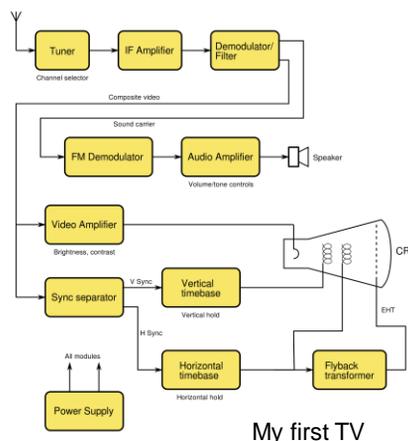


SMPTE Standards Webcast Series  
SMPTE Professional Development Academy – Enabling Global Education



# SMPTE ST 2094 and Dynamic Metadata

Lars Borg  
Principal Scientist  
Adobe  
linkedin: larsborg



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## SMPTE Standards Update Webcasts



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- Series of quarterly 1-hour online (this is 90 minutes), interactive webcasts covering select SMPTE standards
- Free to everyone
- Sessions are recorded for on-demand viewing convenience SMPTE.ORG and YouTube

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## Your Host

- **Joel E. Welch**
- Director of Education
- SMPTE



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## Today's Guest Speaker

### Lars Borg

Principal Scientist in  
Digital Video and  
Audio Engineering

*Adobe*



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## What?

- HDR vs SDR
- Tone mapping
- HDR systems & tone mapping options
- Dynamic metadata

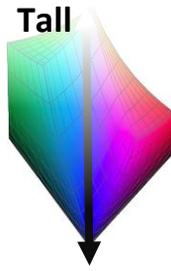
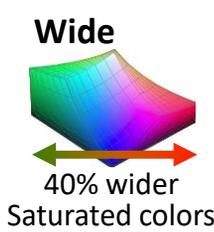


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# High Dynamic Range - Slim, Wide, Tall Volumes

TV System	ITU Std	Image Size	Color Volume
HD	BT.709	1920 x 1080 "2K"	Slim (SDR)
UHD 1	BT.2020	3840 x 2160 "4K"	Slim or Wide Color Gamut (WCG)
UHD 2	BT.2020	7680 x 4320 "8K"	Wide Color Gamut (WCG)
HDR	BT.2100	2K, 4K, 8K	Wide & Tall (HDR)



High dynamic range  
10-100x brighter peaks  
100x darker than SDR ref

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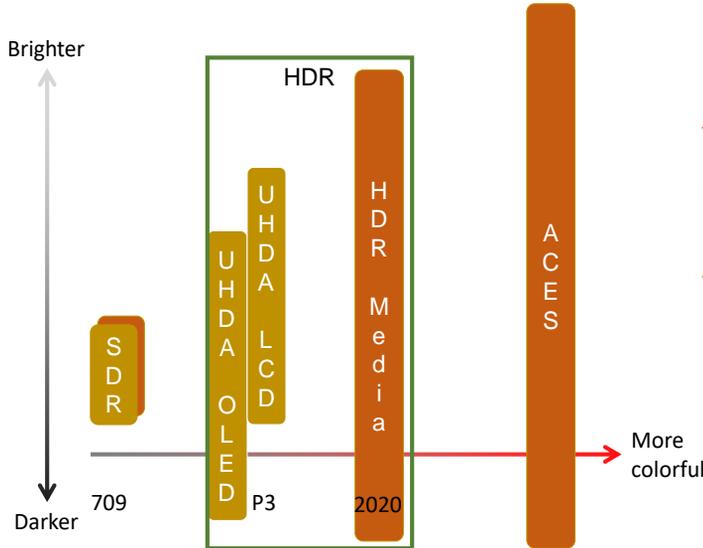
# Wide Color Gamut makes deeper colors available



# HDR brightness ranges and gamuts



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**HDR media color volume**  
is much larger than  
**HDR display color volume**

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# Comparing SDR and HDR system details



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Feature	Old: SDR TV (Rec. 709, Rec. 601)	New: HDR TV (Rec. 2100)
Max Resolution	1920 x 1080	7680 x 4320
Max Frame rate	60 fps	120 fps
Bit depth	8 or 10	10 or 12
Media Color Volume	Small (Rec. 709)	Wide (2020) and Tall (10,000 nits)
Display Color Gamut	Small (Rec. 709)	Medium (P3)
Display Peak Brightness	typically 300 nits, studio mon. 100 nits	At least 1,000 nits (LCD), 530 nits (OLED)
Transfer Characteristics	BT.1886 Gamma 2.4	PQ curve or HLG curve
Color models	RGB, YCbCr	+ ICtCp (Constant Intensity)
Compression	MPEG-2, AVC, J2K	AVC, J2K, HEVC
Color Volume Metadata	None	None, HDR10, or ST2094

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# Which grade first? You pick!



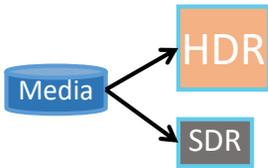
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- HDR first
  - Most exciting version first
  - SDR grades from HDR version
  - Best for real-time workflows



- SDR first
  - Do the money-making (2017!) version first
  - HDR uses SDR master files, not 10-bit SDR distribution images



- HDR and SDR independently graded from master media
  - Very expensive (double effort)
  - Highest quality for both versions

• Some colorists find it difficult to grade both HDR and SDR!

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# Why do I need tone mapping?



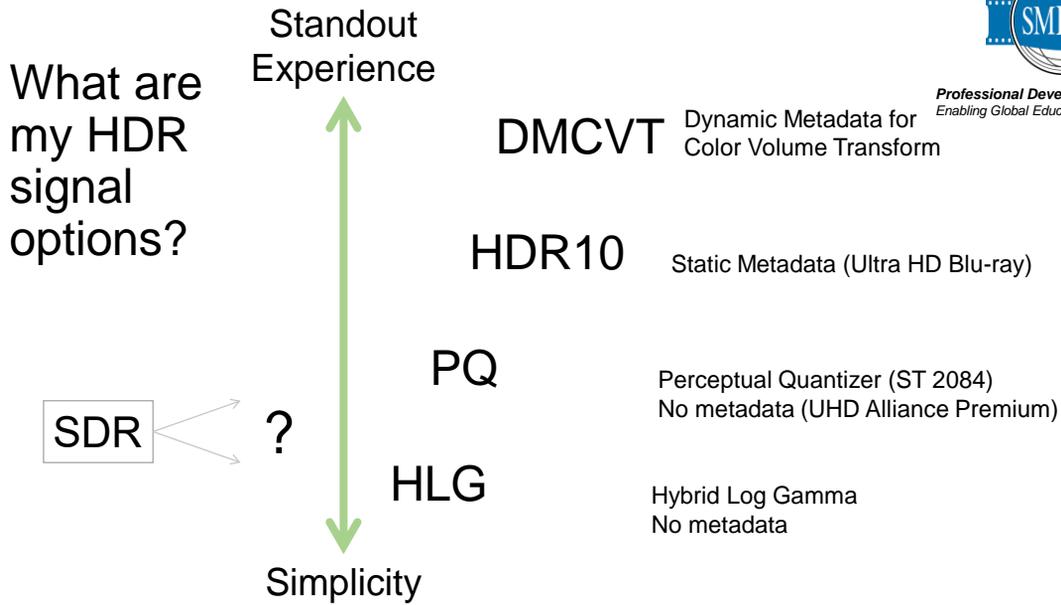
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Clipped highlights and shadows

Compressed highlights and shadows

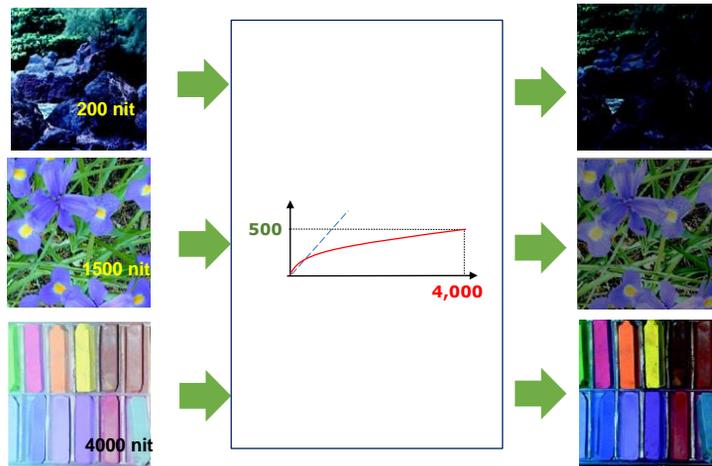
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## Static Tone Mapping – HDR10

Optimized **only for the brightest scene** in the contents



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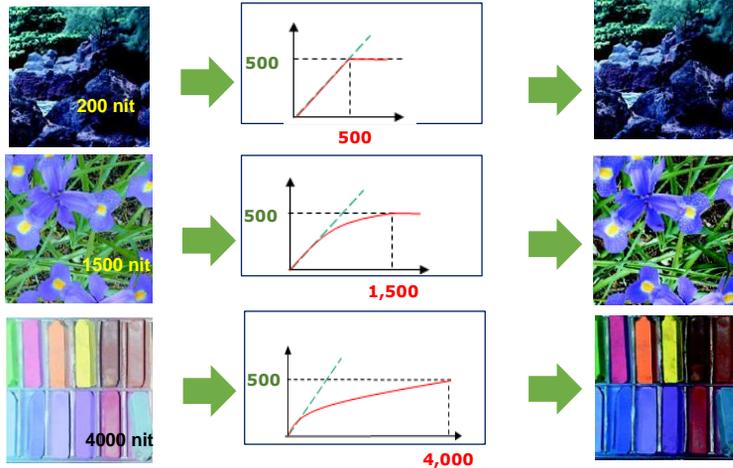
Illustrations courtesy of  
YT Kim, Samsung

# Dynamic Tone Mapping – DMCVT



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Optimizes each scene



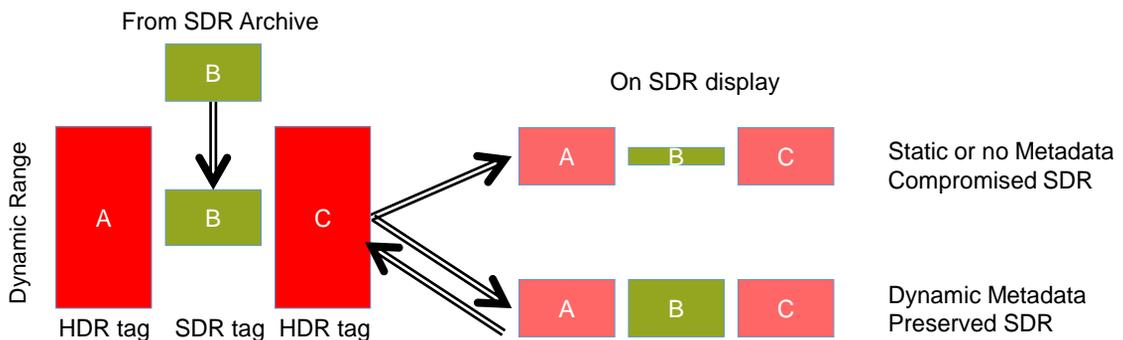
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# Dynamic Tone Mapping can preserve SDR image quality



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- SDR footage inserted in HDR program needs special handling when converting to SDR
  - To preserve original SDR imagery and prevent loss of image quality
- Dynamic Metadata provides the info



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# ST 2094 — Dynamic Metadata for Color Volume Transforms (DMCVT)



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- Color transforms optimized for each scene, and each display
- SMPTE ST 2094, in six parts, published 2016
  - Carried in HEVC SEI, ETSI TS 103 433, CTA 861-G
- Standardizes HDR color transform technologies from
  - Dolby (Parametric Tone Mapping)
  - Philips (Parameter-based Color Volume Reconstruction)
  - Technicolor (Reference-based Color Volume Remapping)
  - Samsung (Scene-based Color Volume Mapping)
  - And 80 other participating companies

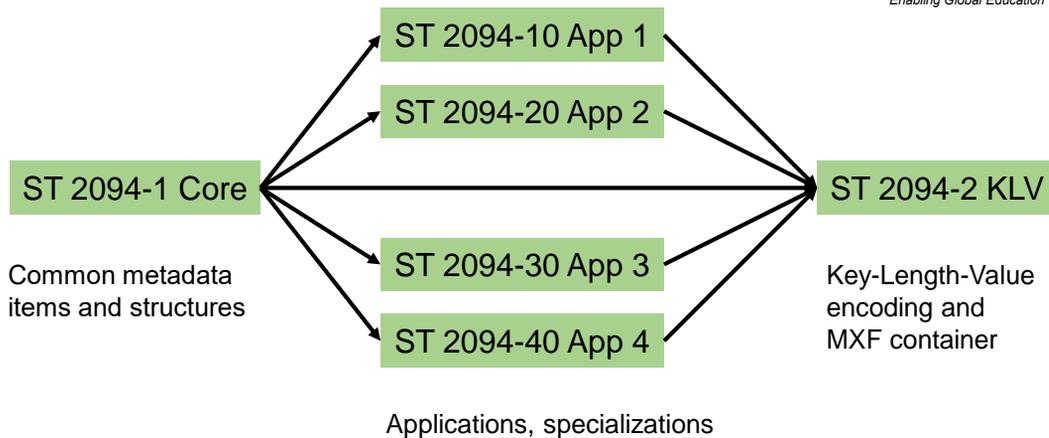


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# ST 2094 Document Structure



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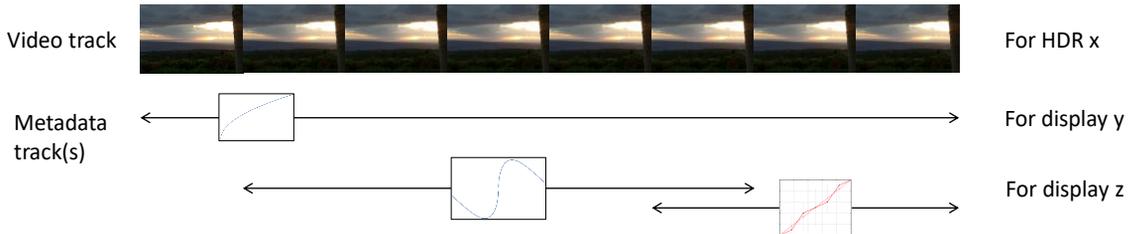


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# Parallel metadata track(s)



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- Master HDR video track
- Metadata tracks carry supplementary color grading information
- Select where to apply the metadata
  - By time, window, target display

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# The ST 2094 metadata set



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Each ST 2094 metadata set specifies one of each of:

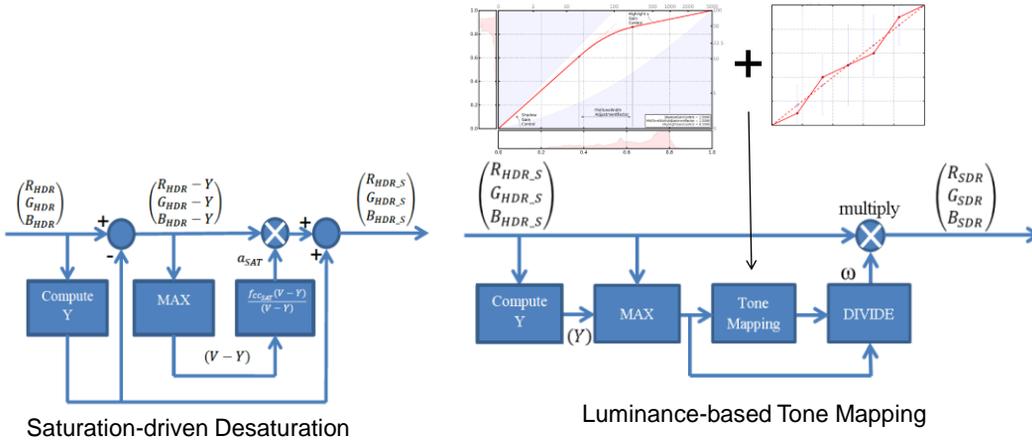
Method	Target Display	Time Interval	Window	Transform
Which?	For what display?	When?	Where?	What to do?
	Rec. 709 Rec. 2020 UHDA OLED	← □ □ □ □ □ □ → ← □ □ □ →	 	 
App # Version #	Color Volume: RGB primaries, WP, max/min	Start and duration	Pixel coordinates Baseline = full screen	4 flavors of parameter sets

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## App. 2 — Color Transform in Parameter-based Color Volume Reconstruction (Philips)



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Lots of math for calculating the curves

$$TMO(x) = \begin{cases} SGC \times x, & 0 \leq x \leq x_{SGC} \\ ax^2 + bx + c, & x_{SGC} < x < x_{HGC} \\ HGC \times x + 1 - HGC, & x_{HGC} \leq x \leq 1 \end{cases} \quad (1)$$

$$a = \begin{cases} 0, & para = 0 \\ -0.5 \times \frac{SGC - HGC}{para}, & otherwise \end{cases} \quad (2)$$

$$b = \begin{cases} 0, & para = 0 \\ \frac{1 - HGC}{para} + \frac{SGC + HGC}{2}, & otherwise \end{cases} \quad (3)$$

$$c = \begin{cases} 0, & para = 0 \\ -\frac{((SGC - HGC) \times para - 2(1 - HGC))^2}{8 \times (SGC - HGC) \times para}, & otherwise \end{cases} \quad (4)$$

$$x_{SGC} = \frac{1 - HGC}{SGC - HGC} - \frac{para}{2} \quad (5)$$

$$x_{HGC} = \frac{1 - HGC}{SGC - HGC} + \frac{para}{2} \quad (6)$$

$$exposure = \frac{ShadowGainControl}{4} + 0.5 \quad (7)$$

$$expgain = v \left( \frac{L_{source}}{L_{target}} \right) \quad (8)$$

where: (8)

$L_{source}$  = Maximum Display Mastering Luminance  
 $L_{target}$  = Targeted System Display Maximum Luminance

$$SGC = expgain \times exposure \quad (9)$$

$$HGC = \frac{HighlightGainControl}{4} \quad (10)$$

$$para = \frac{MidToneWidthAdjustmentFactor}{2} \quad (11)$$

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$$a_{Adj} = TMO(a_{BW}) \quad (12)$$



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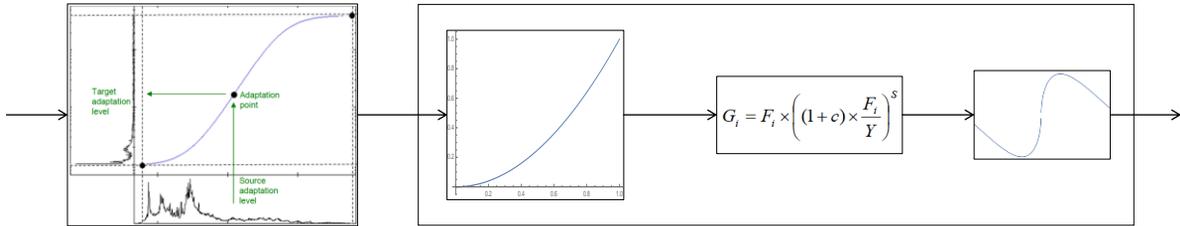
# App. 1 — Color Transform in Parametric Tone Mapping (Dolby)



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Automatic, data-driven

Optional, under manual control



Data-driven tone mapping  
min/avg/max clip RGB

Colorist's  
Lift, Gamma, Gain

Boost  
Saturation

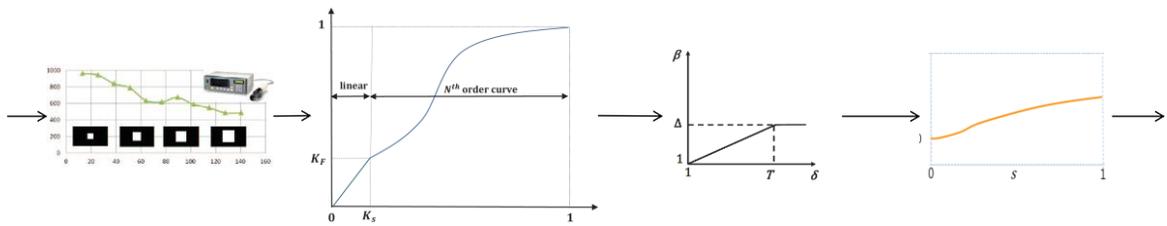
Enhance  
Details

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# App. 4 — Color Transform in Scene-based Color Volume Mapping (Samsung)



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Normalized by  
Actual Peak  
Luminance

Tone Mapping Curve  
In Normalized space

Auto-Gain  
Tinted  
Clips

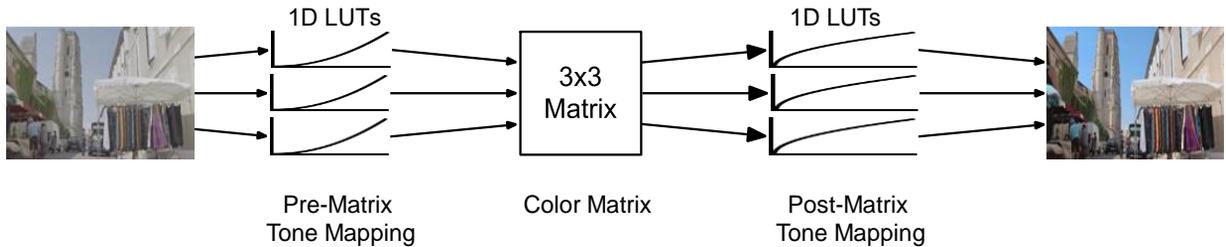
Boost  
Saturation

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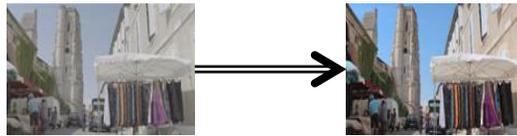
### App. 3 — Color Transform in Reference-based Color Volume Remapping (Technicolor)



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Metadata is not manually created.  
Calculated through data fitting  
between two grades of same clips

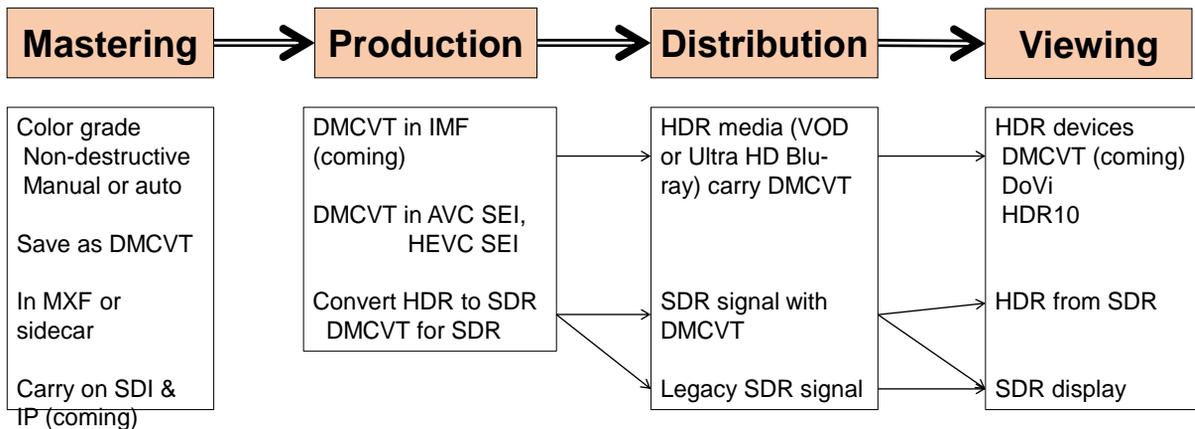


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### The DMCVT HDR Flow



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## Summary



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- **Dynamic Metadata for Color Volume Transforms (DMCVT)**
  - Can preserve the creative intent in HDR media across a variety of displays
  - Carried in files, video streams, packaged media
  - Standardized in SMPTE ST 2094

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## New Acronyms, Terms, Standards



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- WCG – Wide Color Gamut - Rec.2020 has 2x more colors than Rec.709
- HDR – High Dynamic Range TV (ITU-R BT.2100)
- SDR – Standard Dynamic Range TV (Rec.601, Rec.709, Rec.2020)
- HFR – High Frame Rate (100 & 120 fps)
- HEVC – High-Efficiency Video Codec (ITU-T H.265) - 2x more efficient than AVC
- PQ – Perceptual Quantizer Transfer Function for HDR signals (SMPTE ST 2084, ITU-R BT.2100)
- HLG – Hybrid Log Gamma Transfer Function for HDR signals (ITU-R BT.2100)
- HDR10 – 10-bit HDR using BT.2020, PQ and static metadata
- Mastering Display Metadata – SMPTE ST 2086 (min/max luminance, color volume)
- MaxCLL – Maximum Content Light Level
- MaxFALL – Maximum Frame-Average Light Level
- DoVi (Dolby Vision) – 12-bit HDR, BT.2020, PQ, Dolby Vision dynamic metadata
- DMCVT - Dynamic Metadata for Color Volume Transforms, SMPTE ST 2094
- Ultra HD Blu-ray – HDR disc format using HEVC, HDR10, and optionally Dolby Vision
- UHD Alliance Premium Logo – High-end HDR TV requirements

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# Q&A – Verbal Questions Encouraged!

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