhard

Example: 3B: Destroying highlights vs darkening (source)

ITU-R BT.2446
Method A

Reinhard

ITU-R BT.2408 Annex 5

Part 3b: Algorithm Outline

Algorithm outline

1. Convert to display luminance as per ISO 22028-5 / ITU-R BT.2100
   - Apply PQ EOTF
   - Apply HLG EOTF for a 1,000 nit reference display (OOTF gamma=1.2)

2. Apply curve to map content max luminance to nominal diffuse white level
   - Context max luminance: From content color volume (if present, else) content light level info (if present, else) mastering display color volume (if present, else) 1,000 nits
   - Nominal diffuse white level: From metadata (if present, else) 203 nits

3. Divide by nominal diffuse white level
   - Result is in Rec2020 linear space with (1,1,1) as white

ISO 22028-5 HDR Metadata

- Content color volume (CCV)
- Nominal diffuse white level (NDWL)
- Content light level info (CLLI)
- Mastering display color volume (MDCV)
- Reference viewing environment (REVE)

Algorithm outline

1. Convert to display luminance as per ISO 22028-5 / ITU-R BT.2100
   - Apply PQ EOTF
   - Apply HLG EOTF for a 1,000 nit reference display (OOTF gamma=1.2)

What curve, how to apply it?

2. Apply curve to map content max luminance to nominal diffuse white level
   - context max luminance: From content color volume (if present, else) content light level info (if present, else) mastering display color volume (if present, else) 1,000 nits
   - nominal diffuse white level: From metadata (if present, else) 203 nits

3. Divide by nominal diffuse white level
   - Result is in Rec2020 linear space with (1,1,1) as white

Algorithm outline A: What curve?

Reinhard et al 2002

ITU-R BT.2408 Annex 5

ITU-R BT.2446 Methods A,B,C

SMPTE ST 2094-10

(More?)

Algorithm outline B: How to apply the curve?

The final step is to invert the normalization of the PQ values based on the mastering display black and white luminances, L_B and L_W, to obtain the target display PQ values.

Step 5: $E_4 = E_3\,(EOTF_{PQ}^{-1}[L_W] - EOTF_{PQ}^{-1}[L_B]) + EOTF_{PQ}^{-1}[L_B]$

The EETF may be applied in many colour representations [12]. Here are some options:

1) IC_TC_P

$$I_2 = EETF(I_1)$$

$$C_{T2}, C_{P2} = min\left(\frac{I_1}{I_2}, \frac{I_2}{I_1}\right) \times (C_{T1}, C_{P1})$$

2) $Y'C'_BC'_R$

$$Y'_2 = EETF(Y'_1)$$

$$C'_{B2}, C'_{R2} = min\left(\frac{Y'_1}{Y'_2}, \frac{Y'_2}{Y'_1}\right) \times (C'_{B1}, C'_{R1})$$

3) *YRGB*

$$Y_1 = 0.2627R_1 + 0.6780G_1 + 0.0593B_1$$

$$Y_2 = EOTF_{PQ}(EETF(EOTF_{PQ}^{-1}(Y_1)))$$

$$(R_2, G_2, B_2) = \frac{Y_2}{Y_1} \times (R_1, G_1, B_1)$$

4) $R'G'B'$

$$(R'_2, G'_2, B'_2) = EETF(R'_1, G'_1, B'_1)$$

5) *maxRGB*

$$M_1 = max(R_1, G_1, B_1)$$

$$M_2 = EOTF_{PQ}\left(EETF\left(EOTF_{PQ}^{-1}(M_1)\right)\right)$$

$$(R_2, G_2, B_2) = (M_2/M_1) \times (R_1, G_1, B_1)$$

TABLE A5.1

Advantages of EETF application space

	IC_TC_P	$Y'C'_BC'_R$	YRGB	R'G'B'	maxRGB
Does not produce colours significantly outside the Target Colour Volume	×	×	×	✓	✓

Part 3c: Proposed algorithm

Algorithm outline suggestions

Curve: Reinhard et al 2002

- Simple
- Strikes a balance between crushing highlights and excessive darkening

Applied on: maxRGB

- Simple
- Preserves chromaticity

Part “3d”: Next steps

Next steps a: Test ISO 22028-5 images

Evaluation framework:

https://ccameron-chromium.github.io/webgl-examples/tonemap.html

Test images:

- https://people.csail.mit.edu/ericchan/hdr/hdr.php
- https://developer.apple.com/documentation/uikit/images_and_pdf/supporting_hdr_images_in_your_app

Next steps b: Algorithm considerations!

What else is to be considered?

Next steps: Get involved

Submit test images

Submit alternative algorithm considerations

Part 4: What about conversion to extended spaces?

Conversion to extended linear space

1. Convert to display luminance as per ISO 22028-5 / ITU-R BT.2100
   - Apply PQ EOTF
   - Apply HLG EOTF for a 1,000 nit reference display (OOTF gamma=1.2)

2. Divide by nominal diffuse white level

Algorithm outline

1. Convert to display luminance as per ISO 22028-5 / ITU-R BT.2100
    - Apply PQ EOTF
    - Apply HLG EOTF for a 1,000 nit reference display (OOTF gamma=1.2)

2. ~~Apply curve to map content max luminance to nominal diffuse white level~~
    - ~~Context max luminance: From content color volume (if present, else) content light level info (if present, else) mastering display color volume (if present, else) 1,000 nits~~
    - ~~Nominal diffuse white level: From metadata (if present, else) 203 nits~~

3. Divide by nominal diffuse white level
    - Result is in Rec2020 linear space with (1,1,1) as SDR white
    - (content max luminance) / (nominal diffuse white level) is “max headroom”

Conversion to extended linear space

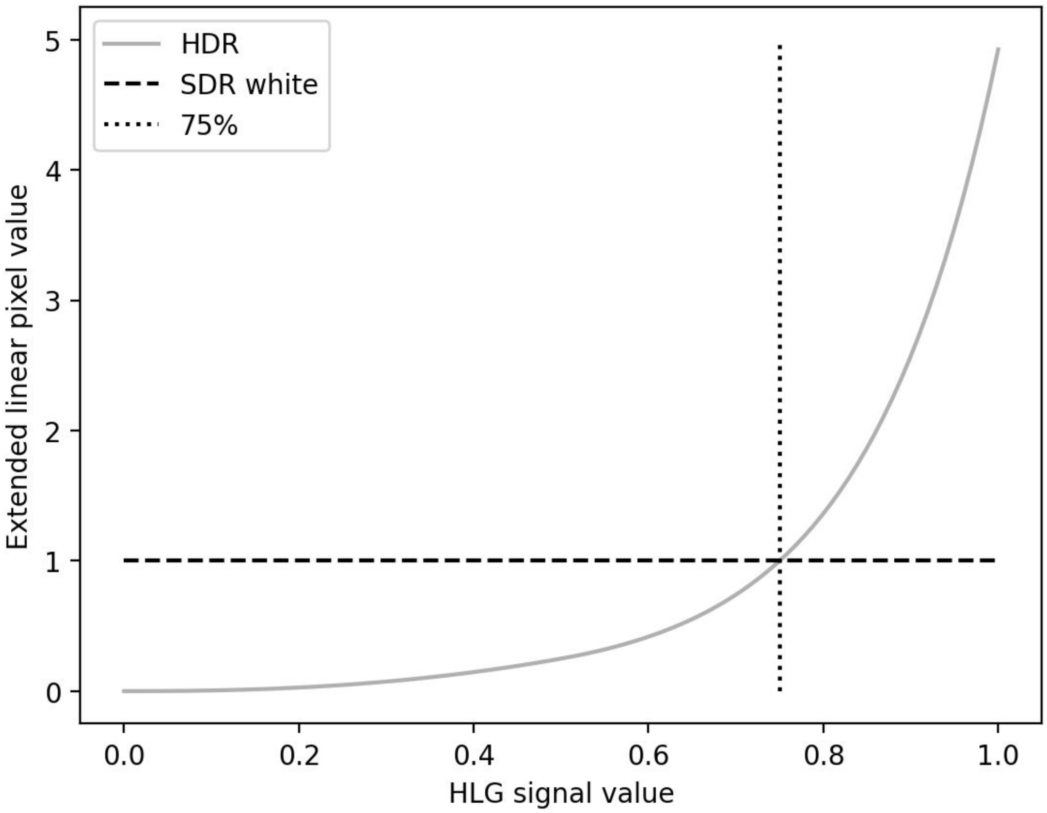
1. Convert to display luminance as per ISO 22028-5 / ITU-R BT.2100
   - Apply PQ EOTF
   - Apply HLG EOTF for a 1,000 nit reference display (OOTF gamma=1.2)

2. Divide by nominal diffuse white level

The image has a “content headroom” of:

(content max luminance) / (nominal diffuse white level)

Conversion to extended linear space



What about adapting to a display with less headroom

Use the same interpolation math as gainmaps do (without formulating a gainmap)

$$\text{Adapted} = \lim_{\epsilon \to 0} \left((\text{SDR} + \epsilon) \cdot \left(\frac{\text{HDR} + \epsilon}{\text{SDR} + \epsilon} \right)^{W} - \epsilon \right)$$

What about adapting to a display with less headroom

Use the same interpolation math as gainmaps do (without formulating a gainmap)

Same W parameter as gainmap

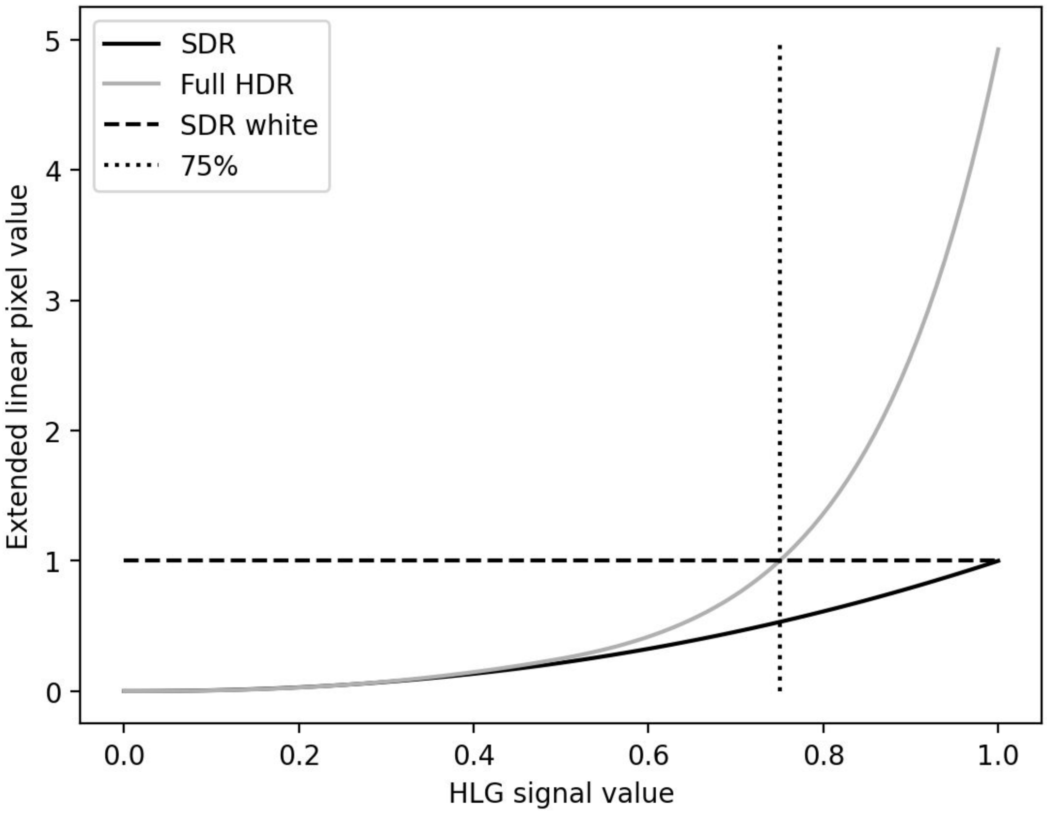
$$\text{Adapted} = \lim_{\epsilon \to 0} \left((\text{SDR} + \epsilon) \cdot \left(\frac{\text{HDR} + \epsilon}{\text{SDR} + \epsilon} \right)^{W} - \epsilon \right)$$

What about adapting to a display with less headroom

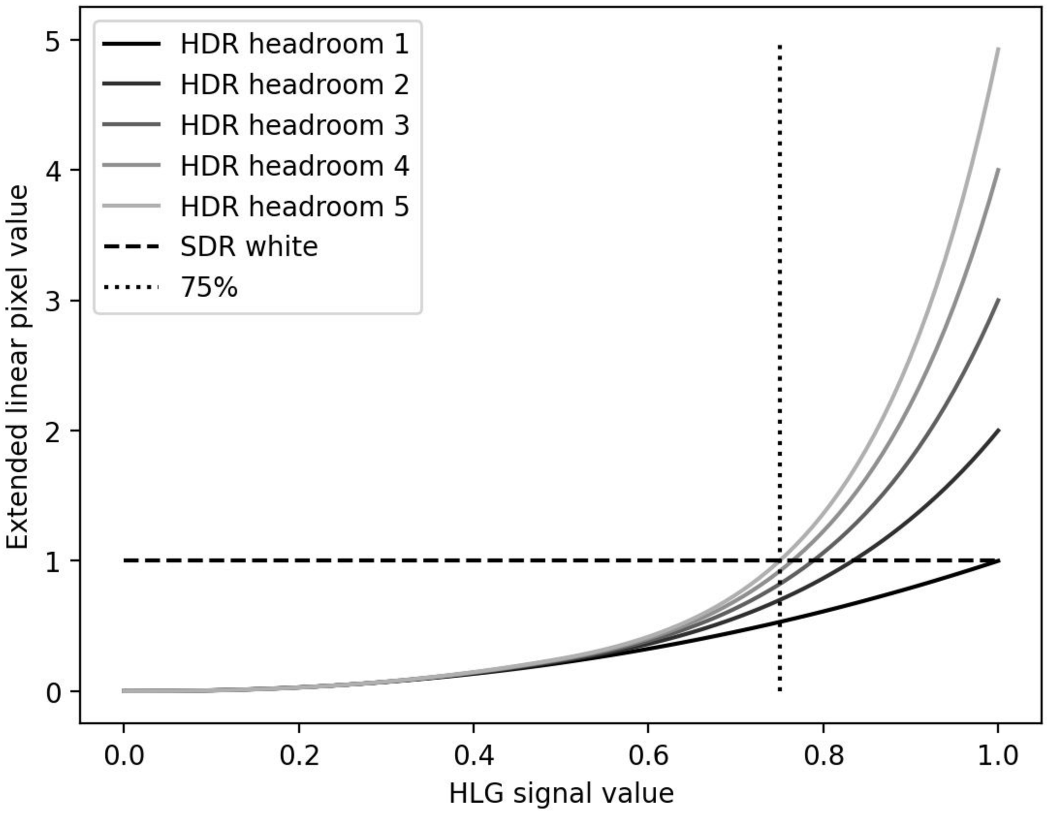
Use the same interpolation math as gainmaps do (without formulating a gainmap)

$$\text{Adapted} = \lim_{\epsilon \to 0} \left((\text{SDR} + \epsilon) \cdot \left(\frac{\text{HDR} + \epsilon}{\text{SDR} + \epsilon} \right)^{W} - \epsilon \right)$$

Conversion to several headrooms (HLG with Reinhard)



Conversion to several headrooms (HLG with Reinhard)



The End