What is High Dynamic Range Imaging?

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Timo Kunkel, PhD

Dolby Labs, Inc.

timo.kunkel@dolby.com

Introduction

- Luminance & color contrast makes real-world objects distinguishable
- This is also true for reproductions in the form of images
  - Drawings, paintings, chemical photographs, digital imaging & display,…
- Sufficient contrast supports the expression of the reproduction e.g., in photography
- In the past 25 years High Dynamic Range imaging or 'HDR' has significantly extended the luminance & color contrast ranges available to imaging

https://petapixel.com/2016/06/14/galaxy-resurrecting-dry-plate-photography-large-format/

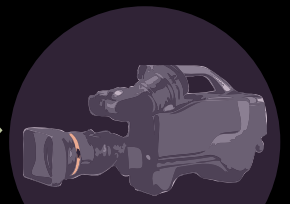
- Since then, the HDR field has been continuously evolving.
- Today, HDR is available & beneficial to many areas of imaging

Let's look at the reasons & benefits of HDR!

What is HDR Technology?

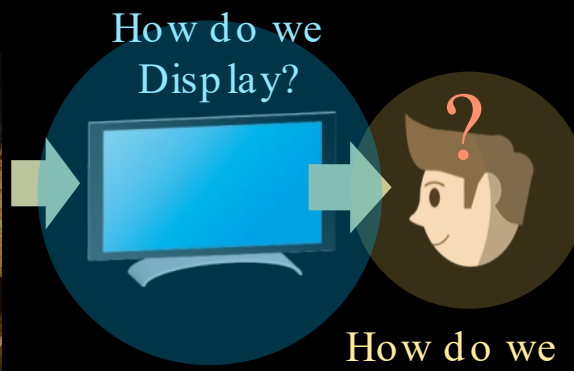
- High Dynamic Range benefits in a nutshell…
- To provide compelling HDR experiences, we need to consider many aspects…

Direct View of Scene
Inherently 'HDR'



How do we
Perceive 'Reality'?

Reproduction of Scene
Not necessarily HDR



How do we
Perceive a
Reproduction?

What do We Want to Achieve with HDR Technology

- Realistic and compelling image quality
- Does this mean to reproduce physical reality?
- An HDR imaging ecosystem, and particular display devices can't reproduce all physical reality
- Actual physical realism is typically not required or even desired
- Instead, recreate the perception of a realistic world on a display
- Maintain the intent of the content

Contrast & Color Saturation Appearance

Diffuse vs Emissive and Specular Highlights

- Peak white is not the only ‘white’
- Consider the luminance & perceptual differences between emissives & diffuse white

Shadow & Black Appearance

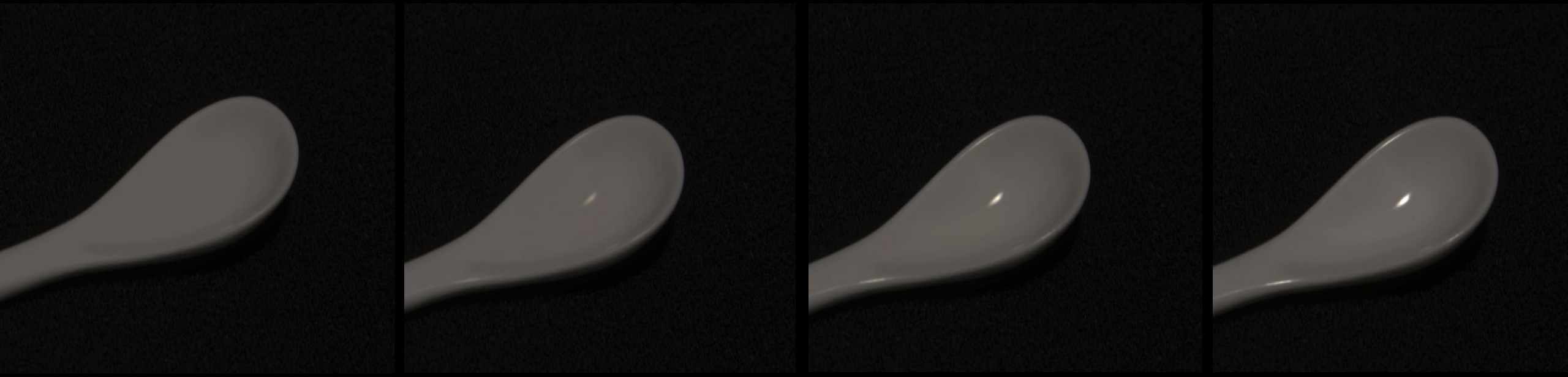
Sense of Depth
from Lower Black

Detail Visible

Lifted/'Muddy' Blacks:
Provide 2D Planar Cues

Deep Blacks:
No 2D Planar Cues

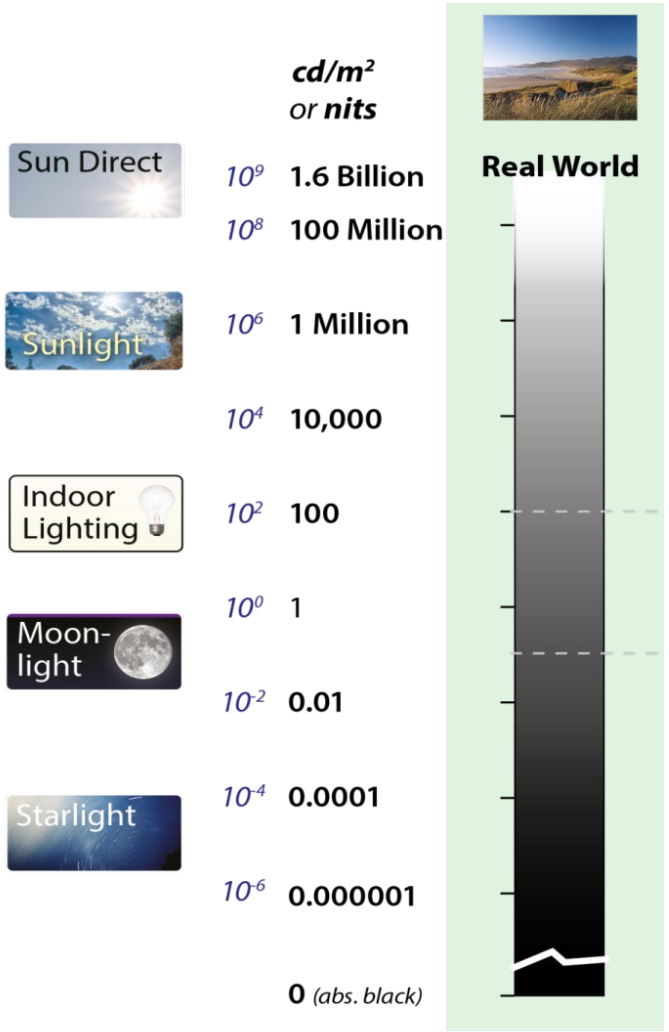
Realistic Material Appearance



The appearance of a material is connected to its reflectivity

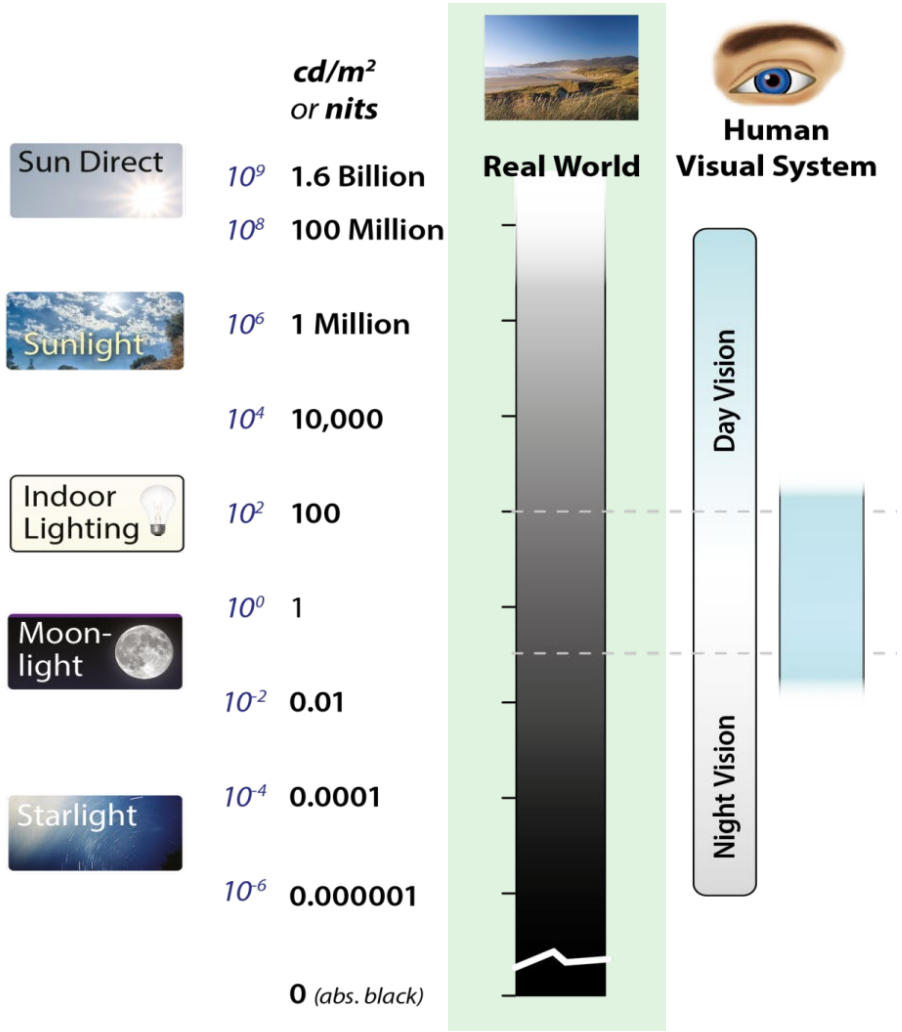
Image Context

Real World Luminance Levels & the HVS



- Absolute **luminance** does not necessarily match **appearance**!
- We **can't see everything in the physical world**

Real World Luminance Levels & the Human Visual System (HVS)



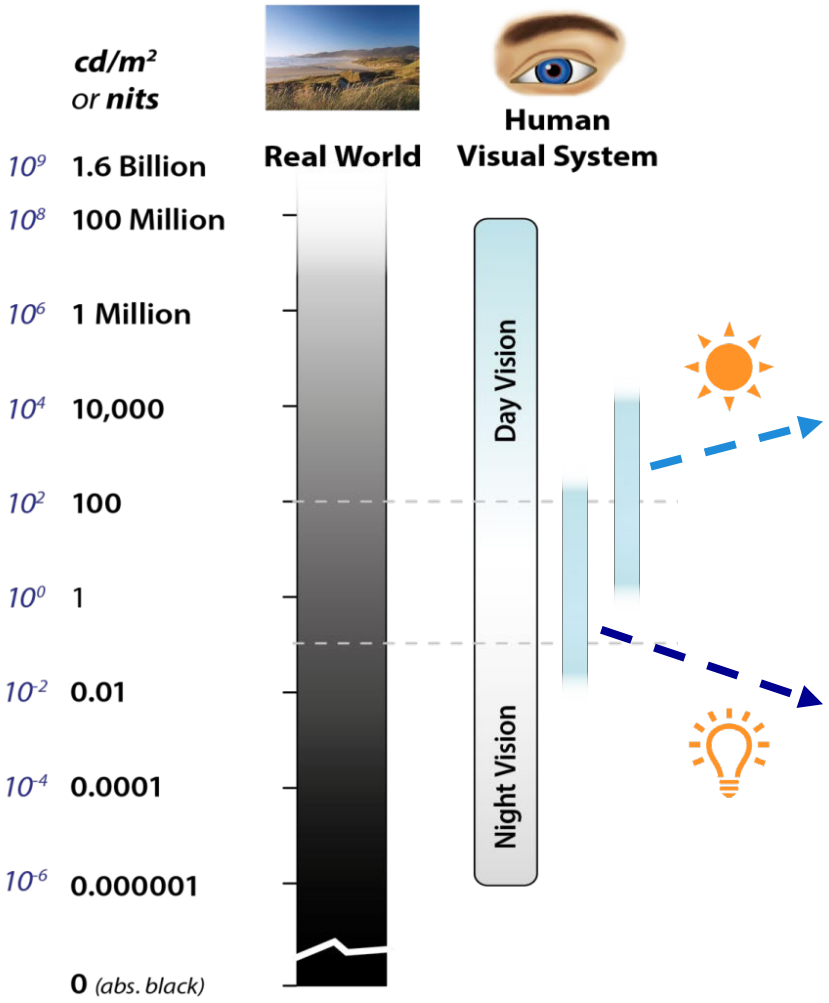
Steady State Dynamic Range (SSDR)

Adaptation Processes

Objective of HVS:

Align visual sensitivity to the environment

Real World Luminance Levels & the HVS



Change of Environment

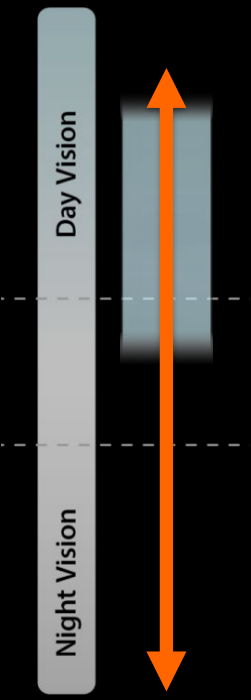
Temporal Aspect

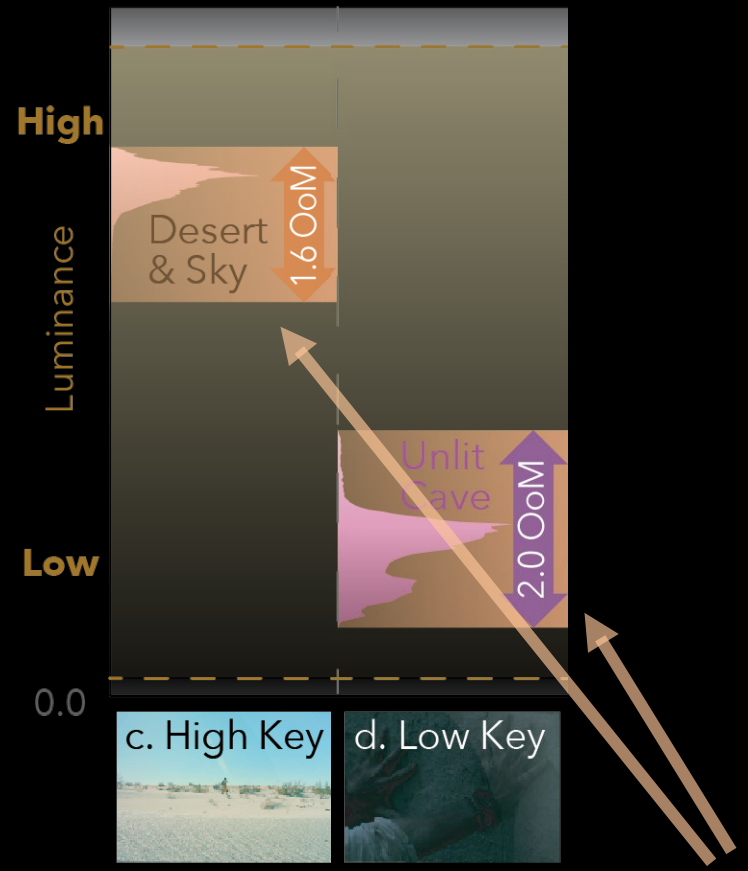
- The HVS is not a Camera
- Adaptation is continuous over time
- Even with Still Images
- Changes do not have to be extreme!

Adapt to Higher Local Luminance
Adapt to Lower Local Luminance

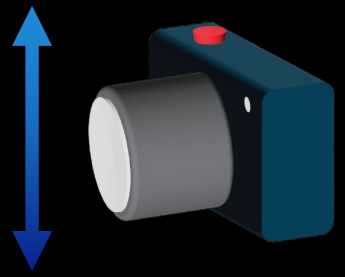
Gaze Pattern

Camera Capture





Camera SNR ('Dynamic Range')



'Single Exposure'

Exposure: $^{1}/_{2000}$ sec.
Aperture: f8.0
ISO: 100

} Exposure Value (EV)

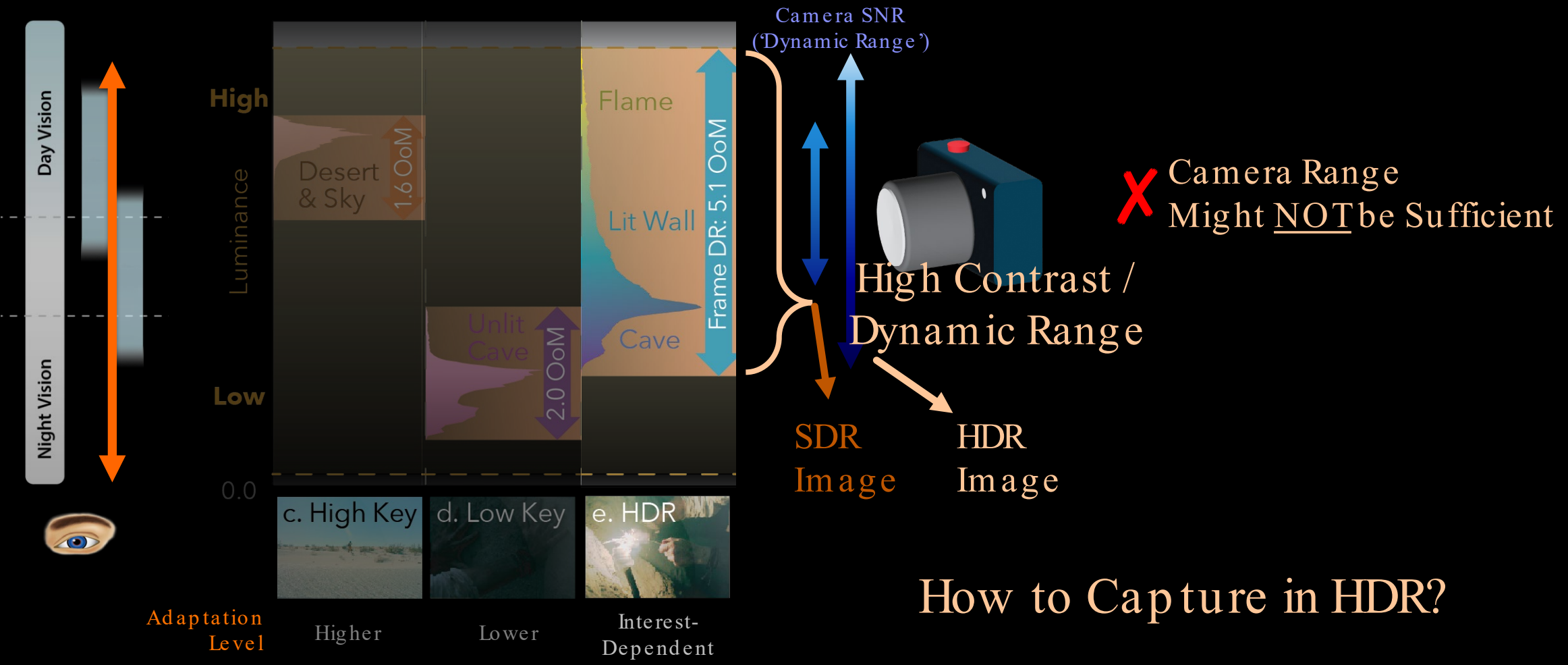
✓

Exposure: 1 sec.
Aperture: f1.8
ISO: 800

Objective: Capture the dominant illumination / luminance window

Example Luminance Range not High!
Camera Range Sufficient

HVS Adaptation & Exposure Values (EV)



How to Capture in HDR?

OVER EXPOSURE: DARKS

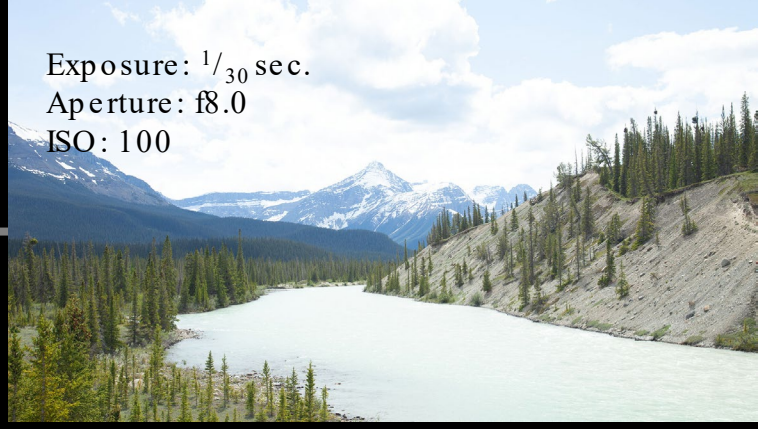
Clipped Areas
in Brights

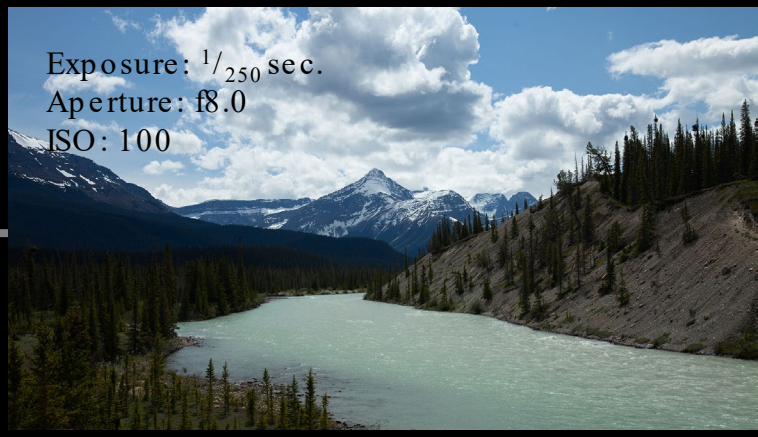
Crushed Areas
in Darks

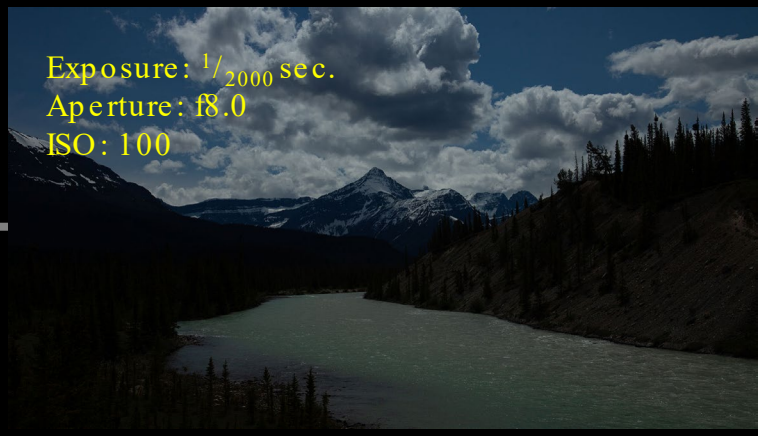
SASKATCHEWAN
RIVER CROSSING
CANADA, 2012

HDR Merging

HDR Merge





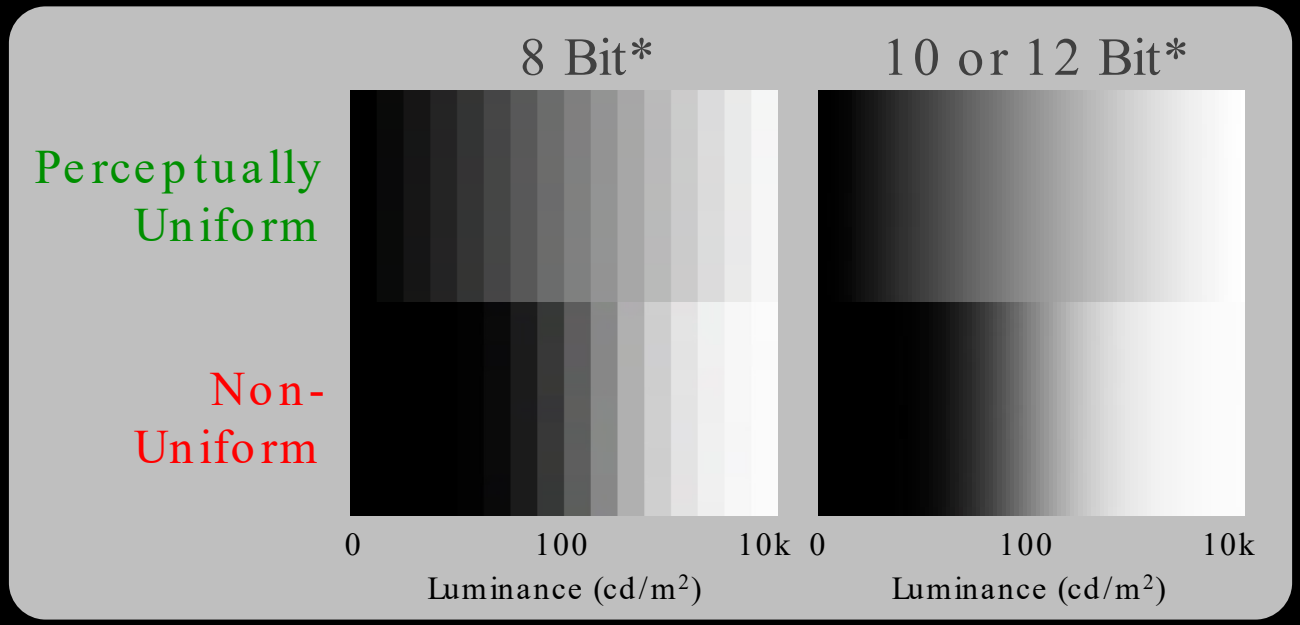


1. User does this manually (traditional approach)
2. Camera does exposure merging internally
3. Camera sensor has large dynamic range

} often mixed & achieved using AI

Signal Granularity

- Objectives: 1: Avoid Contouring!, 2: Be efficient!
- SDR: Gamma at 8 Bits (0.1-100 cd/m², sRGB, Rec.709) → not efficient
- HDR: Linear Light at 16 Bits (e.g. OpenEXR) → not efficient
- Perceptually Efficient (e.g., ITU-R. BT Rec. 2100 PQ)
- Over large luminance ranges



*Simulation

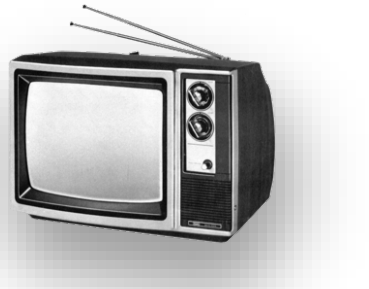

HDR Content with insufficient quantization granularity*


Granularity Sufficient - No Contouring

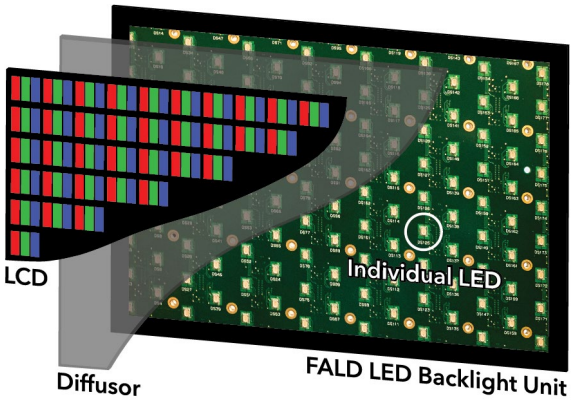
* Simulation

Display Technologies

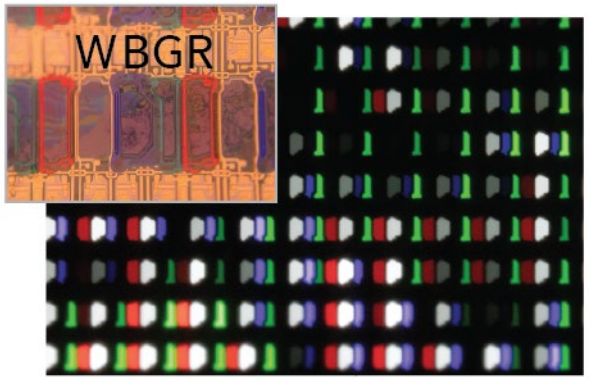
- We've come a long way from CRT Technology



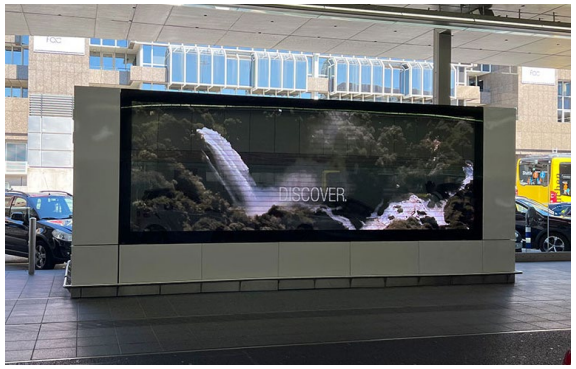
- Many Modern Display Technologies are HDR capable
- Exact Display Capabilities Vary
- How can we still maintain fidelity?



Dual Modulation LCD



OLED



Direct View LED

MicroLED

Using the Full Capabilities of HDR

- Not every element in the HDR ecosystem is equally capable
  - Cameras, encodings, delivery paths, display devices, printers,…
- We can't limit the HDR ecosystem to the least common denominator
- This would leave a lot of capabilities on the table

- Implement approaches for optimized mapping of signals, content & intent
- This is called tone mapping, or, more accurately color volume mapping
  - This is today an integral part of many HDR implementations

Reproduction with Reflective Media

Fine Art Print

Office/Offset Print

Newspaper

Color Volume Increase

High Fidelity LDR Image

Color/Gamut Mapping Using ICC Workflow

Fine Art Print

Office/Offset Print

Newspaper Print

Color Volume Limited by Peak White of Medium:
Limited Headroom for Highlights & Emissives

Reflective Media

Reproduction on Emissive Displays

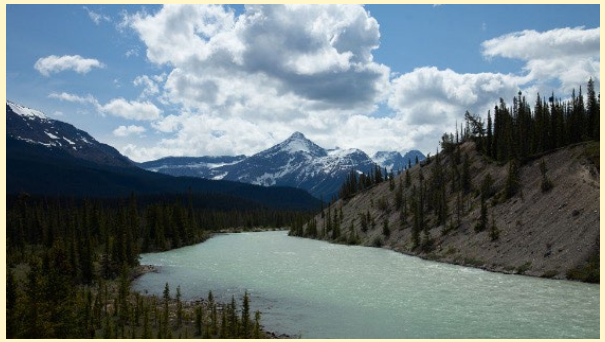
Emissive Display

High End
HDR Display
peak ~4000cd/m²

'Mild' HDR
Display
peak ~600cd/m²

SDR Display

HDR Image



HDR
Color/Gamut
Mapping

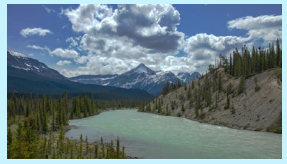
Color
Volume
Increase

Fine Art Print

Office/Offset Print

Newspaper

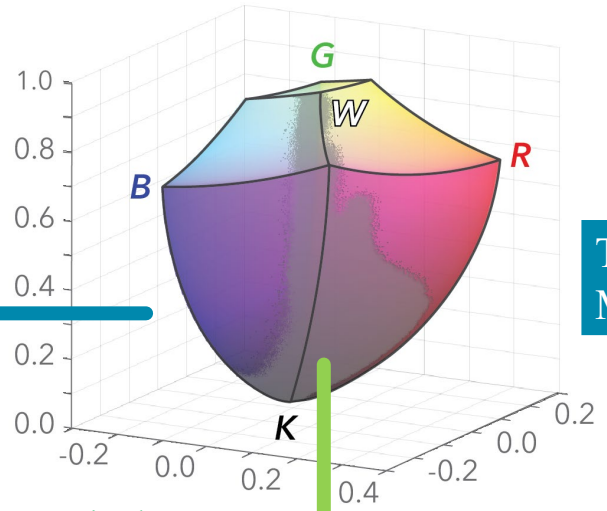
High Fidelity
LDR Image



Reflective Media

Concept for Content Mapping

Large Color Volume

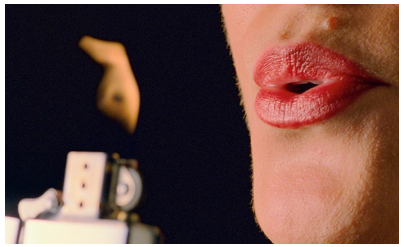


All the colors encoded by image format.

Can be > display capabilities

Examples:
Reference or
High-End Consumer
HDR Display

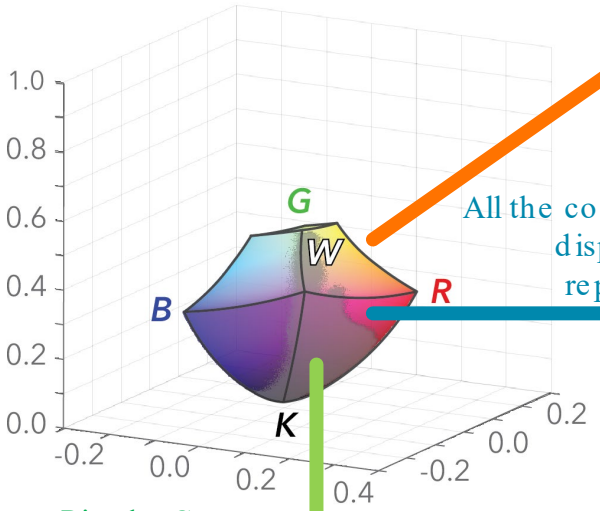
Pixels: Current Content Image



Tone Mapping

Can be Supported by Static or Dynamic Metadata

Small Color Volume

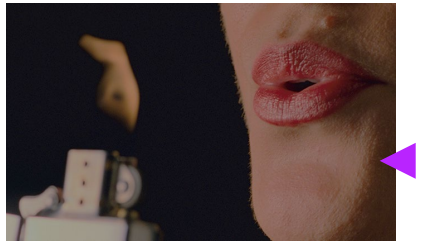


All the colors this printer can reproduce

All the colors this display can reproduce

Examples:
Consumer
HDR Display

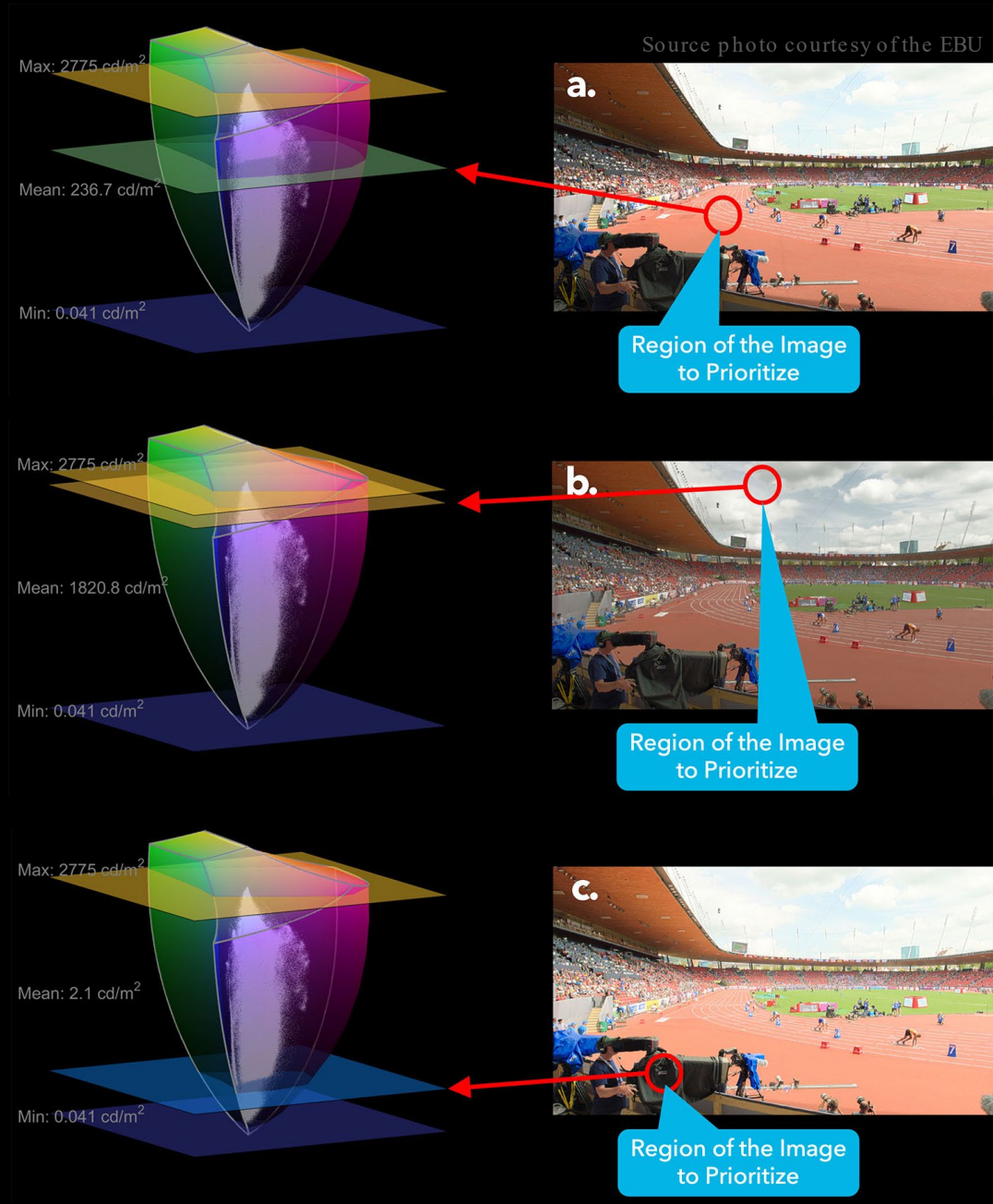
Pixels: Current Content Image



Result: Image can be faithfully displayed on target display

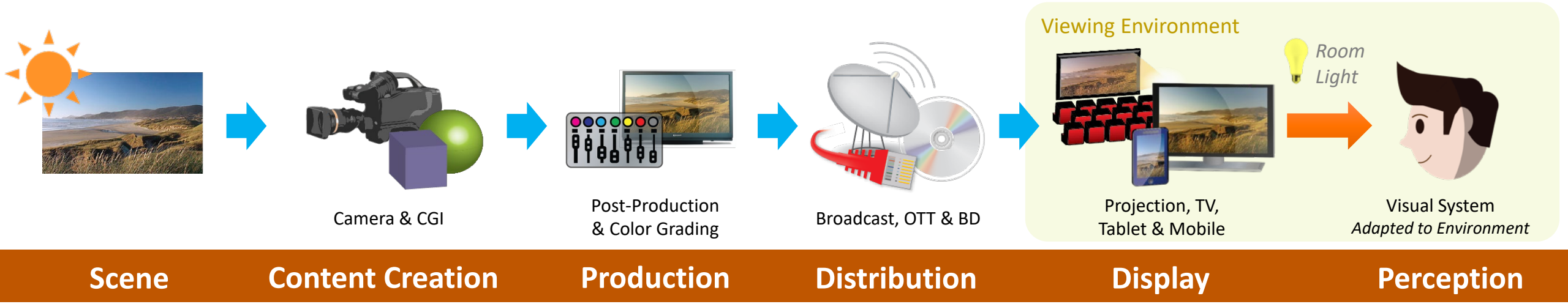
Metadata

- HDR standards such as Dolby Vision, HDR10 and HDR10+ utilize Image Metadata (MD)
  - MD can provide information about the image context
- Display Tone Mapper can use this image MD to optimize image
  - MD can have significant impact on image appearance
- Highly beneficial to Fidelity e.g., for movies, photos,…
- Content pipelines are established
- Formats differ in capabilities!



Current State of HDR

- Over the past 10 years, a complex and effective Ecosystem has been established to facilitate HDR from the start to the end of an imaging pipeline



Summary

Perceptual Aspects

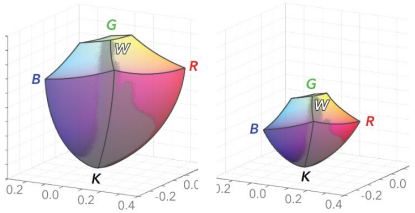
- Highlights, Whites & Blacks
- Color & Material Appearance

1

Tonemapping Enables:

- Color Volume Reduction
- Artistic Options
- Maintain Creative Intent

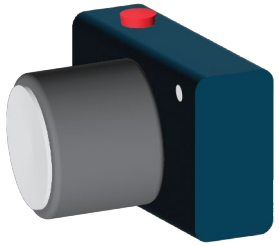
3



Capture HDR w/o Artifacts

- No Clipping/Crushing
- Headroom for Highlight
- Merging to extend DR

2



We have HDR Capable Displays

- Reproduce Realistic Luminance Ranges

4

HDR is established as a foundational component defining today's image fidelity.

There are still Areas that can Benefit from HDR Technologies


With HDR…
…you can feel the heat…

…create an experience as if you're there!

THANK YOU!

Contact: timo.kunkel@dolby.com