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Clearing the way
to
free, open, user-friendly, and viable
HDR/SDR workflows

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www.videoq.com

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1. HDR/SDR Open Workflow – Executive Summary

What is the challenge and the opportunity?

Well-established workflows exist across the industry – from production to packaging, through to presentation and final content distribution. These workflows rely on tried and tested rules and guidelines, that should also now become **simple** and **unified.**

The rules need to be well understood, to work together and thus allow for free interchange of content at each juncture without technical risks and the fear of the unknown.

The advent of **HDR** and **Wide Color Gamut** technologies demands changes to customs and practices. New workflow rules must also be established and honed. The problem is that in this early adoption phase, competing standards are anything but unified.

*This presents the industry with an **opportunity** to establish an agreed upon **commonality** between the current incompatible array of standards and self interest.*

The solution to this issue is harmonious, technically correct and agile content production and distribution, proposed here in the form of a **Target Display Agnostic HDR Workflow**, plus **Video and Audio Levels Mapping,** adaptive to **viewing/listening conditions**, and in addition a **Unified HDR Reference White** approach. Please read on…

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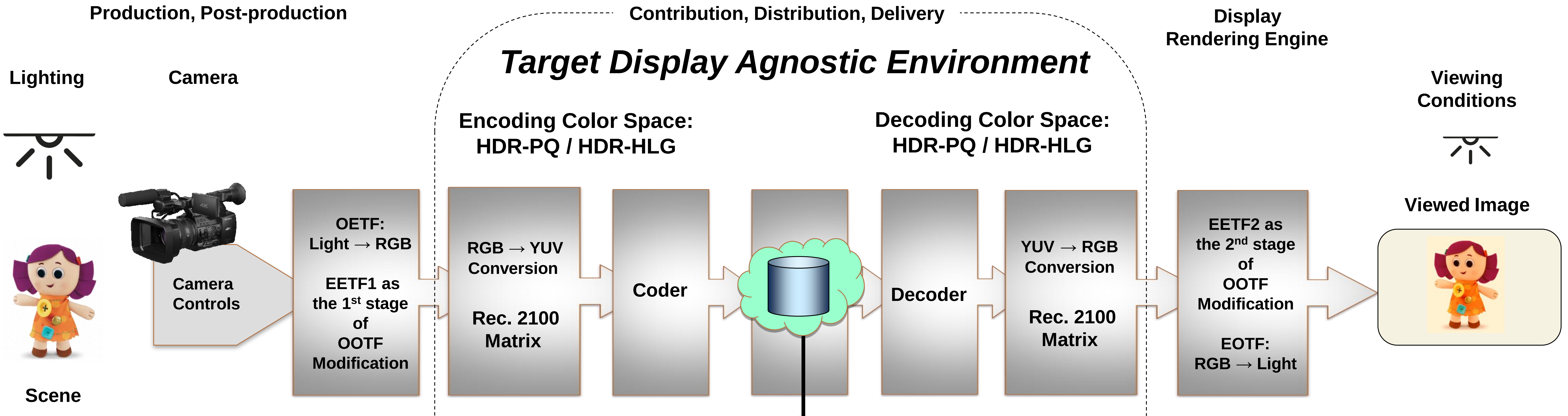
The Big Picture – Overall HDR System View



Engineering Controls,

***Optional* Color Grading,**

Optional creation of
Rendering Instructions
Dynamic Metadata
for the specified **array** of
Target Displays

Content Levels Metering and QA/QC,
Content Levels Alignment,
Routing & Secondary Compositing,
Ad & Graphics Insertion,
Up, Down and Cross-conversion,
Transcoding & Distribution,
Insertion & Checking of Test Patterns

Normalized HDR content data and light levels
*are **highly desirable** at this stage,*
*especially for **routing**, **compositing** and **adverts insertion***

Display Designer Decisions:

Display Parameters/Capabilities,

Color Gamut & **Light Levels Mapping**,
Execution of **Rendering Instructions**
(driven by ***optional*** **Content Metadata**),

Viewer Controls:
Brightness, Gamma, Saturation, etc.

OOTF *stands for Opto-Optical Transfer Function.*

OOTF *is the composition of the* ***OETF*** *(opto-electronic transfer function) and the* ***EOTF*** *(electro-optic transfer function).*

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Who needs open HDR/SDR technologies?

An **open** HDR/SDR ecosystem, **not limited by proprietary metadata**, is a major advance in HDR and SDR AV content delivery. It provides an efficient solution for well-known critical viewing & listening environment issues.

Customers:

Their **HDR and SDR TVs**, **desktop computers** and **mobile devices** are all operating in unpredictable ambient light and acoustic noise environment.

Open technologies, e.g. VideoQ **ViDiChoice™** (VDC) technology, provide the customers with a range of content viewing and listening modes.

Each customer can select the mode better matching the current **viewing and listening conditions** as well as the **customer personal preferences**.

Content Distributors:

They want more **happy viewers**, less churn, and a marketing edge advantage.

These goals can be achieved in a relatively short time without massive investment and significant changes to the existing workflow.

Cost-effective automated re-purposing and transcoding of the HDR content opens the new window of opportunities. This includes **unattended HDR ⇔ SDR conversion.**

Thus, **HDR/SDR simulcasting** becomes practical and affordable.

Content Originators:

They also want **happy viewers** and better ratings.

*Investment in the future-proven HDR production will be **paid back much faster** via the cost-effective HDR to SDR conversion and subsequent SDR versions release*.

Compliance with the **Unified Reference White rules** increases the **HDR content value** because it provides for easy automated conversion to any destination format.

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2. Background Information

Standardization bodies:

The BT.2100 Recommendation specifies the parameters of **HDR-PQ** and **HDR-HLG** transfer functions. It does specifies **HLG Reference White Signal Level** as 75% of the signal range.
The recommendation ***does not*** specify **PQ Reference White**, and it ***does not*** specify **HLG Reference White Light Level**.

The BT.2111 Recommendation specifies the parameters of color bar test pattern for **HDR-PQ** and **HDR-HLG** systems and it ***does*** specify **PQ and HLG Reference White Signal Levels**.

The SMPTE ST2086 specifies the parameters of ***optional indicative global*** **Static Metadata** – **Mastering Display Color Primaries** and content **Light Levels** for any given piece of **HDR**-**PQ** content. The LL metadata include max Frame Average Light Level (maxFALL) and absolute max Light Level aka Content Light Level (CLL).

The SMPTE ST2094 specifies the parameters of ***mandatory, company specific*** **Dynamic Metadata** containing detailed instructions of **mandatory light levels mapping operations** which **must be performed** by the “white-listed and certified” displays, sorted by **categories**.

See next slides for more details

Industry Experts:

Despite fundamentally different approaches, very different transfer curves, etc., many experts express the opinion that it is essential to find common ground.

In the daily practice of live event coverage and similar challenging production situations, engineers found practical solutions and established ***de-facto*** methods for working in such multi-format environments.

Describing **HDR** video content levels as **”linear” light levels**, i.e. as \`nits\`, can be considered a current trend. This is an opposite to the usage of traditional **“non-linear”** 10/12 bit **data values** or **percentages of the signal range**.

The variety of **content re-purposing tasks,** e.g. to match various **viewing conditions** and various **viewer preferences** (*ignored by the metadata driven “walled garden” systems*), must be taken into account.

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3. HDR Metadata Issues

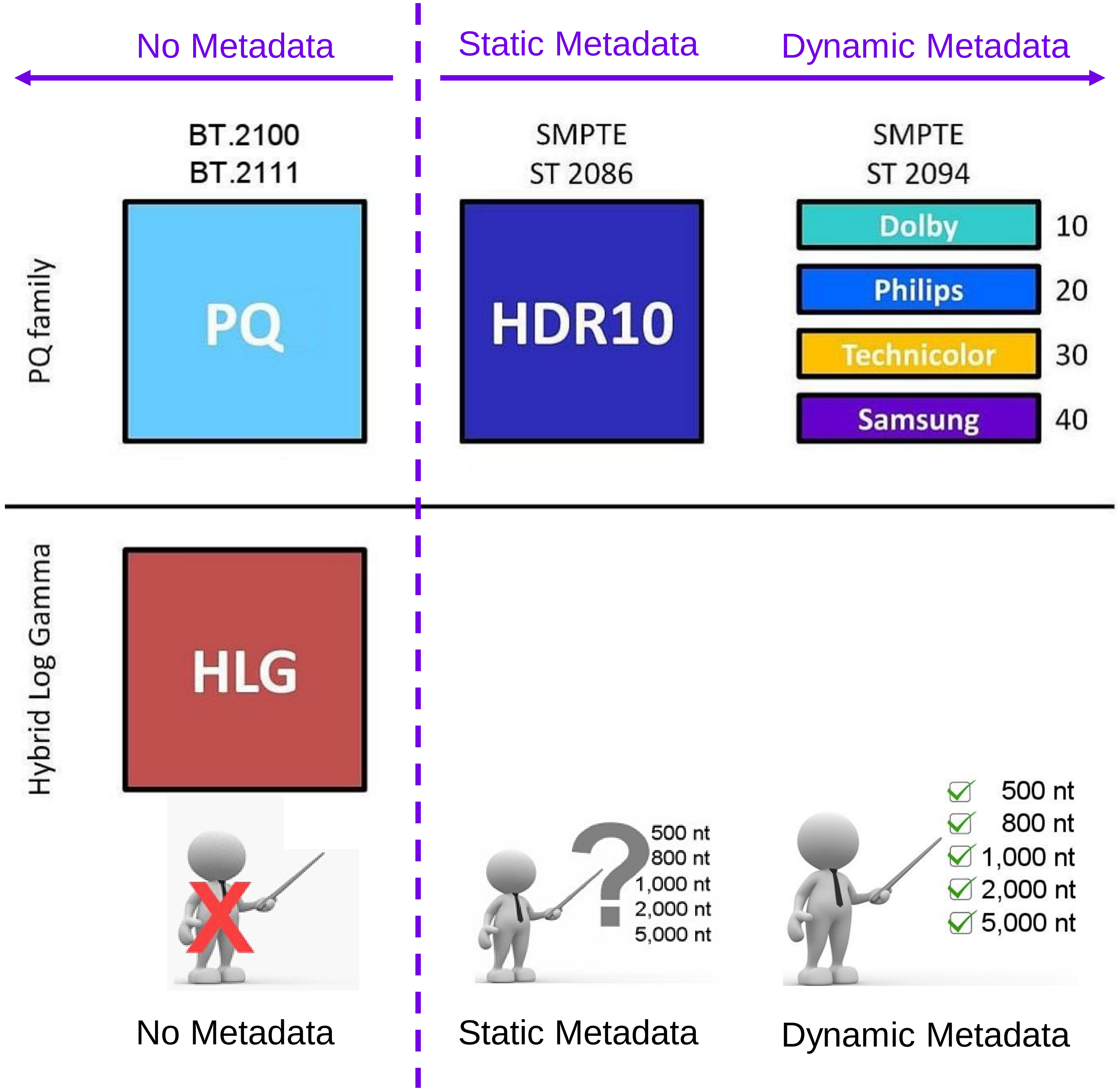
Does HDR need metadata?

The **no-metadata HDR** systems are based on the concept of **“the Hypothetical Reference Display”**.

“Plain” no-metadata HDR-PQ and HDR-HLG formats **allow** all kinds of derivations from this base **without** restricting content re-purposing and display rendering options.

These formats require only one simple **PQ/HLG switch** in the stream header.

For example, it is possible to use a custom tone mapping for different environments to accurately reproduce details so they remain easily visible in **any lighting condition**.



The **metadata-driven HDR-PQ** systems are based on the concept of a pre-defined **“Target Display”**.

This **prevents** any deviation from this base and limits the number of content re-purposing and display rendering options.

Static and dynamic metadata presumably serve for the preservation of a content originator’s “creative intent” and related “authoring rights”.

This concept is **applicable** to **controlled environments**, such as digital cinema or home theater, but it is **not applicable** to open, thus not controlled, consumer, prosumer, broadcasting and web-casting environments.

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Static Metadata 1 – Mastering Display and Light Levels

The HDR10 (SMPTE ST 2086) **static metadata** provide the **HDR display** with a bizarre mixture of **irrelevant** values with few **useful** values. The first **irrelevant** sub-set of metadata tells us about the Mastering Display and Global Light Levels:

Mastering display color primaries : **DCI P3**
Mastering display luminance : min: **0.0005 cd/m2**, max: **1000 cd/m2**
Maximum Content Light Level : **1200 cd/m2**
Maximum Frame-Average Light Level : **360 cd/m2**.

OK, thank you, now we know that **some colorist** used **this type of monitor** for the **color grading** of this piece of content.

This info was ***maybe useful*** for the other team members performing **QA/QC** or **editing**,
But, what should a supposedly "smart" **TV** do with this information?
Shall the TV ***refuse*** to show this movie if its screen brightness is **lower** or **higher** than **1200** nit of the brightest pixel?
And what do you do if the display screen is of LCD type, i.e. **not capable** of rendering **0.0005** nit?

One really tricky question:
What to do if the **master display primaries**, e.g. **DCI-P3**, do not match the **BT.2020 content primaries** specified a few lines below in the Media Info report (see next slide)?
Note that **BT2020 WCG set of primaries** is the only **legal set of primaries** for **HDR-PQ** content.

Hopefully, it is yet another piece of **irrelevant info**, but it may mean that the display ***is expected*** to **fix the bug** of the content originator!

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Static Metadata 2 – Primaries and Color Matrix

The HDR10 (SMPTE ST 2086) **static metadata** also provide the **HDR display** with another bizarre mixture of **irrelevant** values with few **useful** values. The second sub-set of static metadata tells us about the **Color Space**:

Color space	: **YUV**
Color primaries	: **BT.2020**
Matrix coefficients	: **BT.2020 non-constant**
Transfer characteristics	: **PQ**

Only the **first** and **last** lines of these four are **really useful**:
The display **must** convert **YUV to RGB** and enable the **BT.2100 HDR-PQ EOTF LUT** to convert RGB signals to **Light Levels**.

But!
The **BT.2100** standard **mandates** that **color primaries** and **YUV to RGB matrix** must be set to **BT.2020** values.

The presence of the second and third lines is, in fact, a symptom of a quite dangerous trend – an implicit "de-facto" legalization of **illegal** HDR and SDR content formats.

Such "metadata" open the way to the "semi-legal" usage of ***some other*** primaries and matrices. Which are ***not specified*** by the **BT.2100**, **BT.2020**, **BT.709** standards and are not even ***listed*** in any official document!

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Informative Metadata vs. Instructive Metadata

Let us consider a ubiquitous pack of spaghetti.

1. Informative metadata: Made with 100% Durum Wheat.

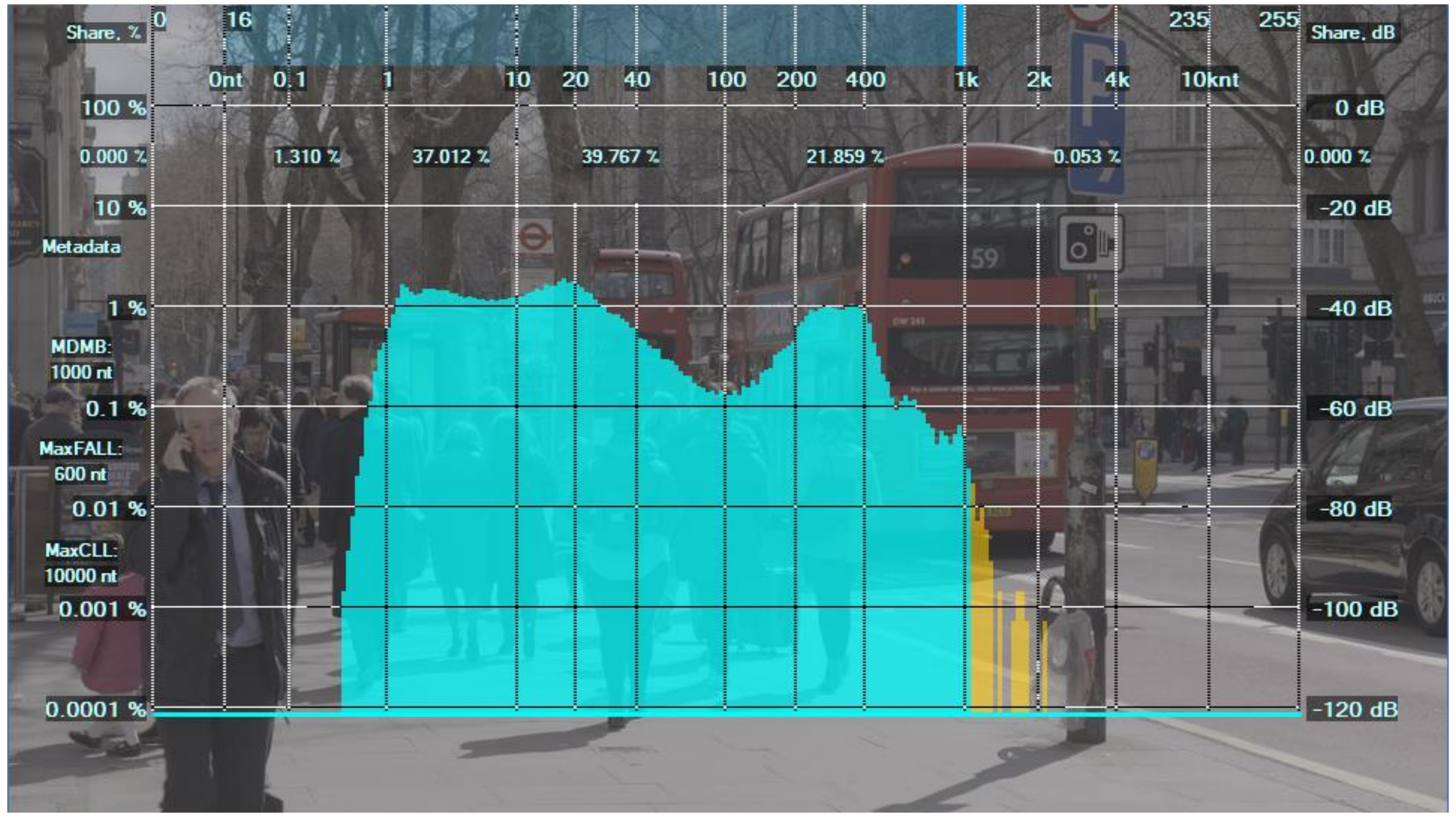
2. Instructive metadata: Bring a saucepan of lightly salted water to the boil. Add pasta, reduce heat and simmer for approx. 8-9 minutes.

Both parts are useful, but the **instruction** part should not be treated as ***restriction***, i.e. if we simmer our favorite pasta for less than 8 or over 9 minutes, it does not mean that our restaurant license should be **revoked.**

Likewise, we should stop the ***compulsory*** usage of Dolby Vision and similar HDR-PQ systems “instructive” dynamic metadata, ***restricting*** millions of very different HDR displays operating in very different conditions.

On the other hand, any “informative” metadata, like **HDR-PQ/HDR-HLG** LL histograms, **HDR10** FALL and MaxFALL values, or **HDR10+** cumulative curve quantile values, can be used for better rendering of **HDR images** and/or down-converted **SDR images**.

HDR-PQ LL Histogram



HDR10+ LL Quantile Values

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Are Dynamic Metadata suitable for any HDR-PQ content?

The **SMPTE ST 2094 dynamic metadata** provide the final destination display with a set of **rendering instructions** sorted by the **limited number** of HDR and SDR **target displays types**.

Thus, the **dynamic metadata HDR-PQ format** is by definition **not suitable** for any **unlisted, generic HDR display**.

This format is helpful for improving and preserving the “visual impact” of HDR-PQ content in **carefully controlled environments**, such as digital cinema and/or home theatres (via BD players, streaming or files delivery).

Each set of rendering instructions is suitable **only** for the **pre-selected timeline segment** of the given piece of HDR-PQ content.

Any useful dynamic metadata can be created **only** as a result of **time and money consuming color grading** effort.

This requires **highly skilled** and **highly paid colorists** to work with **relatively expensive tools**.

Thus, the **dynamic metadata HDR-PQ format** is **not suitable** for:

- Live events coverage, e.g. live sport streaming
- Cost-effective production of “regular” HDR content, e.g. serials, commercials, educational programs, etc.

Color Spaces and Video Data Conversion Workflows

The **BT.2020 Recommendation** defines various aspects of ultra-high-definition television (**UHDTV**) with standard dynamic range (**SDR**) and wide color gamut (**WCG**).
It also mandates the use of RGB ⇔ YUV Color Space Conversion **BT.2020 Matrices** for the frame sizes greater than HD.

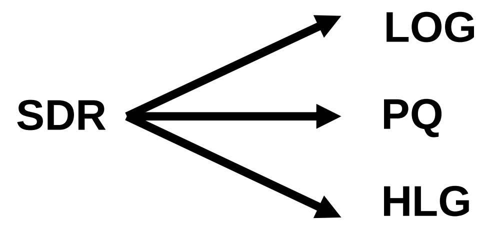
The **BT.2100** mandates the same **WCG** parameters for **HDR-PQ** and **HDR-HLG** video frames of **any size**.

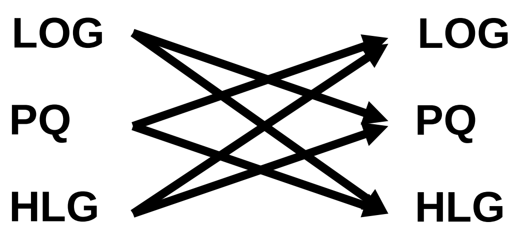
Note that RGB ⇔ YUV conversion in ubiquitous **HD SDR** format relies on significantly different **BT.709 Matrices**.

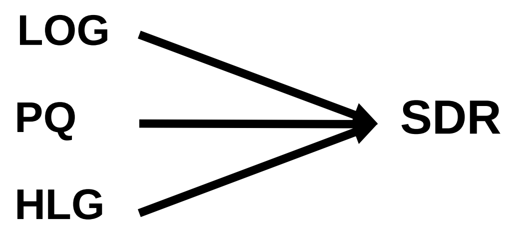
Since the introduction of **BT.601** standard YUV data are generated in **Narrow Range** format (abbreviated as **NR**).
Main advantage of the NR format is the availability of extra levels below **Reference Black** and above **Reference White**.

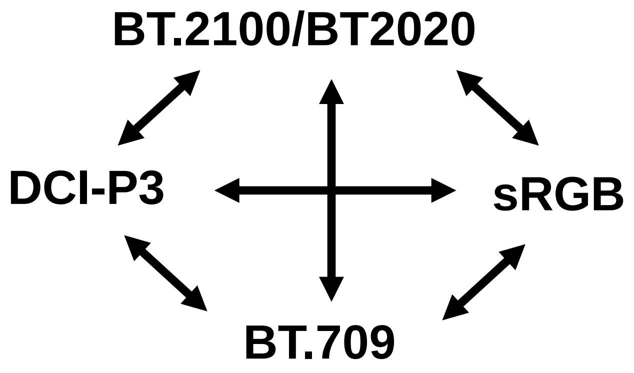
However, the RGB data traditionally used in production and post-production are defined in two formats – **Full Range** format (**FR RGB**, without reserved levels) and **Narrow Range** format (**NR RGB**, similar to NR YUV).
Thus, generic RGB ⇔ YUV conversion workflows should handle FR/NR RGB, NR YUV and BT.2020/BT.709 Matrices.

The **HDR** ⇔ **SDR** conversion processes are even more complicated, note the **Unified Reference White** concept:
http://www.videoq.com/hdr_ref_white.html









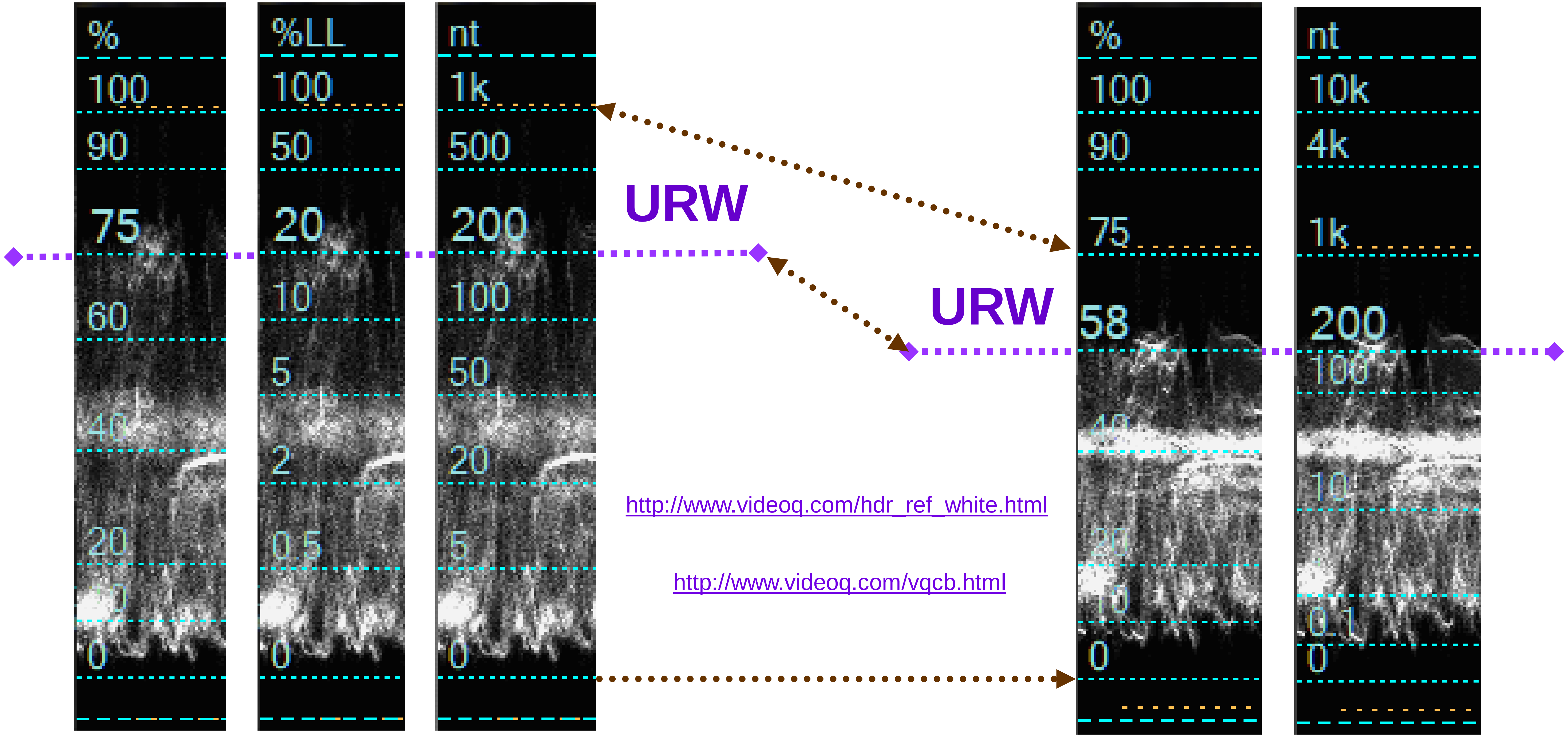
Unified HDR Reference White – Percent & Nit Values

HDR-HLG Reference White:

- Signal Level **75%**
- Light Level **20%**
- *Derived Light Level 200 nit (only for TDMB = 1000 nit)*

HDR-PQ Reference White:

- Signal Level **58%**
- Light Level **200 nit** (*for any TDMB value*)
- *Derived Light Level 2.0% (200 nit of 10000 nit range)*



http://www.videoq.com/hdr_ref_white.html

http://www.videoq.com/vqcb.html

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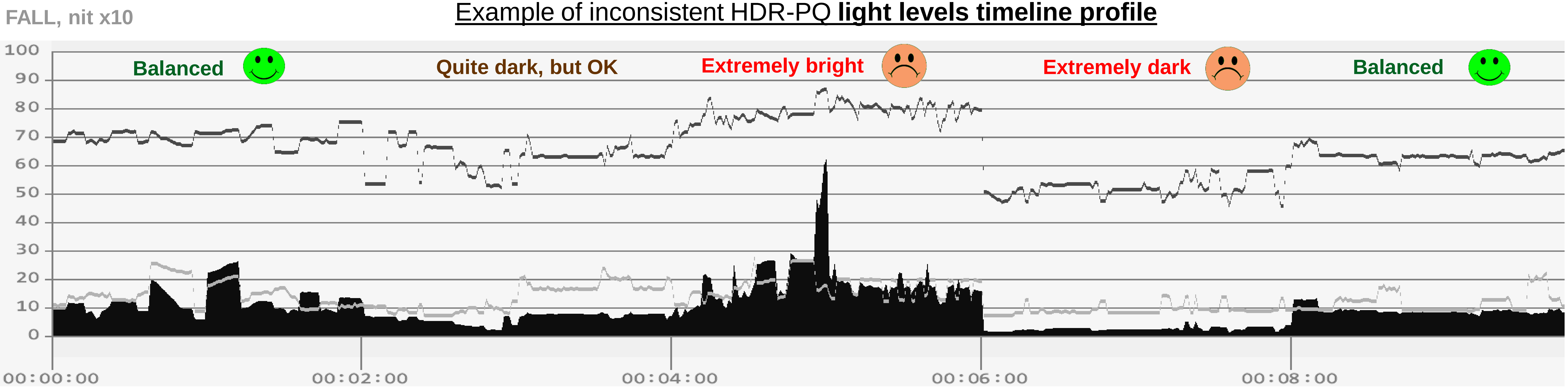
4. VideoQ Tools and HDR Technologies

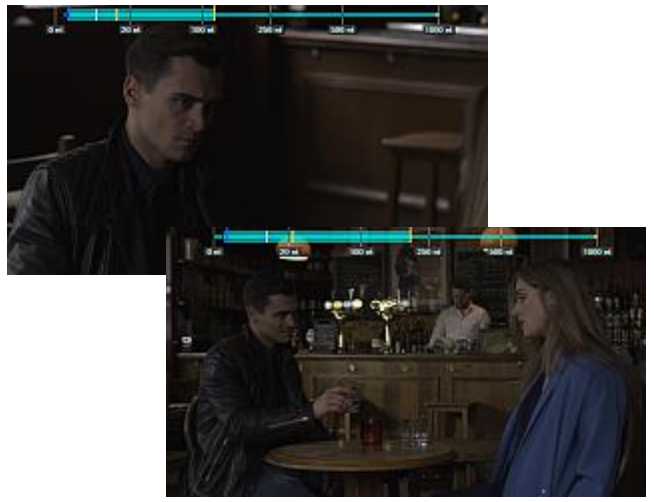
Whilst caring about the **maximum viewing comfort** (aka **QoE** = Quality of Experience) we should be guided by two principles:

- ***Consistency is more important than performance***. I.e. a **consistent** ‘4’ quality mark all the time is better than ‘5’,‘3’,‘5’ up-down-up variation.
  E.g. in the DC industry **sweetening** means adjustments for **consistent** colors, voice pitches, loudness, etc. – all movie segments from start to finish.
- ***A Happy Viewer is the only measure of success***.

The list of parameters for consistency checks should include video and audio **levels statistics**

Example of inconsistent HDR-PQ **light levels timeline profile**





Video images – courtesy of newsbyte.co.uk

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VideoQ CVC Technology – Gradations Mapping

VideoQ **Color Vectors Correlation™** (**CVC**) technology provides for automated **Light Levels Mapping and Normalization**.

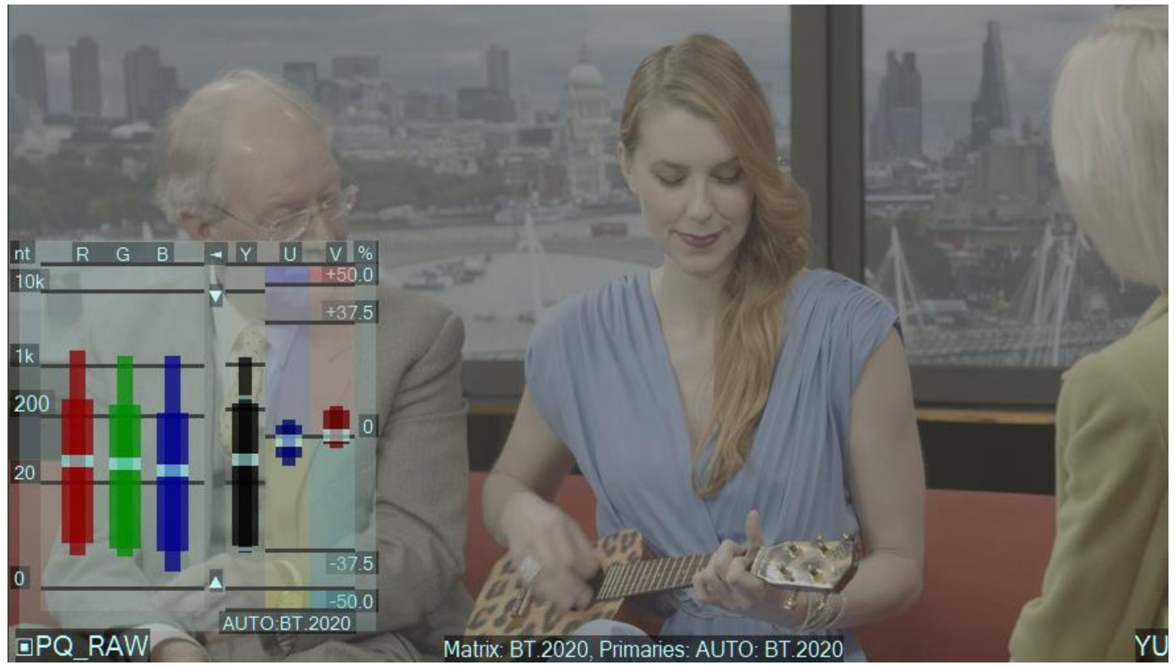
The CVC algorithms are vitally important for the **metadata agnostic HDR ⇔ HDR, SDR ⇔ SDR,** and **HDR ⇔ SDR** conversion workflows.

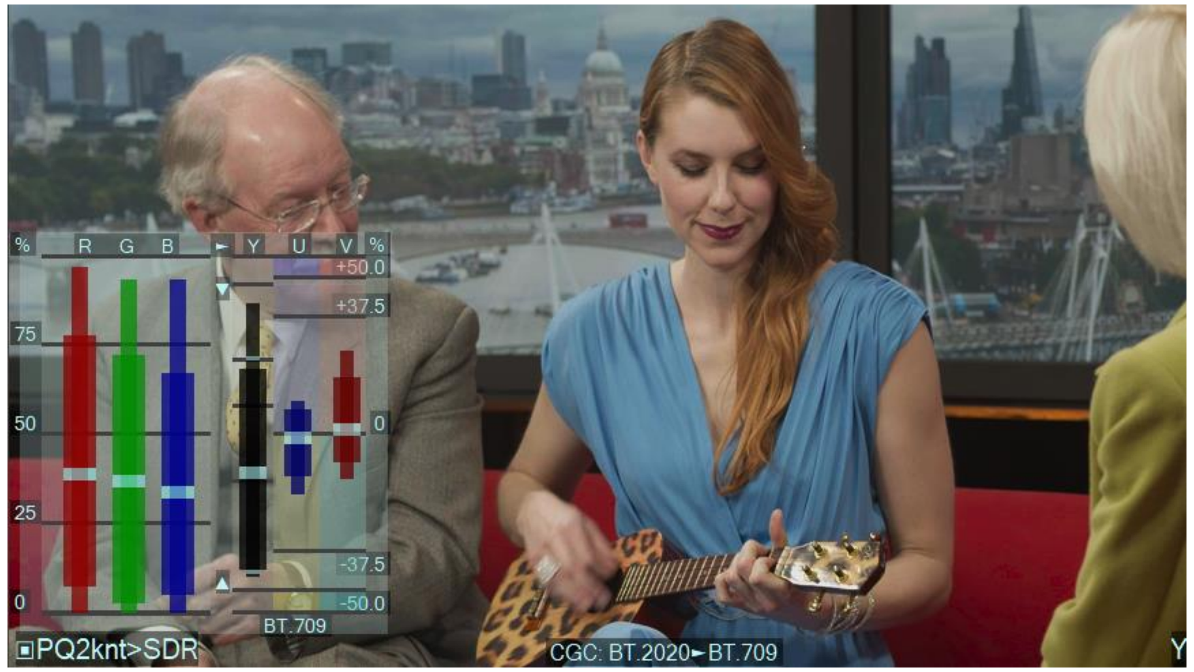
The VideoQ VQV Analyzer screenshots below show **video frame data statistics** and **light levels statistics** for various rendering modes.

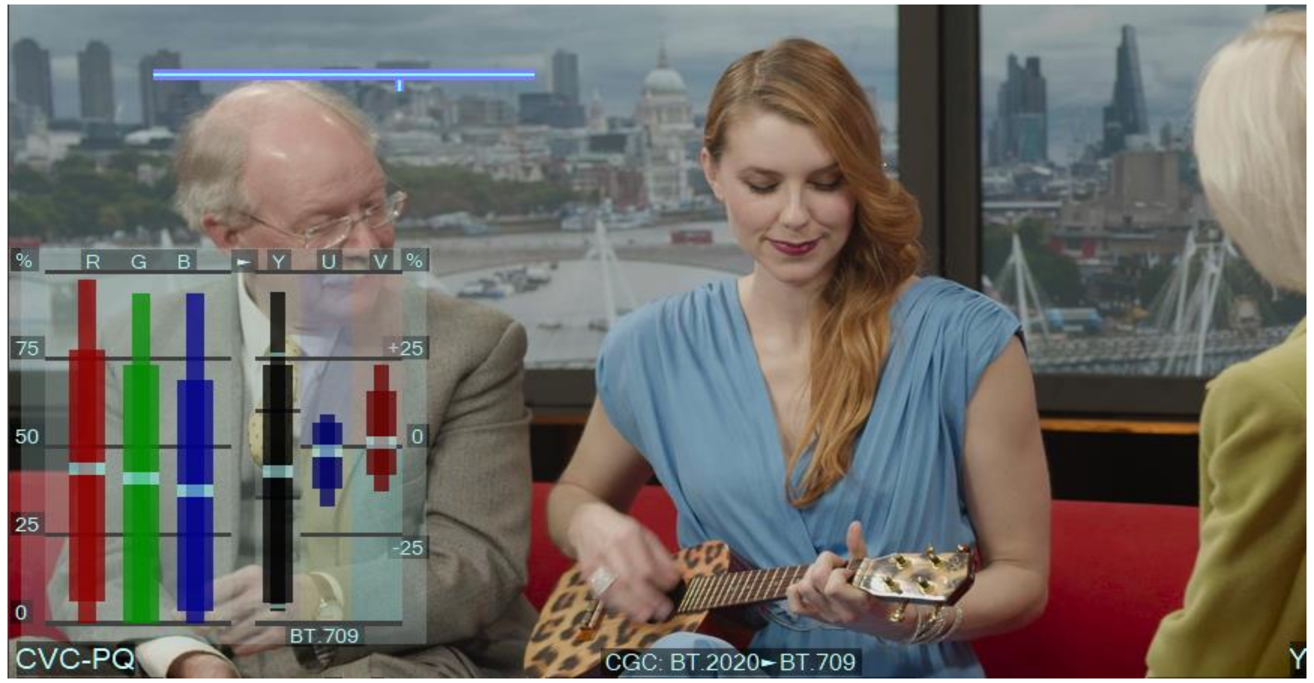
PQ RAW 99%LL = **310nt**, 100%LL (CLL) = **1542nt**.
Bottom: Histogram of LL statistical distribution.

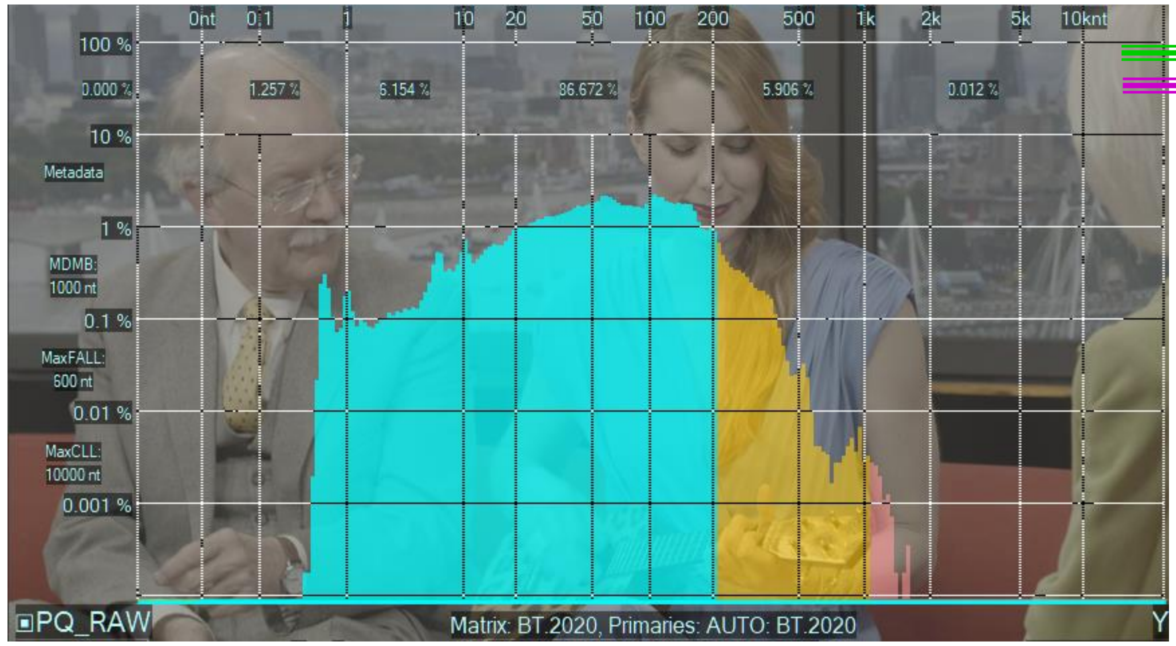
Manually selected HDR⇨SDR EETF: 98% = **2000nt**.
Top: SDR RGB&YUV levels. Bottom: EETF curve

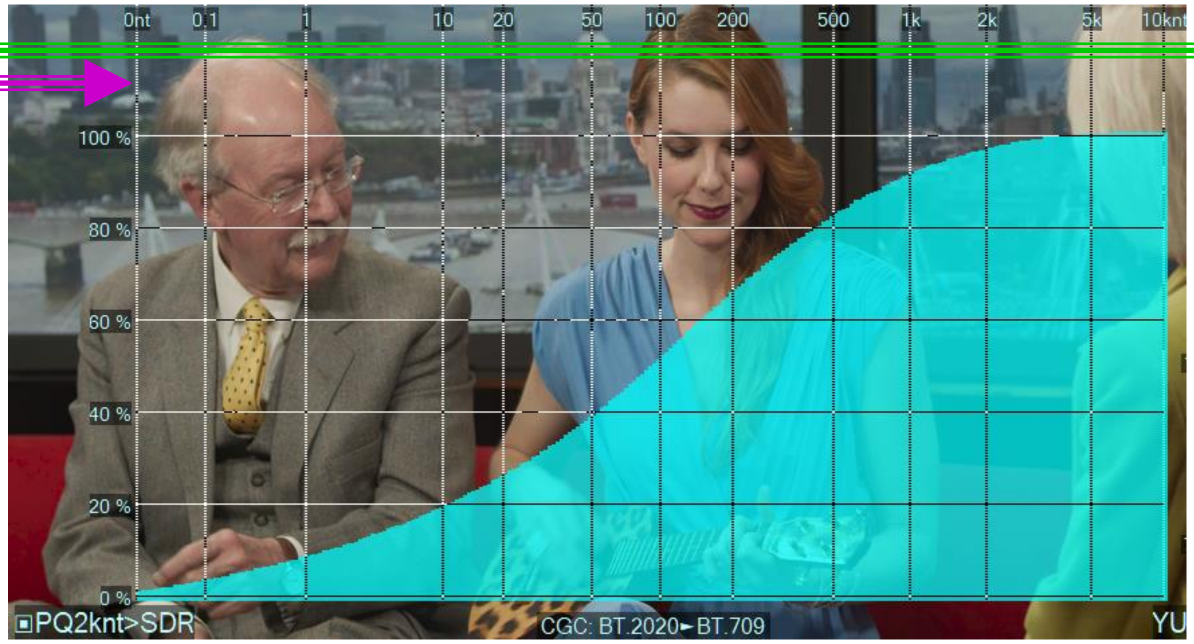
CVC (auto) selected HDR⇨SDR EETF: 98% = **1600nt**.
Top: SDR RGB&YUV levels. Bottom: EETF curve

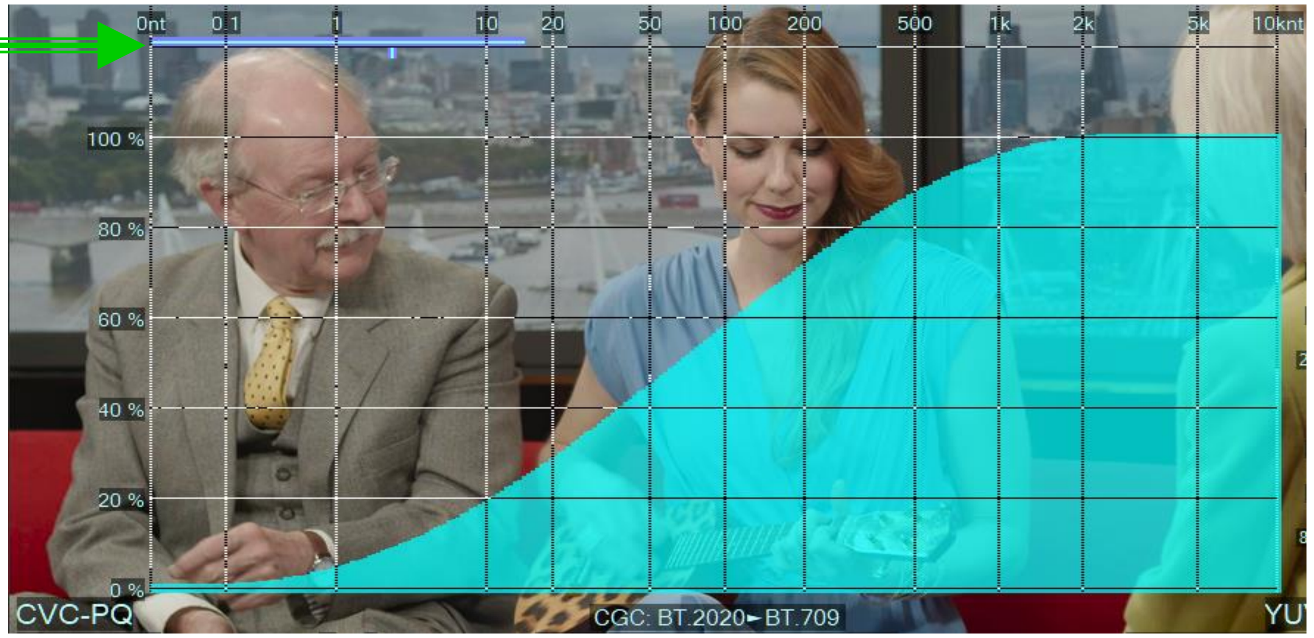












Video images – courtesy of newsbyte.co.uk

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VideoQ CVC Technology – Criteria for Success

The only criteria of success is a Happy Viewer and a visual impact of wonderful video images.

Modern HDR cameras and display screens are much better than their prior-art SDR counterparts.

However the content quality and its availability is dragging behind.

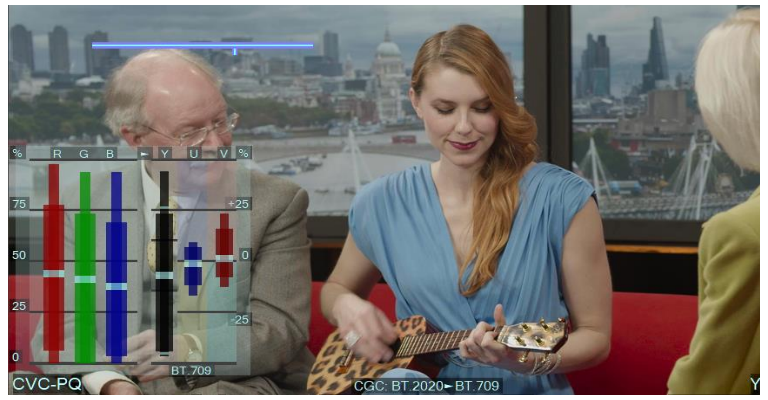
Important facts are:

- **SDR content** made via **HDR to SDR down-conversion** is significantly better than regular SDR content.
- **HDR content** made via **SDR to HDR up-conversion** is nearly as good as regular HDR content, but the **production cost** is order of magnitude **lower**.

There are only **two valid questions**:

1. Are **Video Data Levels** and **Light Levels** suitable for the **distribution context**, e.g. for **streams switching** and **adverts/captions insertion**?
2. Do the converted **images** *at the workflow output* **look good** to millions of viewers?

HDR⇨SDR Conversion with CVC



Note that we **should not** compare **fundamentally different** video images of ***the same object***:

- Original HDR *(WCG)* or SDR image *(WCG UHD or NCG HD)***,**
- Down-converted HDR to SDR image *(WCG UHD or NCG HD),*
- Up-converted SDR to HDR image *(WCG to WCG or NCG to WCG),*

Why? Because they belong to at least **three** quite different **workflows** and quite different **viewing conditions**.

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VideoQ ViDiChoice (VDC) Technology

VideoQ **ViDiChoice™** (VDC) technology is a major advance in HDR and SDR AV content delivery.
It provides an efficient solution for well-known critical viewing & listening environment issues.

User or player manually or semi-automatically selects the **stream** or the **processing algorithm** to get desired (***subjectively optimal***) video and audio levels.

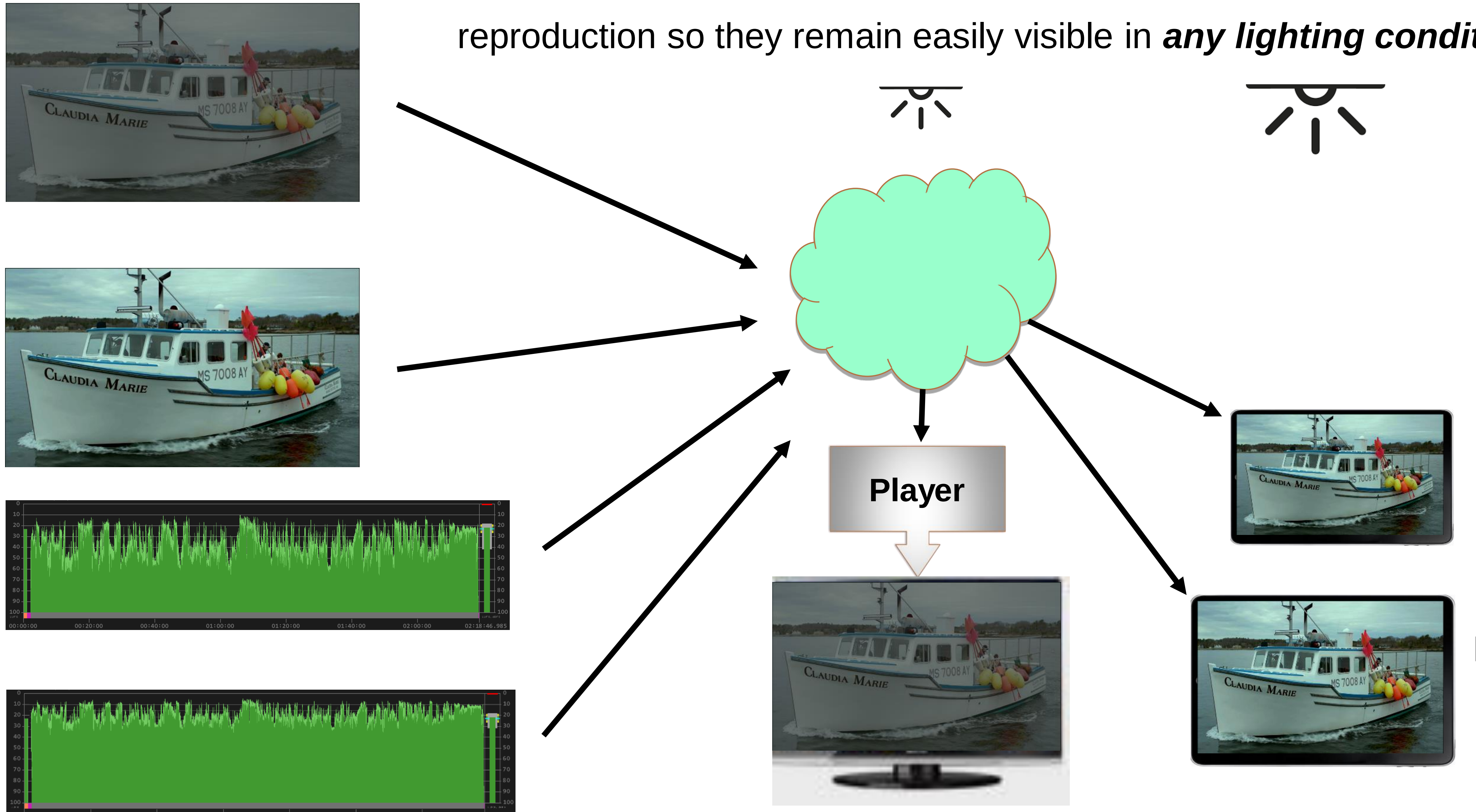
Adaptive tone mapping for different environments allows accurate details reproduction so they remain easily visible in ***any lighting condition***.

Original dynamic range Video

Processed *subjectively brighter* Video

Original loudness range Audio

Processed *subjectively louder* Audio



HDR device

Mobile SDR device

Mobile HDR device

For more details, see next slides.

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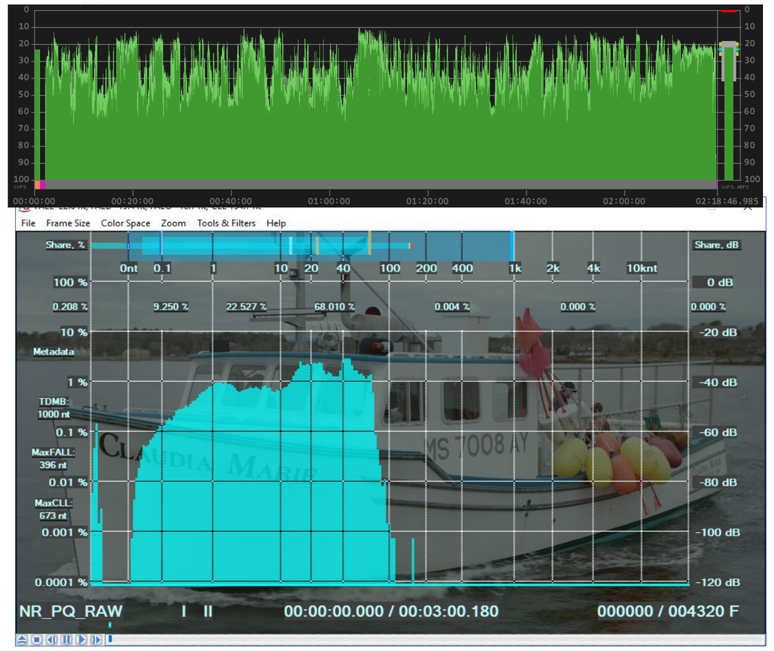
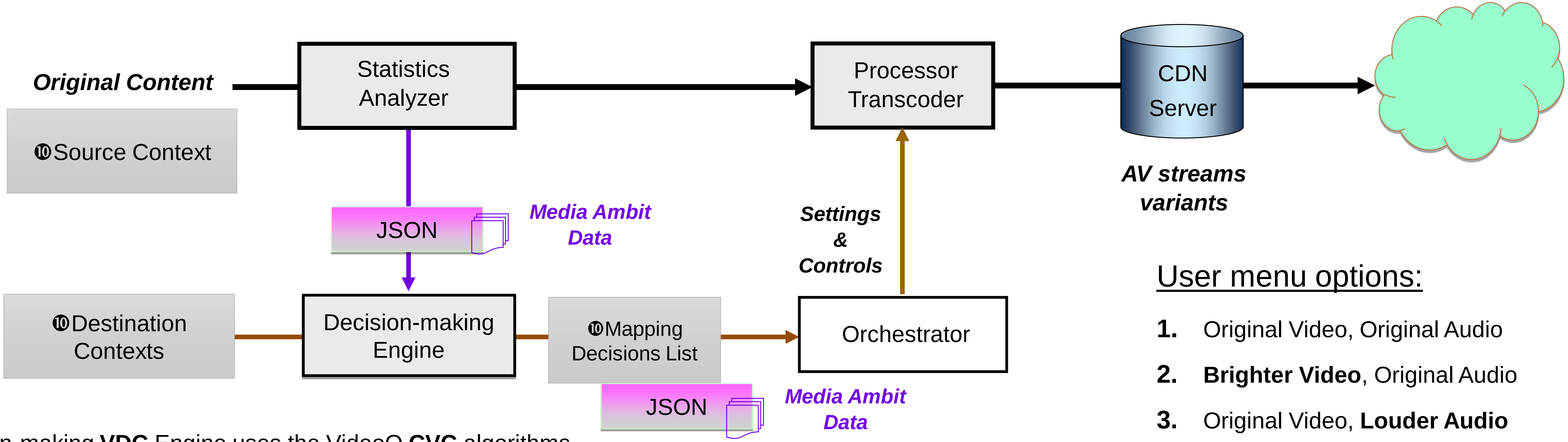
VDC – How does it work on the sending side?





User menu options:

1. Original Video, Original Audio
2. **Brighter Video**, Original Audio
3. Original Video, **Louder Audio**
4. **Brighter Video, Louder Audio**

Decision-making **VDC** Engine uses the VideoQ **CVC** algorithms for the **HDR⇨HDR** and **HDR⇨SDR** EETF LUTs calculations

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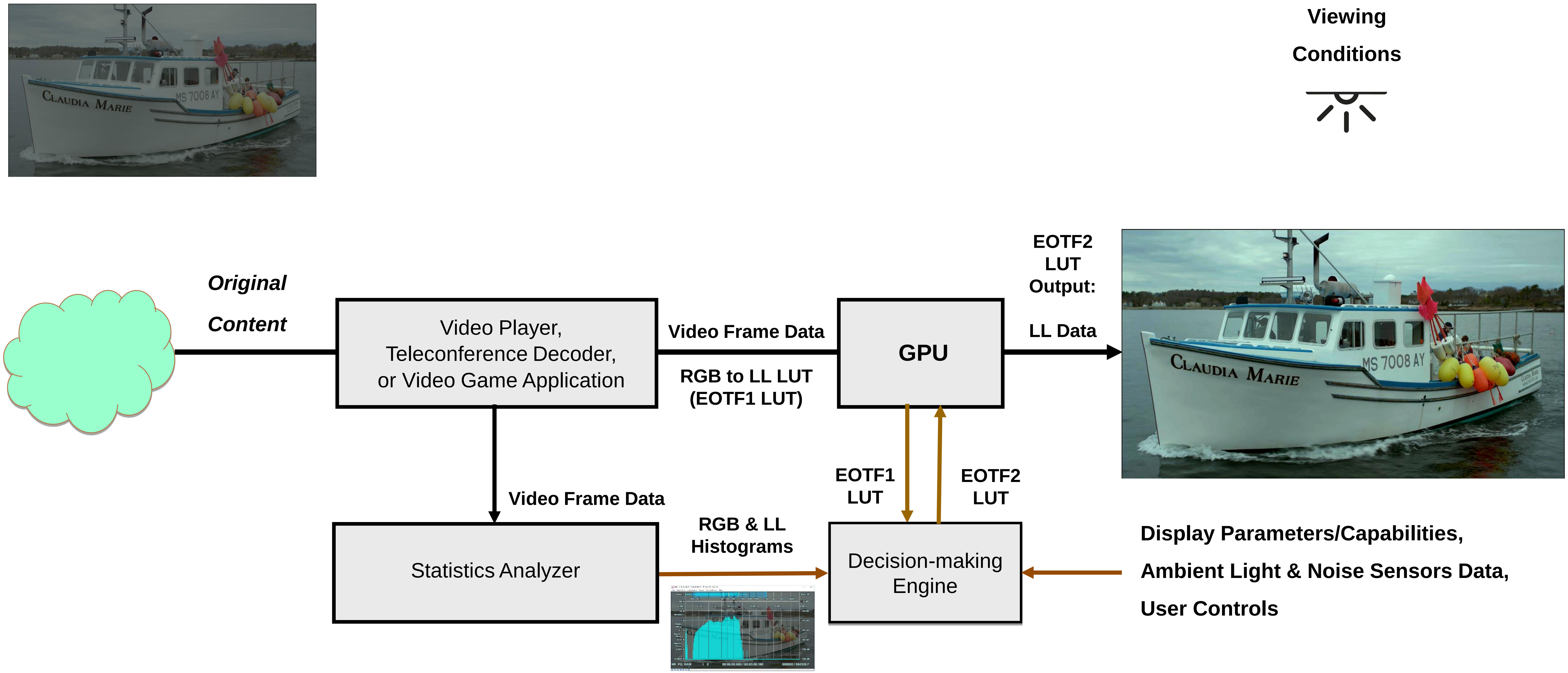
VDC – How does it work on the receiving side?



Decision-making **VDC** Engine uses the VideoQ **CVC** algorithms
for the **HDR⇨HDR** and **HDR⇨SDR** EETF LUTs calculations

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VDC – Audio Content Listening Clarity

Reduction of audio dynamic range may provide for audio clarity – thus, it is important for the listener

Some audio segments are ***below*** the Noise Level

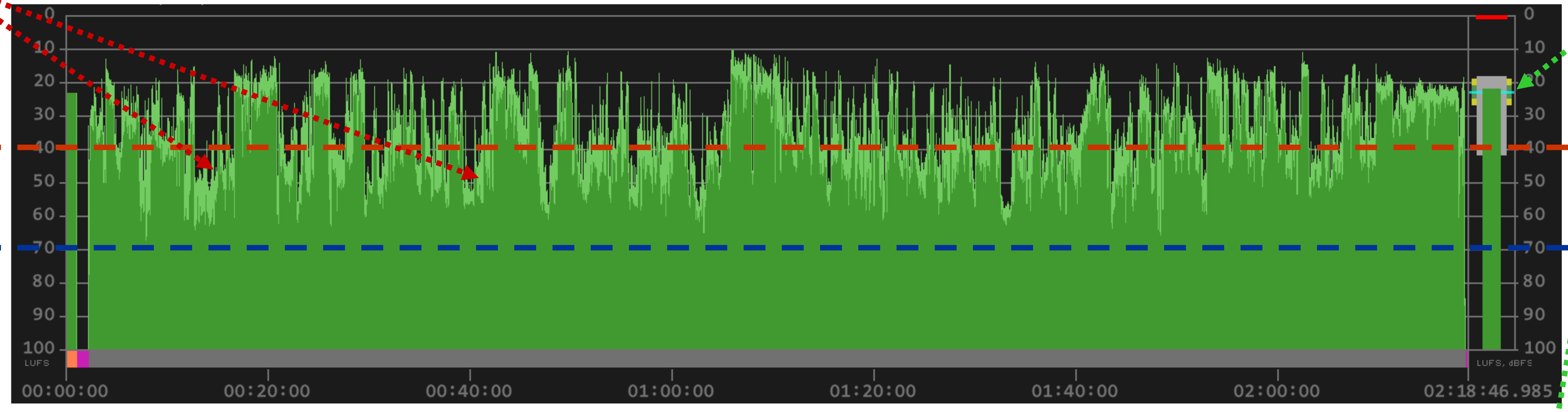
Original audio loudness timeline profile

The same

Integrated Loudness

High ambient noise level

Low ambient noise level



Original audio is good ***only*** for ***low noise*** environment.

All processed audio segments are ***above*** the Noise Level

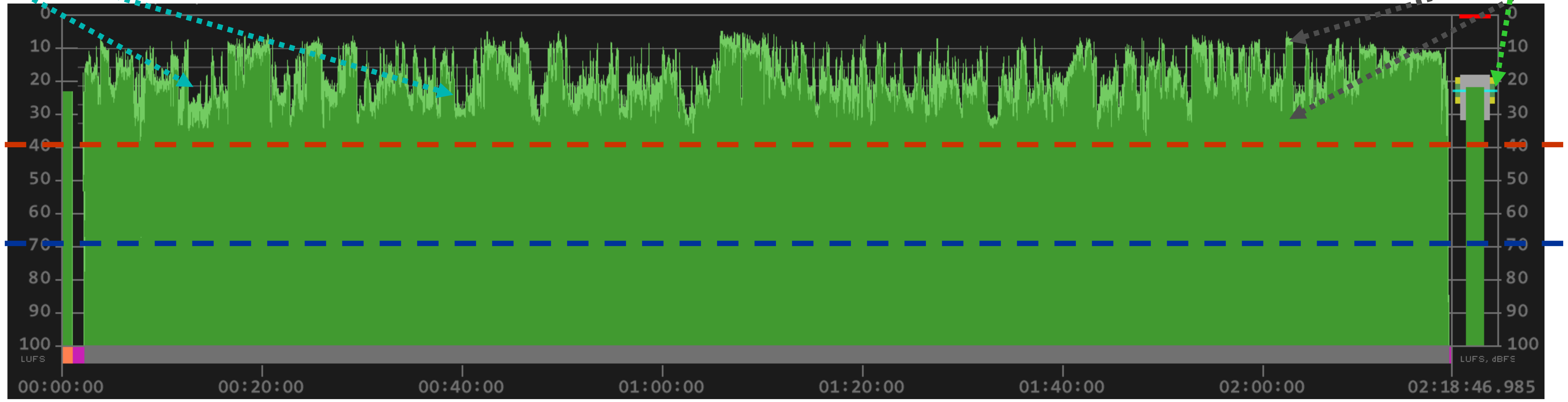
Processed audio loudness timeline profile

Reduced Loudness Range

Note that on average the processed audio sounds louder.

High ambient noise level

Low ambient noise level



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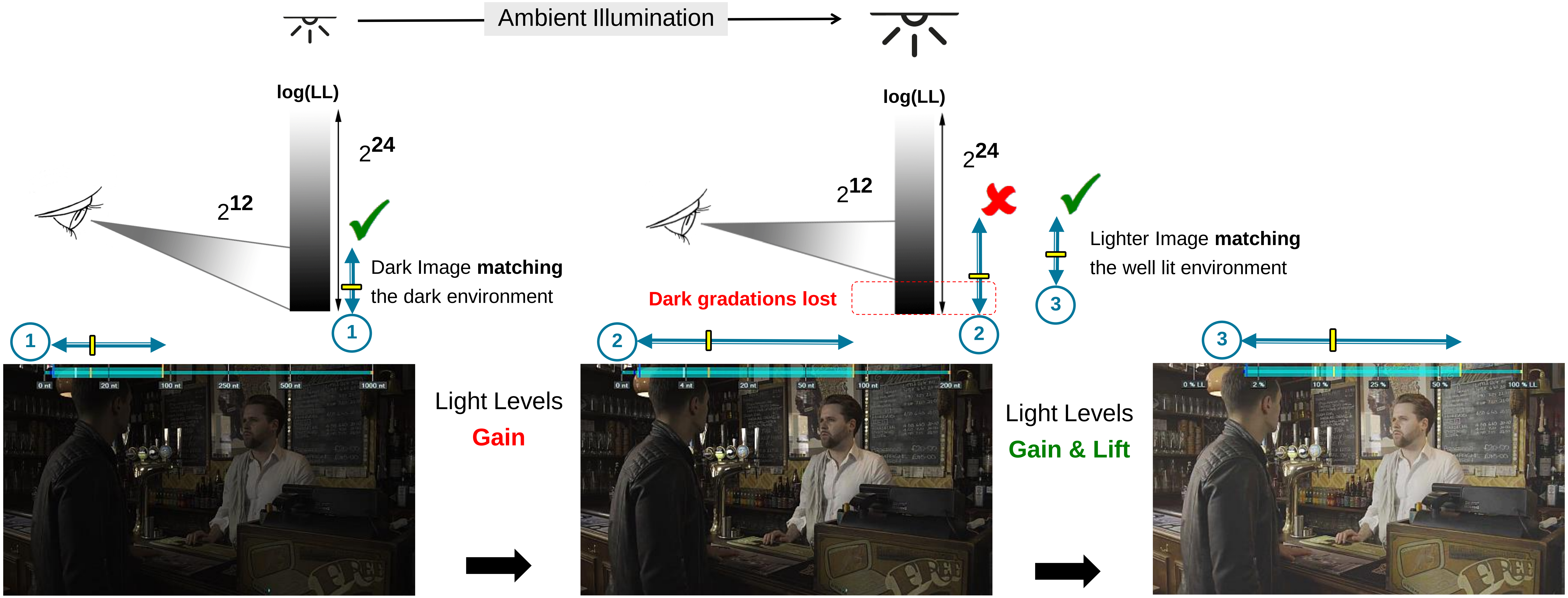
VDC – Ambient Illumination & Video Image Dynamic Range

When the **ambient illumination light level** goes up, the **logarithmic range of visible gradations** does not increase nor decrease, it **moves upwards**.

Therefore, to provide the best **viewing comfort** all gradations of the **rendered video image** must also go up, **following the visible range**.

It is relatively easy to fit the smart TV with the **ambient illumination sensors,** *but for mobile devices it is not so easy, so manual control is preferred*.

The challenge is to find the optimal light levels **re-mapping algorithm**, i.e. to provide **ambient light adaptive EOTF** functionality.



Video images – courtesy of newsbyte.co.uk

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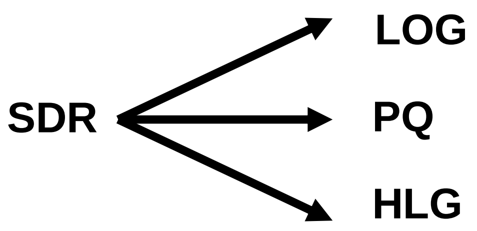
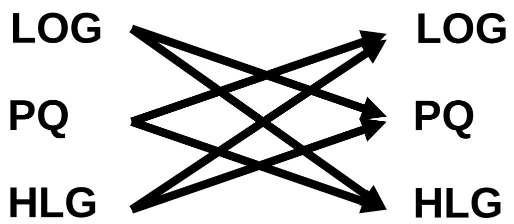
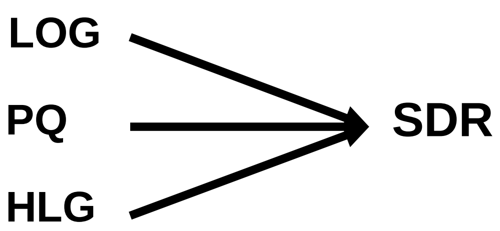
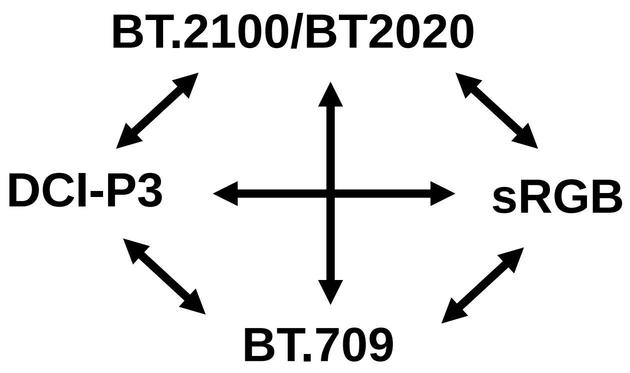
5. Travel across Color Spaces – Guidelines and Pitfalls









The processes of HDR ⇔ HDR or HDR ⇔ SDR conversion (up, down, across) are often combined with the frame size conversion (up or down) and RGB ⇔ YUV conversion. In many cases they also require sophisticated color space conversion.

This means a high number of conversion variants, corresponding workflows, and … potentially serious challenges.

For example, unlike **UHD SDR WCG** content, any standards-compliant **HD SDR** content must be created for **BT.709 display primaries** and via **BT.709 RGB ⇒ YUV matrix**.

But, down-converted HD SDR web-delivery-streams metadata often keep the original **UHD BT.2020** color space parameters. This "saves" on color space conversion procedures, but the delivered content parameters do not match the **mandatory BT.709**. This may result in noticeable color distortions, despite the ***expectation*** that the "smart" player should fix the bug.

The VideoQ **Color Bars Test Patterns suite** serves to detect, prevent and fix serious color space conversion problems.

See next slides for more details.

http://www.videoq.com/vqcb.html

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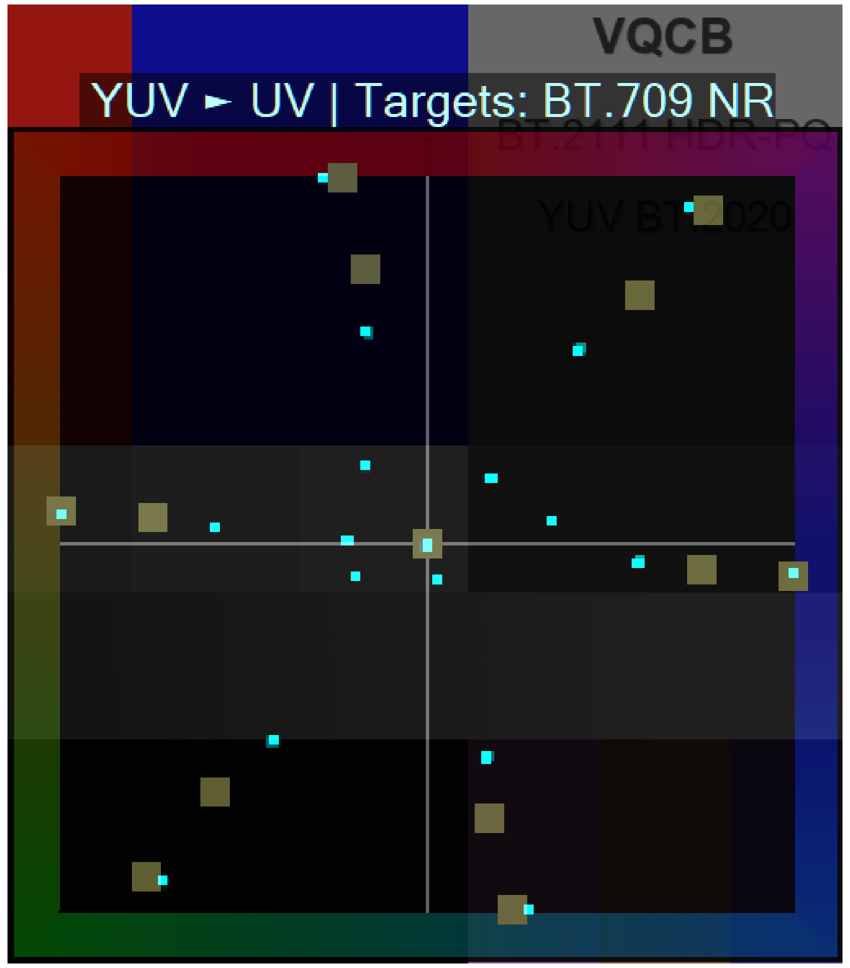
HDR-PQ Color Space Issues Example

VideoQ VQV version 2.2.1, Input Media File SDR/HDR Metadata Validator Report

This tool cross-checks the metadata values for common compliance

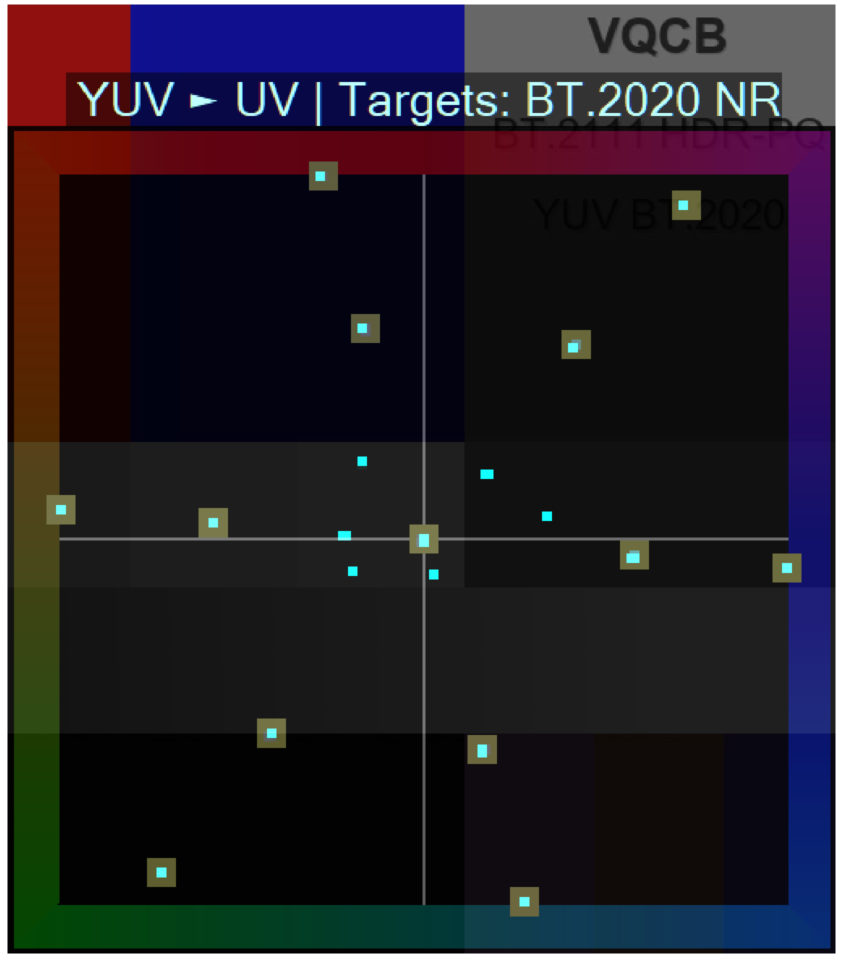
ID	Parameter_Name	Value	Validity	Comment
04	colorMatrix	BT.709	WARNING	HDR format requires BT.2020 color space
05	transferFunction	HDR-PQ	VALID	null
06	colorPrimaries	DCI-P3	WARNING	HDR format requires BT.2020 color space



VideoQ VQV **Metadata Validator** exposed two problems:

1. **RGB ⇔ YUV matrix** is specified as **BT.709** instead of the correct (BT.2100 standard compliant) **BT.2020** matrix. *Testing the workflow with the color bars test pattern and VQV VectorScope tool clearly shows that the YUV values are in fact BT.2020 compliant. Thus, this issue is most likely due to a transcoder script creating the wrong metadata.*

2. **Color Primaries** are specified as a **DCI-P3** set instead of the correct (BT.2100 standard compliant) **BT.2020** set. *This most likely result in significant color errors.*



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VideoQ VQCB HDR-PQ Color Bars Test (BT.2111)

http://www.videoq.com/vqcb.html

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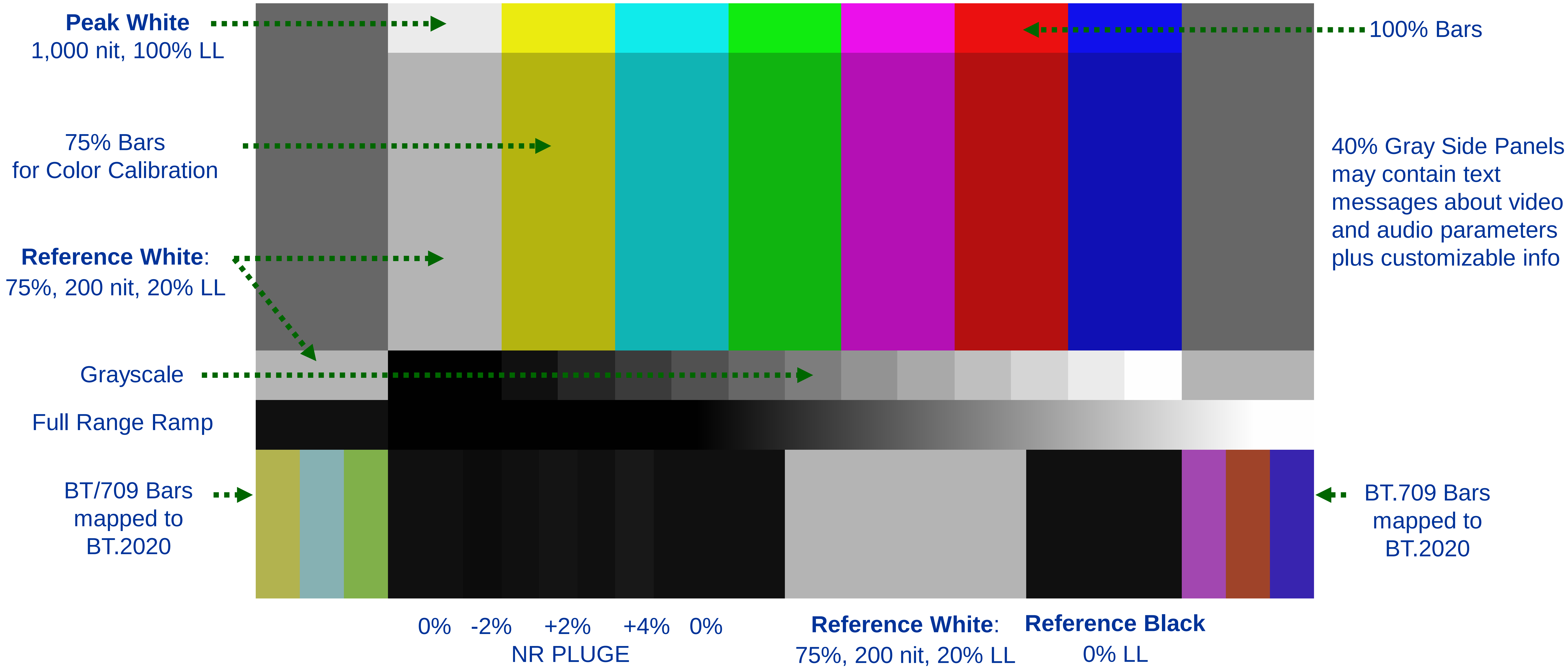
VideoQ VQCB HDR-HLG Color Bars Test (BT.2111)



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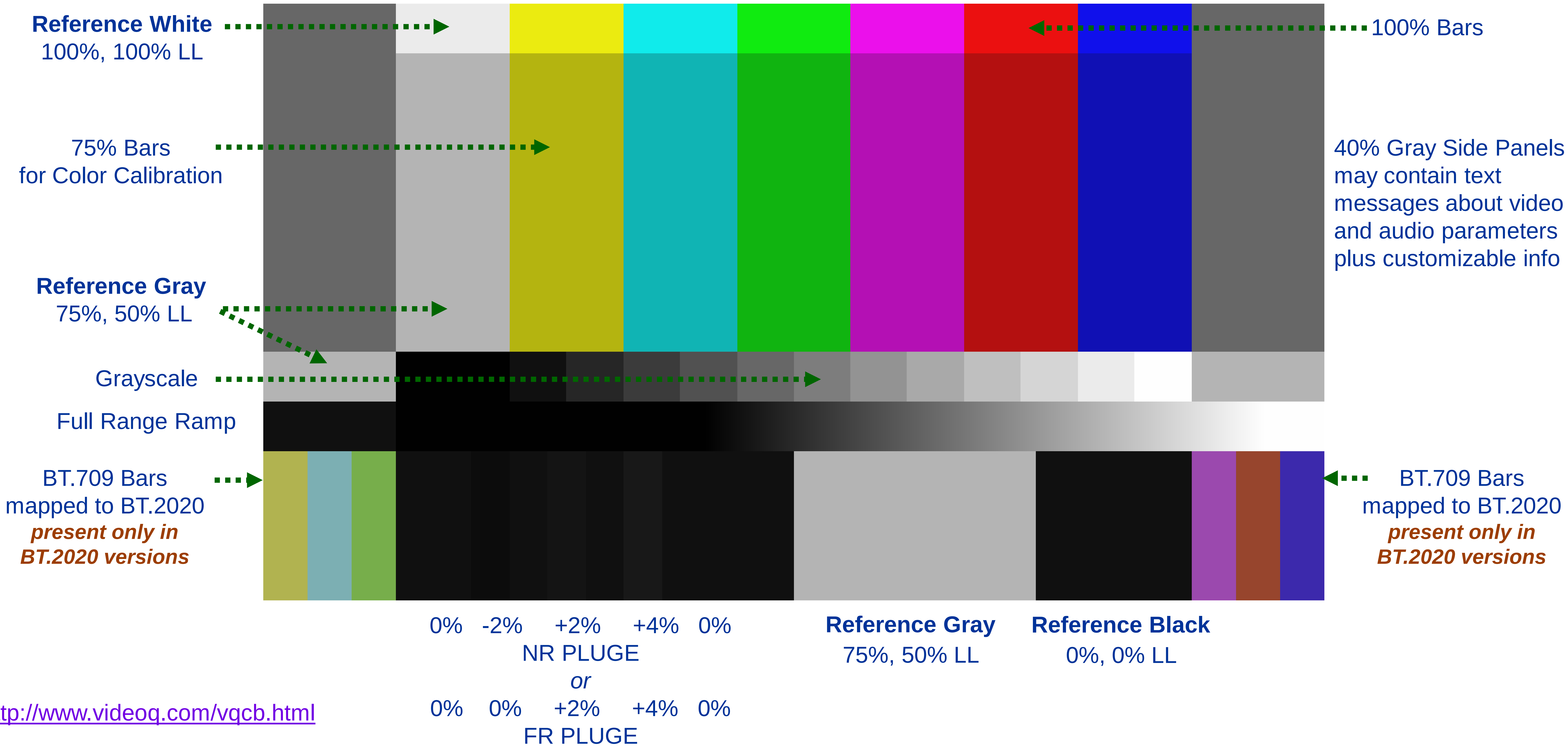
VideoQ VQCB SDR Color Bars Test (derived from BT.2111)



http://www.videoq.com/vqcb.html

6. About VideoQ

Customers & Partners

Company History

- Founded in 2005
- Formed by an Engineering Awards winning team sharing between them decades of global video technology.
- VideoQ is a renown player in calibration and benchmarking of Video Processors, Transcoders and Displays, providing tools and technologies instantly revealing artifacts, problems and deficiencies, thus raising the bar in productivity and video quality experience.
- VideoQ products and services cover all aspects of video processing and quality assurance - from visual picture quality estimation and quality control to fully automated processing, utilizing advanced VideoQ algorithms and robotic video quality analyzers, including latest UHD and HDR developments.

Operations

- Headquarters in CA, USA
- Software developers in Silicon Valley and worldwide
- Distributors and partners in several countries
- Sales & support offices in USA, UK

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For more details – see other VideoQ presentations

VideoQ HDR Technologies:	http://www.videoq.com/hdrtech.html
VideoQ Unified Reference White Proposal:	http://www.videoq.com/hdr_ref_white.html
VideoQ HDR and SDR Test Patterns:	http://www.videoq.com/vql.html
VideoQ HDR/SDR Color Bars Test Patterns Suite:	http://www.videoq.com/vqcb.html
VideoQ HDR-SDR Converter:	http://www.videoq.com/vqc.html

Thank you