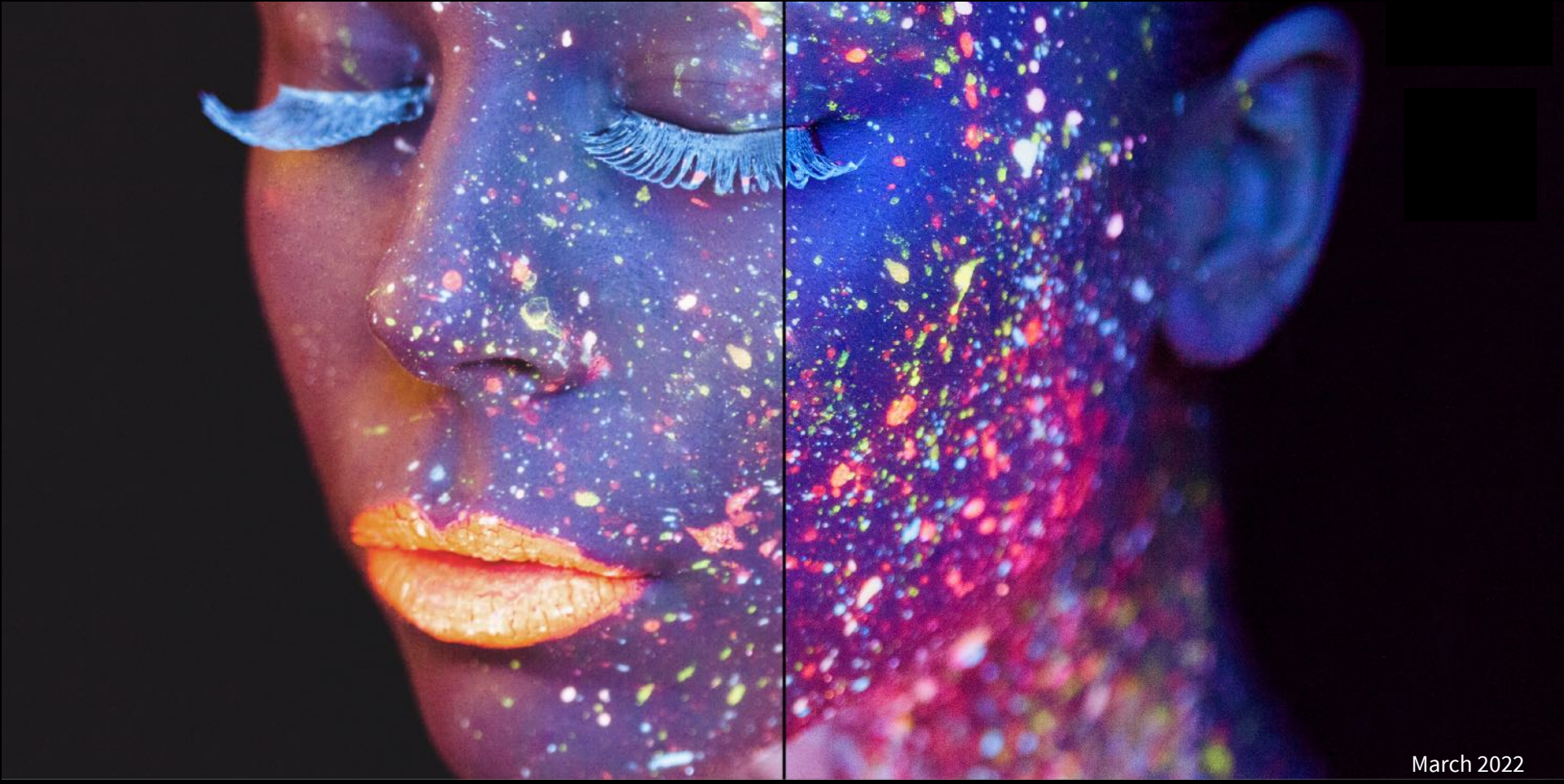


Objective Color Metrics

For Single-Stream High Dynamic Range, Wide Color Gamut and Standard Dynamic Range

Preserving Original Artistic Intent

This presentation covers how NBCUniversal assures that we preserve the original artistic intent during broadcast transmission

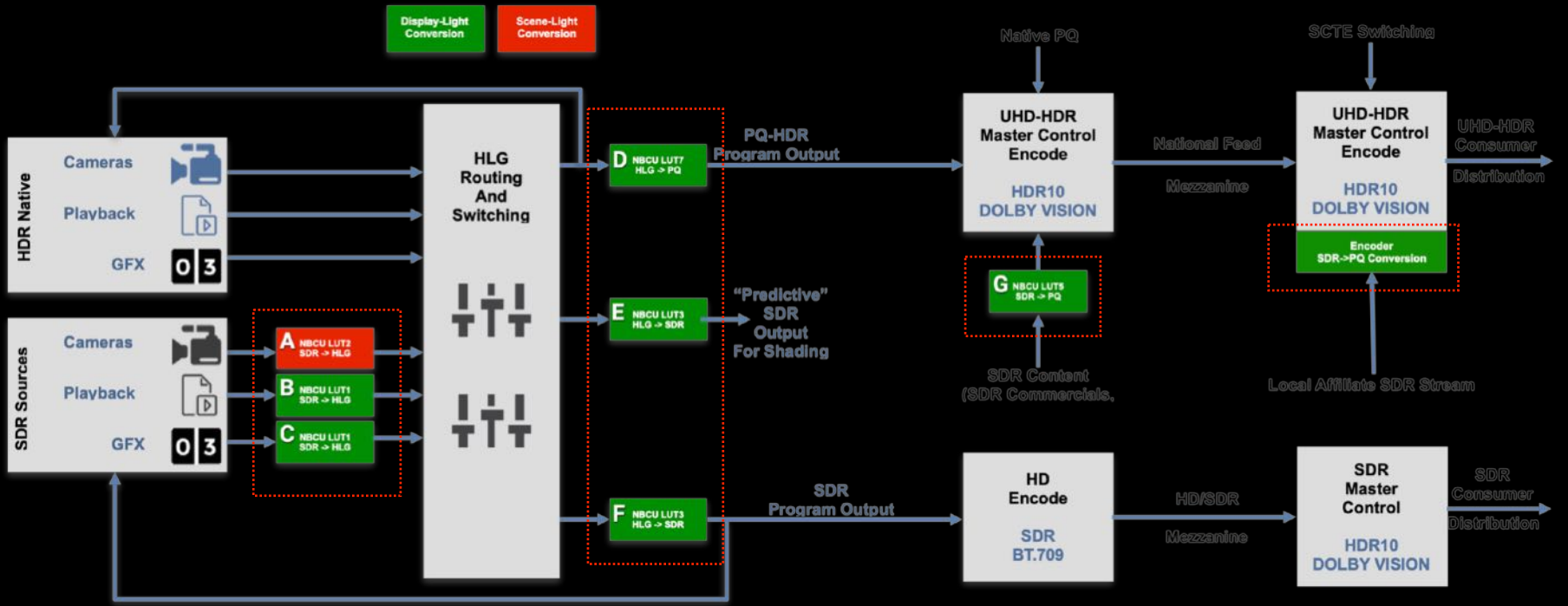
Verifying Our Mappings

...and asks....
How can we use similar tools for testing ICC Mappings?

NBCUniversal UHD HDR Experiences

2015: NYC July 4th Fireworks
2016: RIO Olympics Opening Ceremonies
2018: Pyeongchang Winter Olympics, Men's FIFA
2018-2021: Notre Dame Football Seasons
2020 US Open Golf
2021 Chicago Basketball, Baseball
2021 Tokyo Olympics
2022 Beijing Olympics

Single-Stream Workflow Conversions



- **Determine Conversion Points**
- **Determine conversion goals (i.e. - where is graphics white, what are the anchor points between formats**
- **Make conversions from one format to another without changing perceptual representation (“original artistic intent”).**

NBCU's Single Stream Recommendation

NBCU, in collaboration with Cromorama, and building on ITU working group discussions for HDR operational practices involving Dolby, BBC and Philips, has developed techniques to enable "single-stream" production that feeds both UHD HDR and SDR transmission simultaneously.

The NBCU LUTs developed for this workflow enable single-stream production whereby the HDR and SDR products are consistent to the point where the benefits of HDR are realized making a unified production possible. Subsequently we're sharing these efforts with the broadcast community for continued collaboration and use in production and distribution.

The NBCU LUTS include both HLG and PQ LUTs following similar HDR/SDR conversion methodology and color science.

NBCU has a commitment to industry collaboration and would like to encourage consistent media exchange, therefore we are willing to provide the NBCU LUTs freely. The NBCU LUTs are provided on an "as is" basis with no warranties.
The package of NBCU LUTs with additional documentation are available at the following link:

https://github.com/digitaltvguy/NBCU-HDR-SDR-Single-Stream_Workflow_Recommendation

Chris Seeger and Michael Drazin are happy to answer questions pertaining to this effort and provide further insight into workflow.

Chris Seeger
Chris.Seeger@nbcuni.com

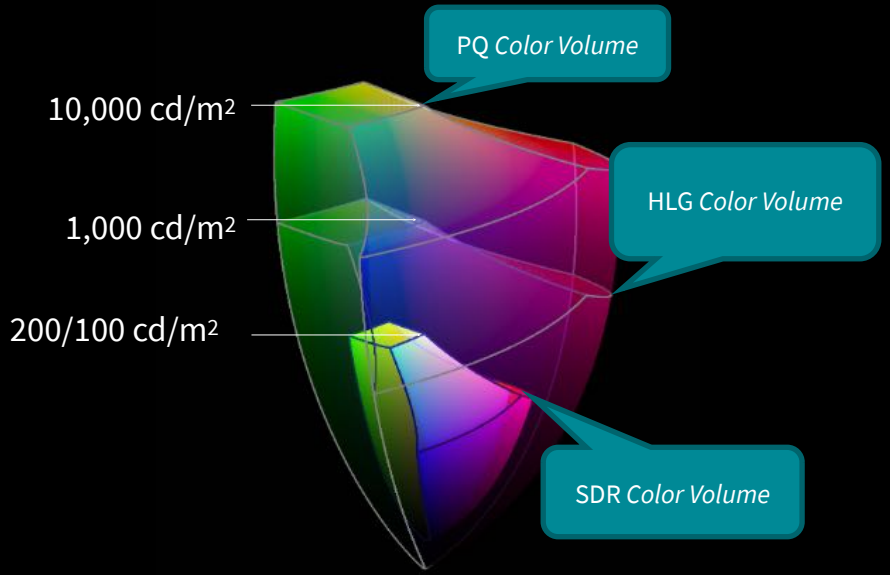
Michael Drazin
michael.drazin@nbcuni.com

Scan This Code To Download
The NBCU Recommendation and
LUTS

We ask that manufactures include an acknowledgment in their license to their customers that the LUTs were "developed by NBCUniversal Media, LLC."

In A Typical Broadcast Workflow There Are Now Several Possible Video Formats

UHD Broadcasting: Today and Tomorrow



* Per ITU-R, HLG reference display normalized at 1k cd/m2

HDR and WCG have a much larger color volume

Compared to SDR

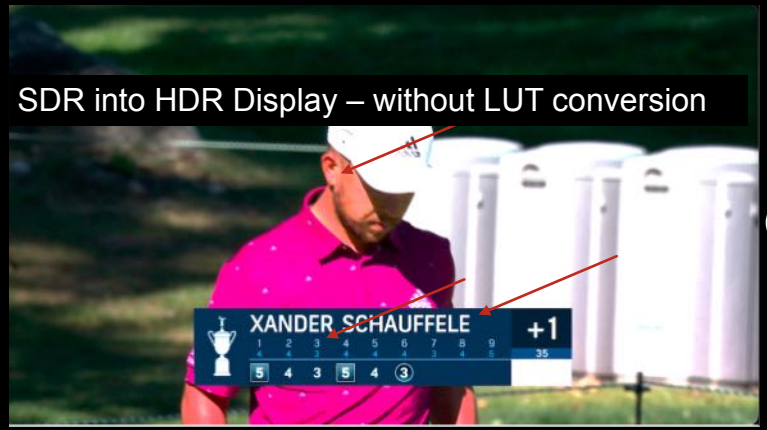
What can possible go wrong ?

ICC Profiles Will Provide New Capabilities For Explicit Mapping of Broadcast Video For Still Graphics Files Using MPEG CICP

Explicit Mappings Define A Specific Mathematical Rendering Of Broadcast Video From Images to Desktop Displays

Example: SDR Content Into HDR Without Proper Conversion

Correct



Content Clips, and over-saturated

Example: HDR Content Into SDR Without Proper Conversion

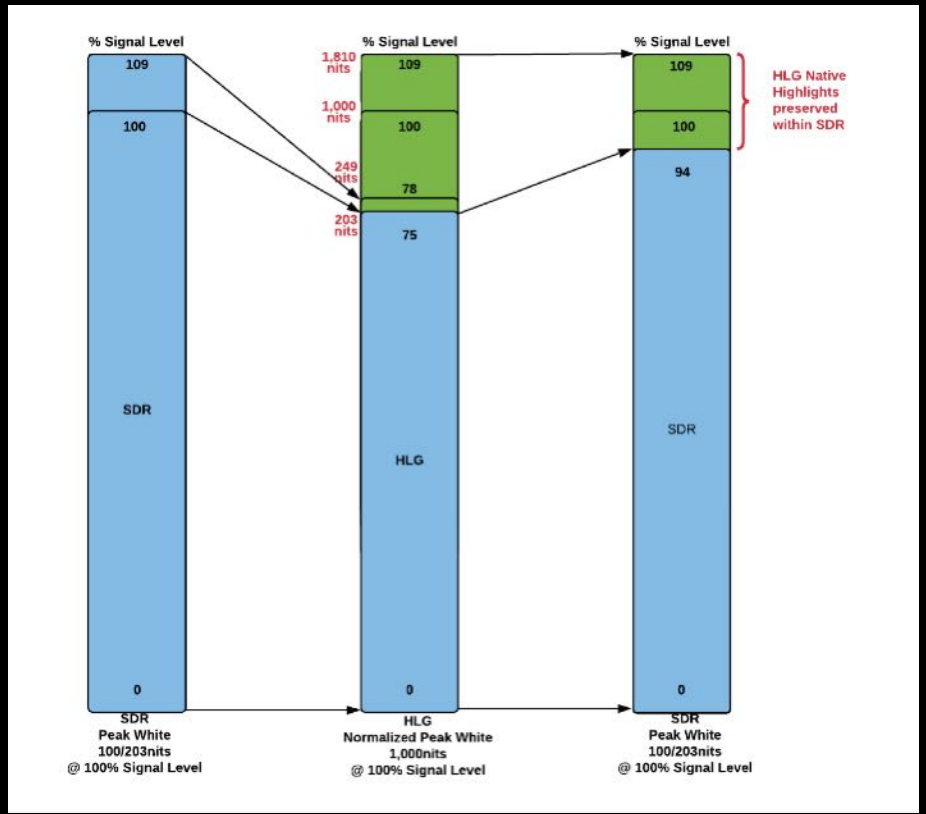
Correct

Dim and under-saturated

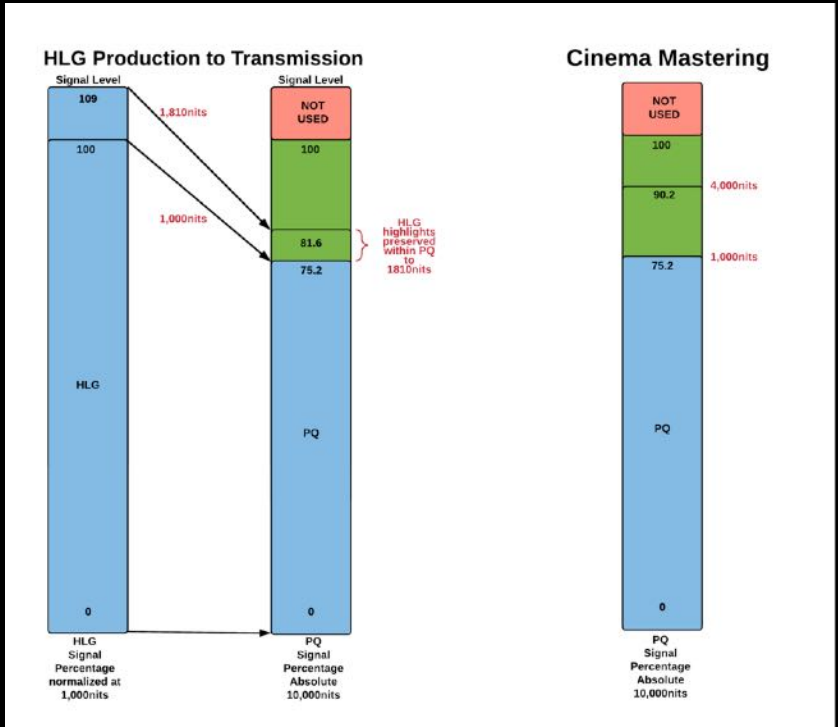
HDR to SDR Conversion - Saturation Preservation

HDR to SDR Conversion - Saturation Clipping

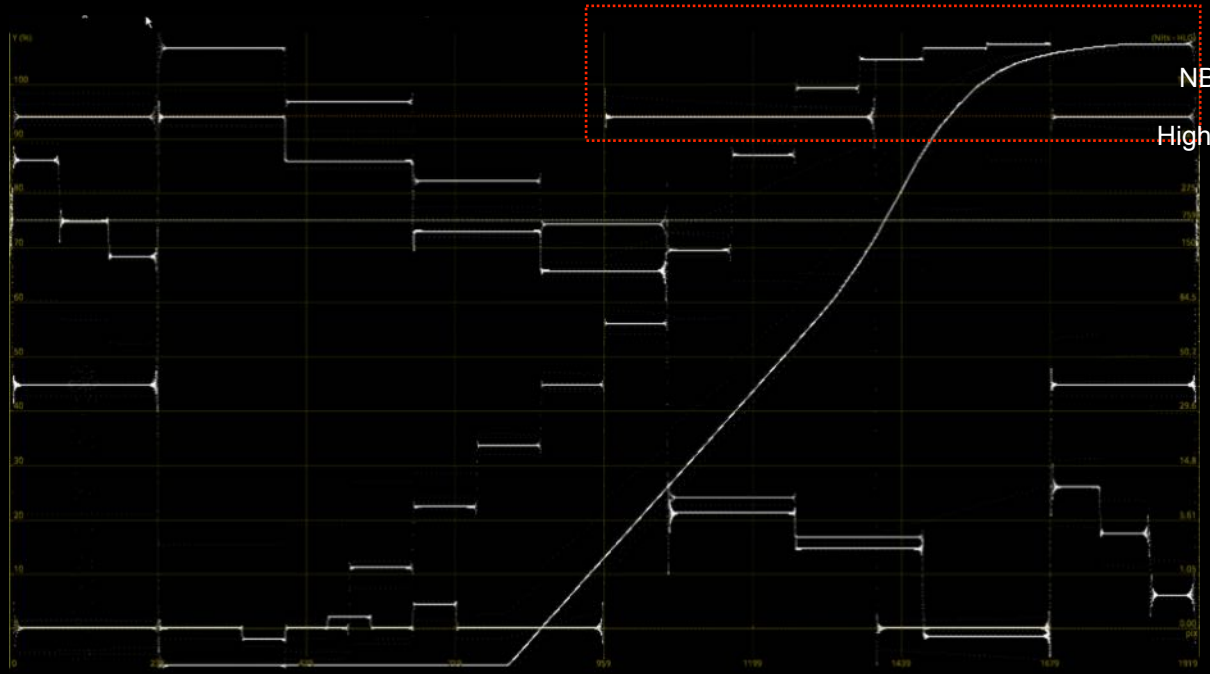
SDR->HLG->SDR (Light-Level Anchor Points)



HLG->PQ (Light-Level Anchor Points)



WaveForms: HDR to SDR Tone-Mapping is hard!



Compressing HDR Highlights to SDR Require
Good LUT Interpolation or Accurate Mathematical Conversions

Subjective assessments
of conversions
yielded inconsistent results

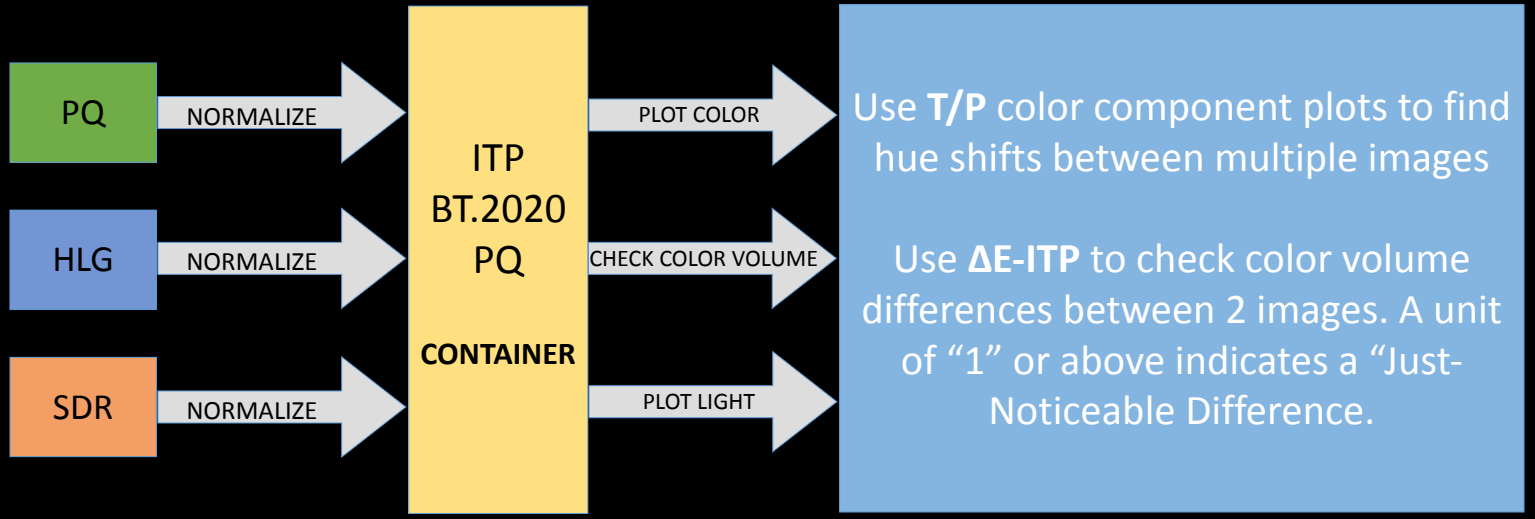
Be Objective!!!

…so… we rely on
Objective Measurements
Based on ITU-R BT.2124

Which allow us to
preserve the original artistic intent

And Preserve The Presentation of
Our Beautiful Pictures

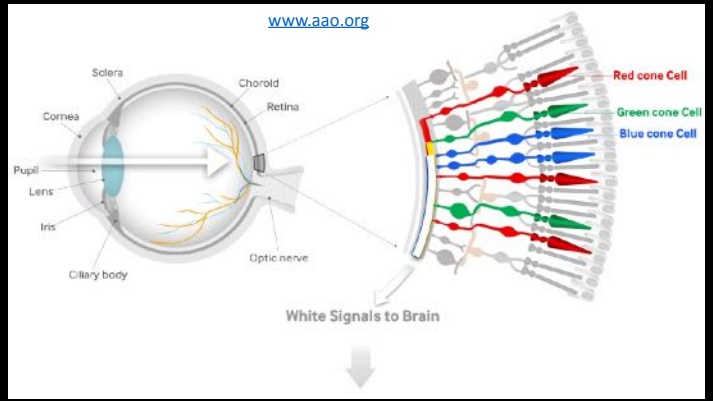
ITU-R BT.2124 OBJECTIVE METRICS DETERMINE ACCURATE CONVERSIONS

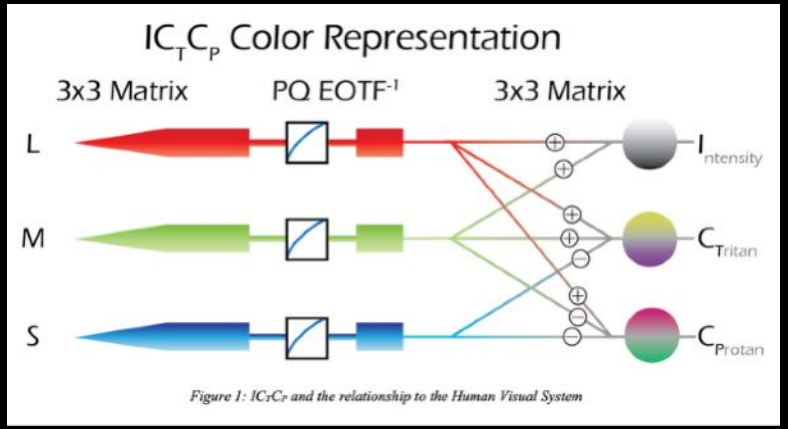


HOW DO WE USE ITP TO COMPARE DIFFERENT VIDEO FORMATS

- PQ, HLG or SDR are converted to a large enough container for all the video formats (ITP-PQ-BT.2020)
- We use the container for plotting all formats together for simplified analysis
- Normalized video colors can be compared in a 2D X/Y (or in this case T/P) plot for hue consistency
- We can compare multiple video sources objectively for perceptual color volume differences of color and light using formulas defined in BT.2124 (ΔE-ITP)

A Newer Color Representation: IC_TC_P and it's sister ITP

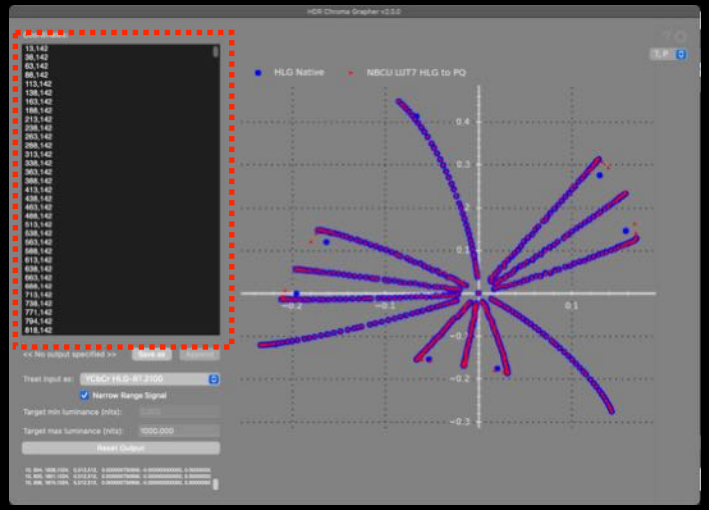


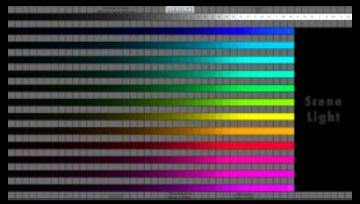


"L", "M", "S" each element captures different wavelengths representing specific color ranges

"I" represents brightness(intensity) while "T/P" represent chroma components (tritan/protan)

Vooya: A Tool for Color Metric Measurement & Plotting





This Plot Compares Sources vs Conversion

- Source = HLG BT.2020 Reference Pattern(BLUE)
- Conversion = HLG to PQ Conversion NBCU LUT7 (RED)

Vooya Color Volume Measurement Plug-In

- NBCU commissioned a plug-in for Vooya which makes it easier to plot video within ITP
- User-supplied X/Y pixel positions allows Vooya to grab YC_BC_R code values from test patterns and convert them to “I-T-P” or “u’v’” for measurement
- Visualize hue consistency thru plots of T/P for (left) or export to a spreadsheet for more sophisticated analysis
- By applying a specific formulas we can compare a source vs the output using specific test patterns.

Delta-E ITP: Examining Color and Light Differences Easily

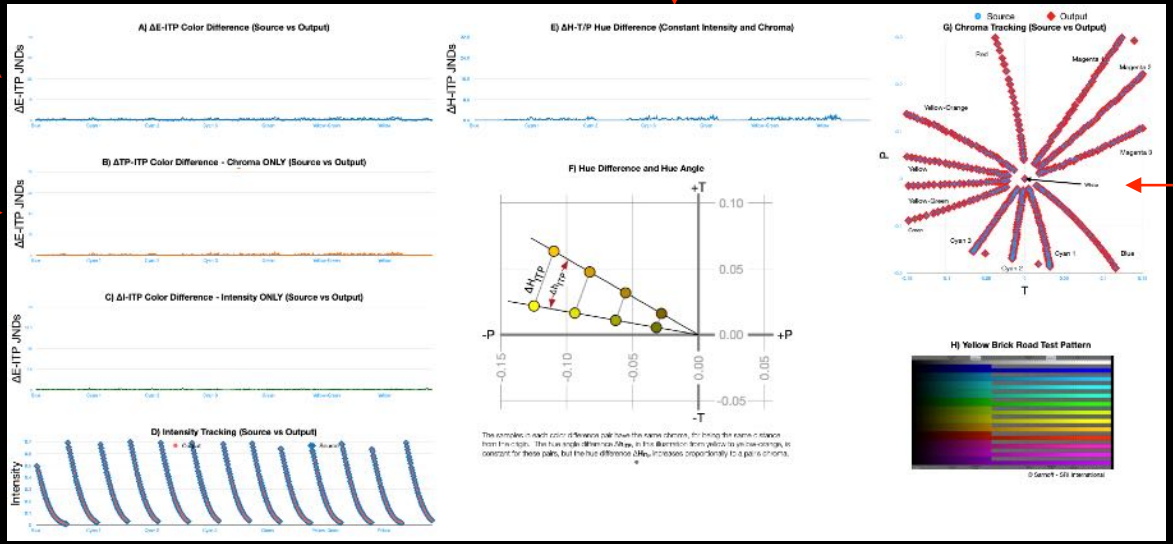
Color Volume Difference

Chroma Difference

Intensity Difference

Input/Output Intensity Plot

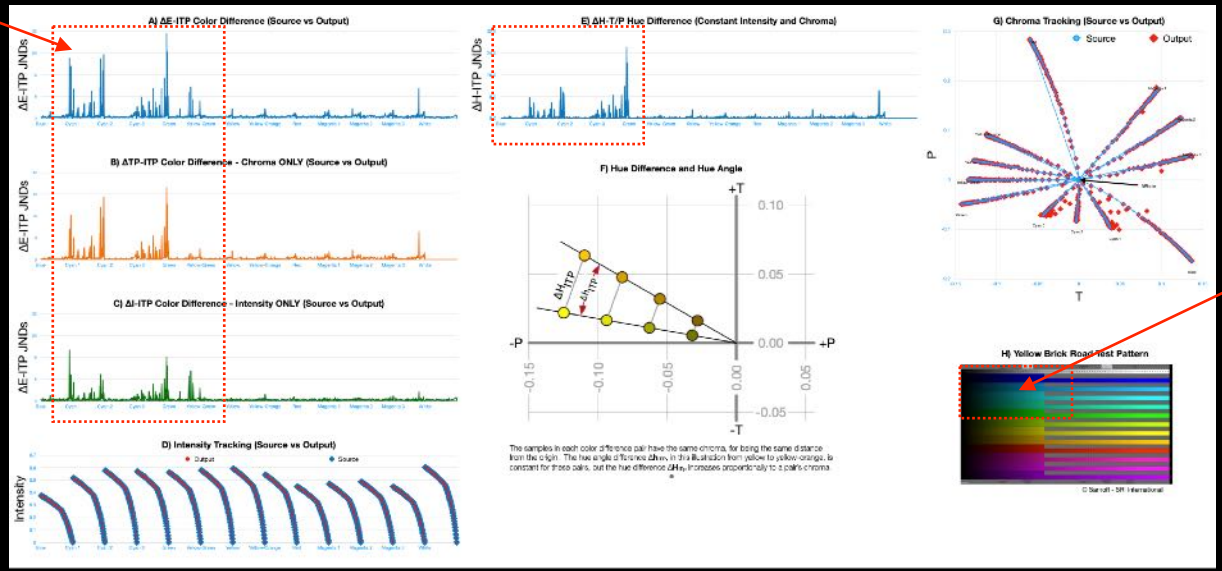
Constant Intensity and Chroma Difference



Visualizing Hue Shifts Blue (Input) Vs Red (Output)

Delta-E ITP: Different processing on 1 quad

Why do we see differences in specific colors

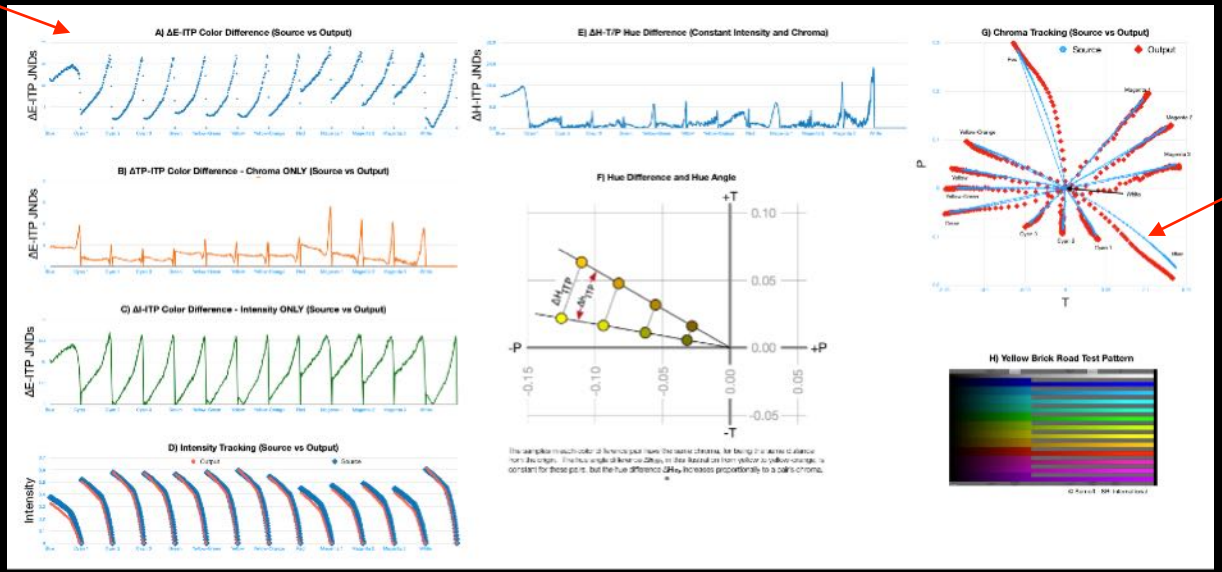


UHD Video is sometimes broken up into QUADS These are the colors that are affected.

A frame-sync Was processing a single quad differently

Delta-E ITP: Examining Color and Light Differences Easily

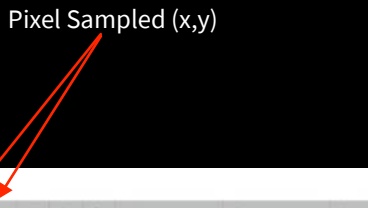
Any # above one(1) is a "Just Noticeable Difference" (JND)

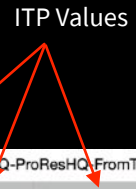


Red (output) that drifts from the blue (source) in this T/P plot identifies a hue shift

Vooya text output: What does it look like

Open CSV ITP results (see example below) into any plotting software including Apple Numbers or MS Excel as a “line graph”.

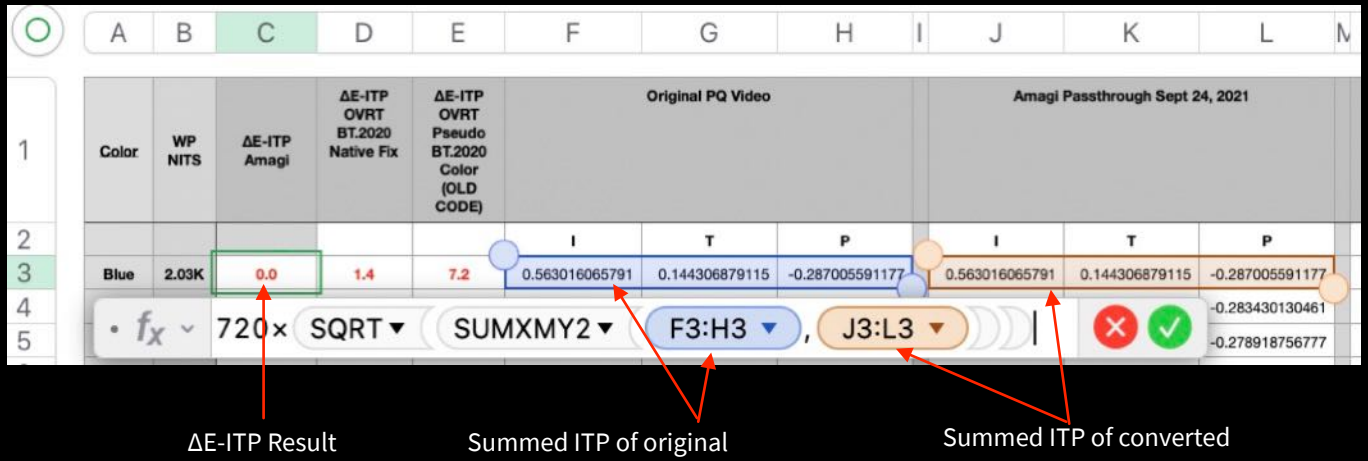




MasterTestPatternLoop-HLGtoPQ-ProResHQ-FromTIFF

Frame	Pixel Nr.	x	y	Y	Cb	Cr	I	Ct	Cp	I	T	P	Y'	u'	v'	min_nits	max_nits	Input
0	1	1620	140	103	851	485	0.496191950231	0.285930978992	-0.276288506140	0.496191950231	0.142965489496	-0.276288506140	0.460626785592	0.159270516932	0.125835866473	0.000	10000	YCbCr PQ-BT.2100
0	2	1580	140	103	849	485	0.492367781869	0.285680042382	-0.275566187942	0.492367781869	0.142840021191	-0.275566187942	0.456903788585	0.159270516941	0.125835866481	0.000	10000	YCbCr PQ-BT.2100
0	3	1540	140	101	832	486	0.458225485602	0.282924405940	-0.268560804617	0.458225485602	0.141462202970	-0.268560804617	0.423737099586	0.159270516692	0.125835866375	0.000	10000	YCbCr PQ-BT.2100
0	4	1500	140	100	821	487	0.436855870268	0.280699377338	-0.263647281564	0.436855870268	0.140349688669	-0.263647281564	0.403046686734	0.159270514687	0.125835875290	0.000	10000	YCbCr PQ-BT.2100
0	5	1460	140	98	808	488	0.411228141881	0.277478705384	-0.257188087235	0.411228141881	0.138739352692	-0.257188087235	0.378306676268	0.159270516717	0.125835866261	0.000	10000	YCbCr PQ-BT.2100
0	6	1420	140	97	795	489	0.387063241645	0.273845521057	-0.250502411447	0.387063241645	0.136922760529	-0.250502411447	0.355055427395	0.159270511358	0.125835890096	0.000	10000	YCbCr PQ-BT.2100
0	7	1380	140	95	781	490	0.360699948940	0.269161212251	-0.242511109929	0.360699948940	0.134580606126	-0.242511109929	0.329778279815	0.159270516717	0.125835866261	0.000	10000	YCbCr PQ-BT.2100
0	8	1340	140	94	769	491	0.339234889982	0.264740975753	-0.235435391779	0.339234889982	0.132370487877	-0.235435391779	0.309270229891	0.159270503639	0.125835924428	0.000	10000	YCbCr PQ-BT.2100
0	9	1300	140	92	756	492	0.315627858264	0.259190843179	-0.227027032022	0.315627858264	0.129595421590	-0.227027032022	0.286795301690	0.159270516717	0.125835866261	0.000	10000	YCbCr PQ-BT.2100
0	10	1260	140	91	743	493	0.293439516172	0.253252528693	-0.218487766966	0.293439516172	0.126626264347	-0.218487766966	0.265751550964	0.159270486147	0.125836002224	0.000	10000	YCbCr PQ-BT.2100

Line Plotting using Vooya ITP Output



Each sampled ITP Value is multiplied by 720 times the Square Root of the sum of squares of the differences of corresponding values in two arrays

This produces each ΔE-ITP Value