Display Metrology Standardization Work

# ICDM

## International Committee for Display Metrology

### VQEG Informational Presentation

November 14, 2018

Google, Mountain View, CA

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SID

ICDM

http://www.icdm-sid.org

# ICDM

## ✦ The ICDM Display Measurement Standard (DMS)

- *Comprehensive display metrology standard*
- *Every measurement within a single book*
- *Pages: 554*
- *Chapters: 18 for measurements, 8 for appendices*
- *Appendices: Over 60*
- *451 parts to the document, with 237 measurements*
- *Over 200 contributors*
  - Over 50 authors
  - Over 60 reviewers
- *Single editor for consistency in the document*
- *Downloads: over 48,000 (as of October, 2018)*


- ICDM Web site http://www.icdm-sid.org

# ICDM Standard Top Level Table of Contents

# + 4 New Chapters for Version 2

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- 3. Setup of Display & Apparatus
- 4. Visual Assessment
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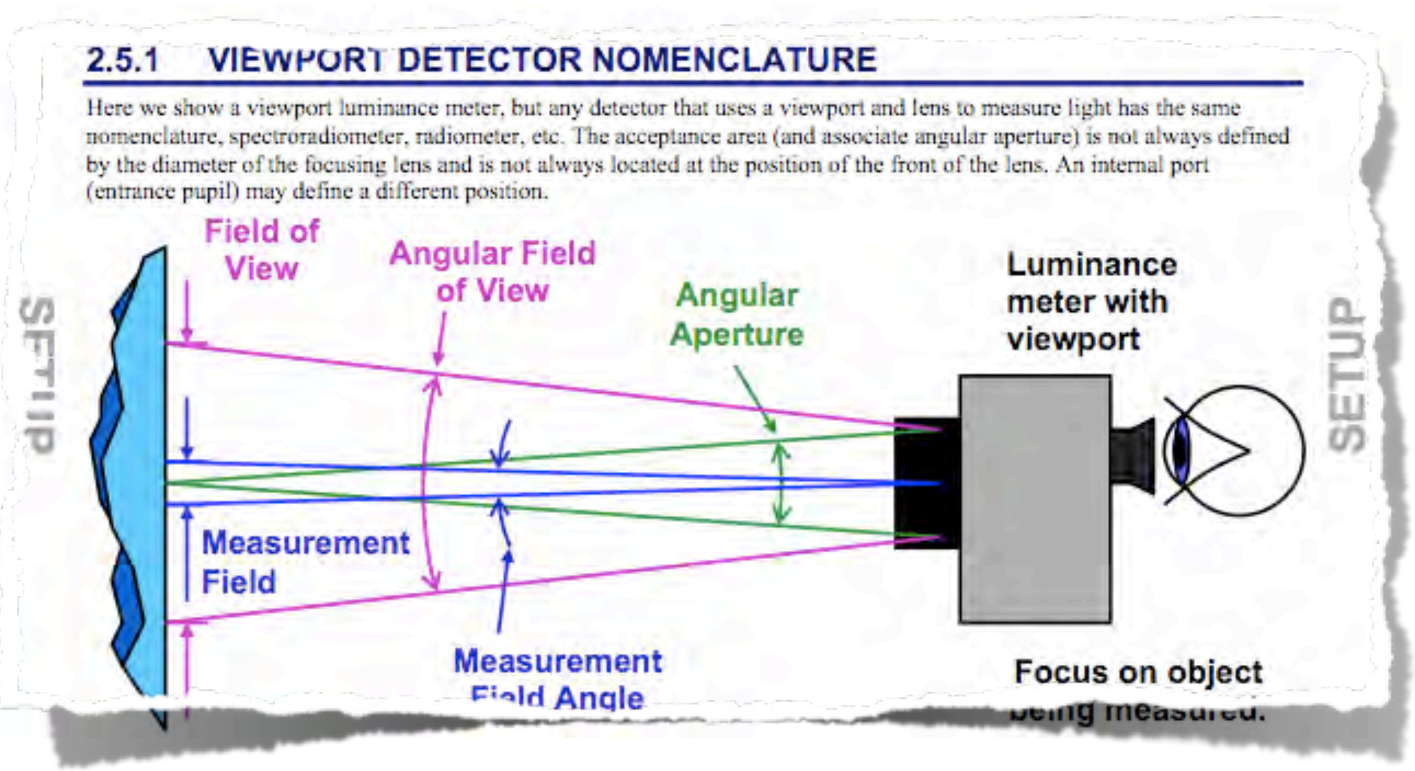
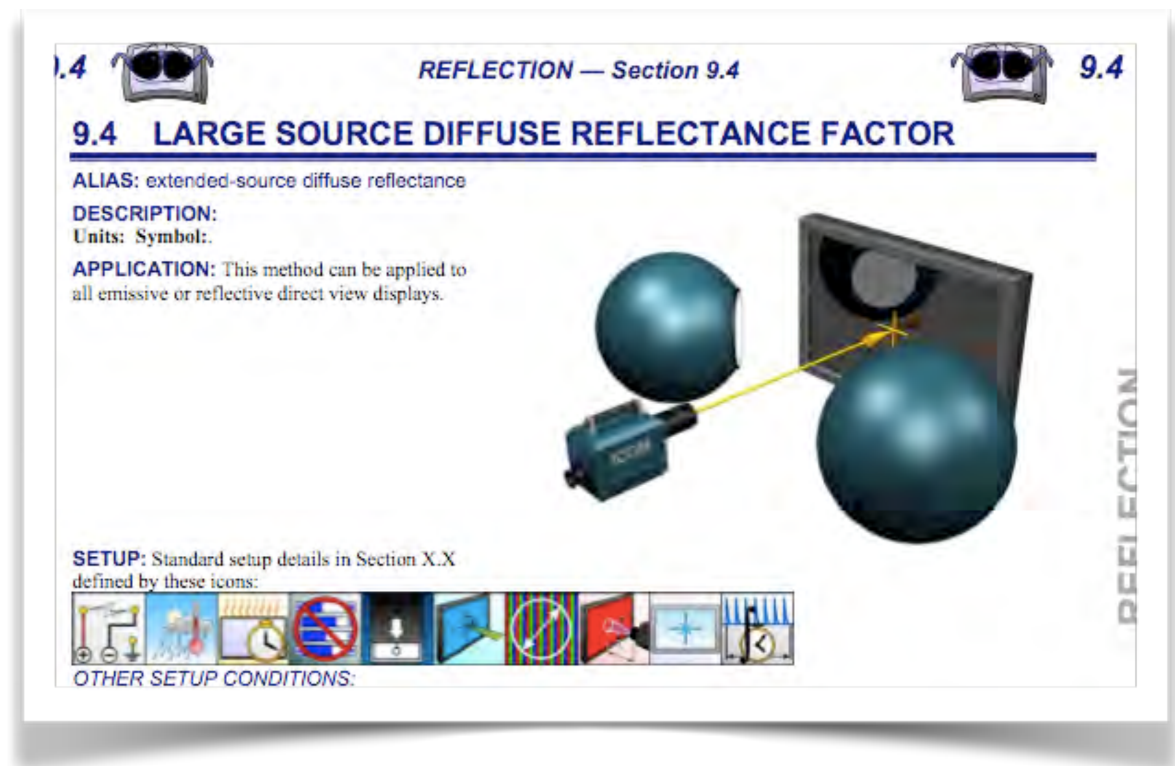
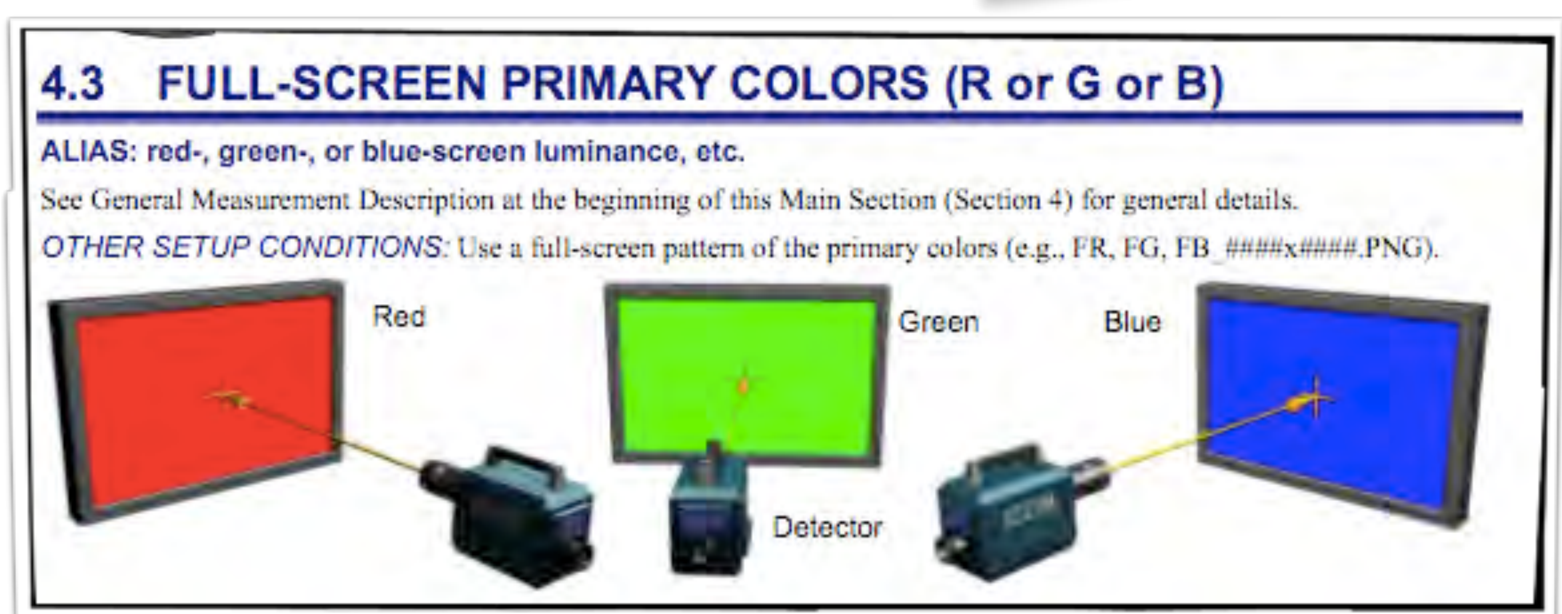
# ICDM Style

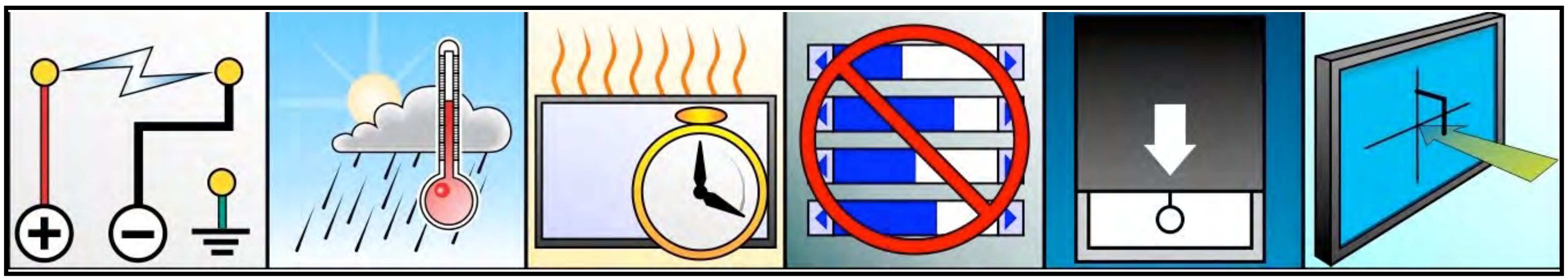
- ICDM - Clear style, extensive use of graphics — simple and clear

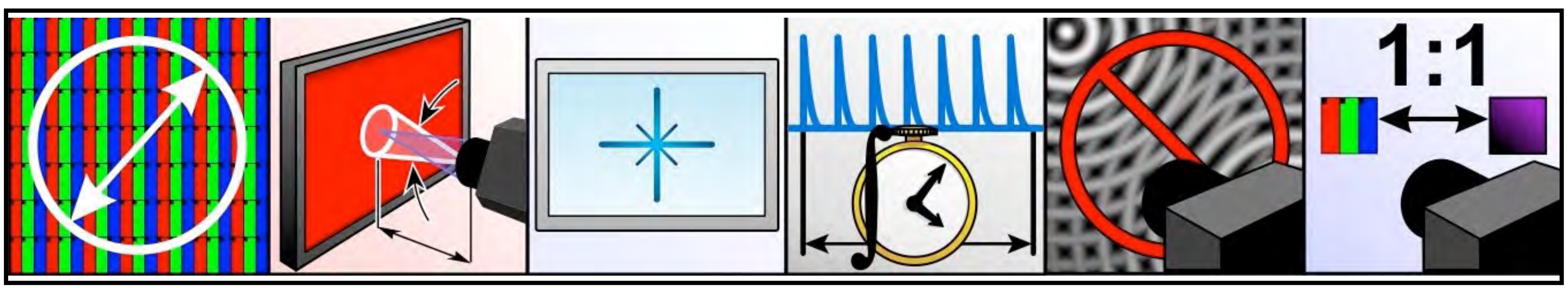


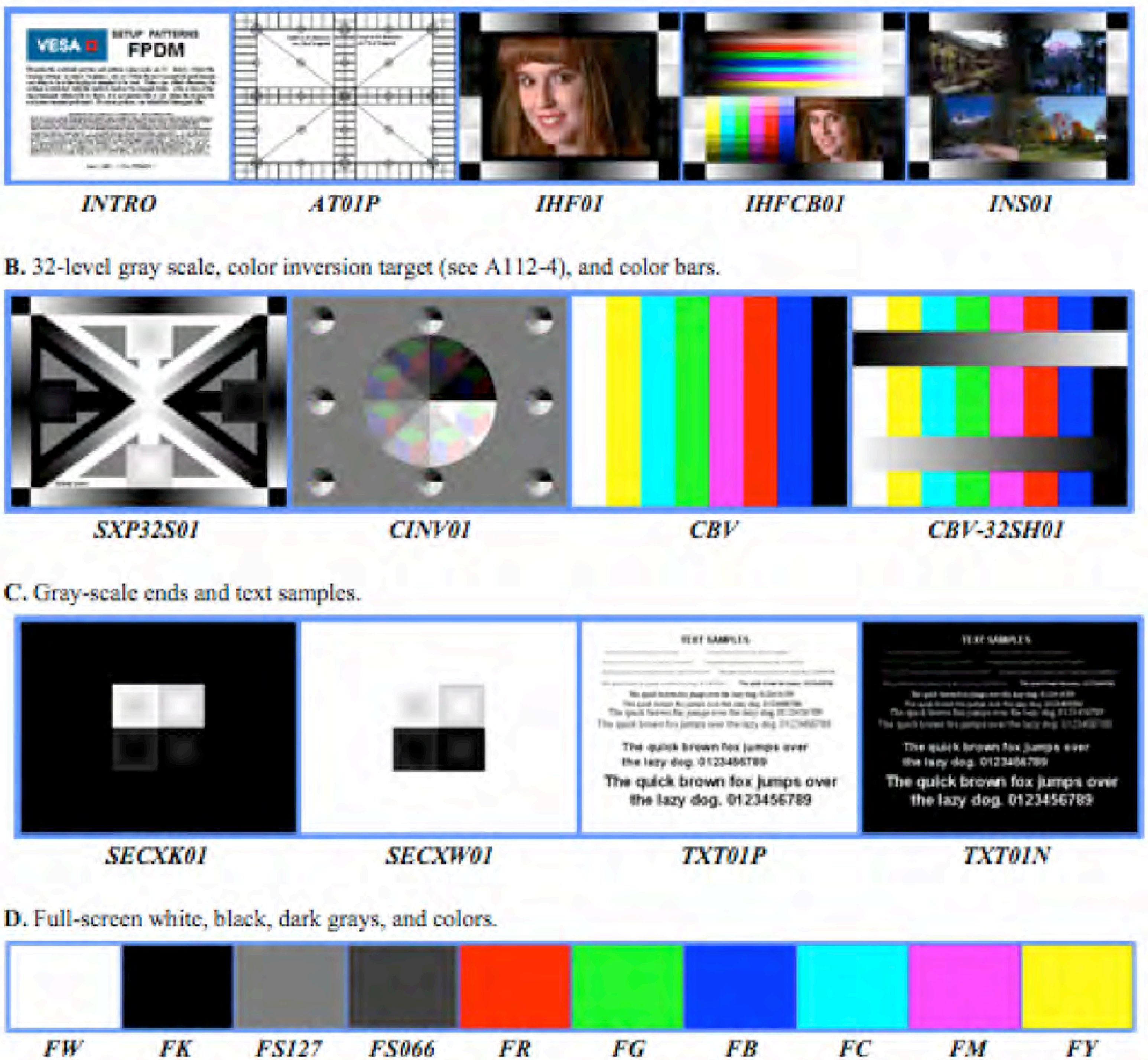



# Setup conditions via icons rather than text



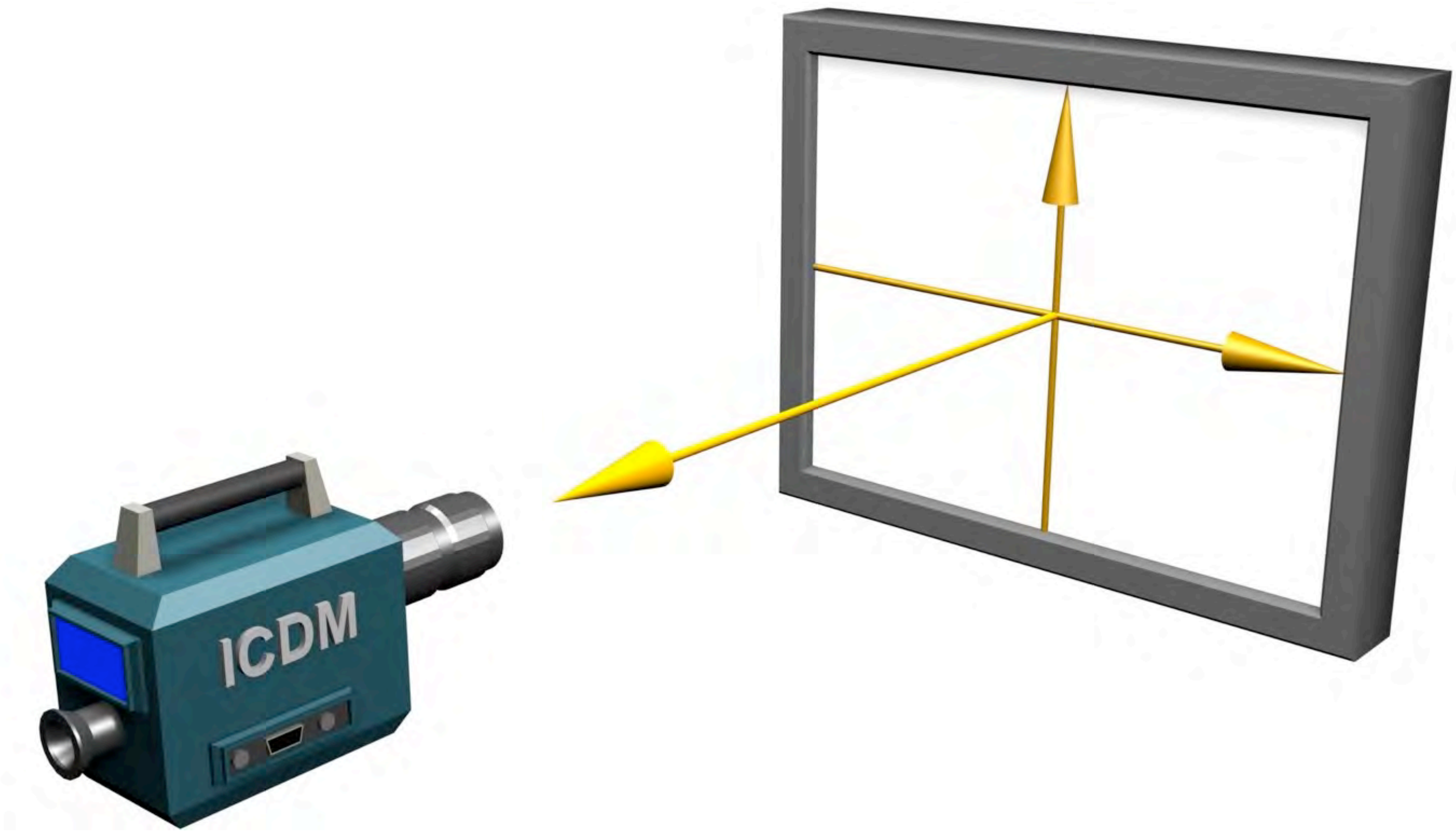


# Test Patterns for Free

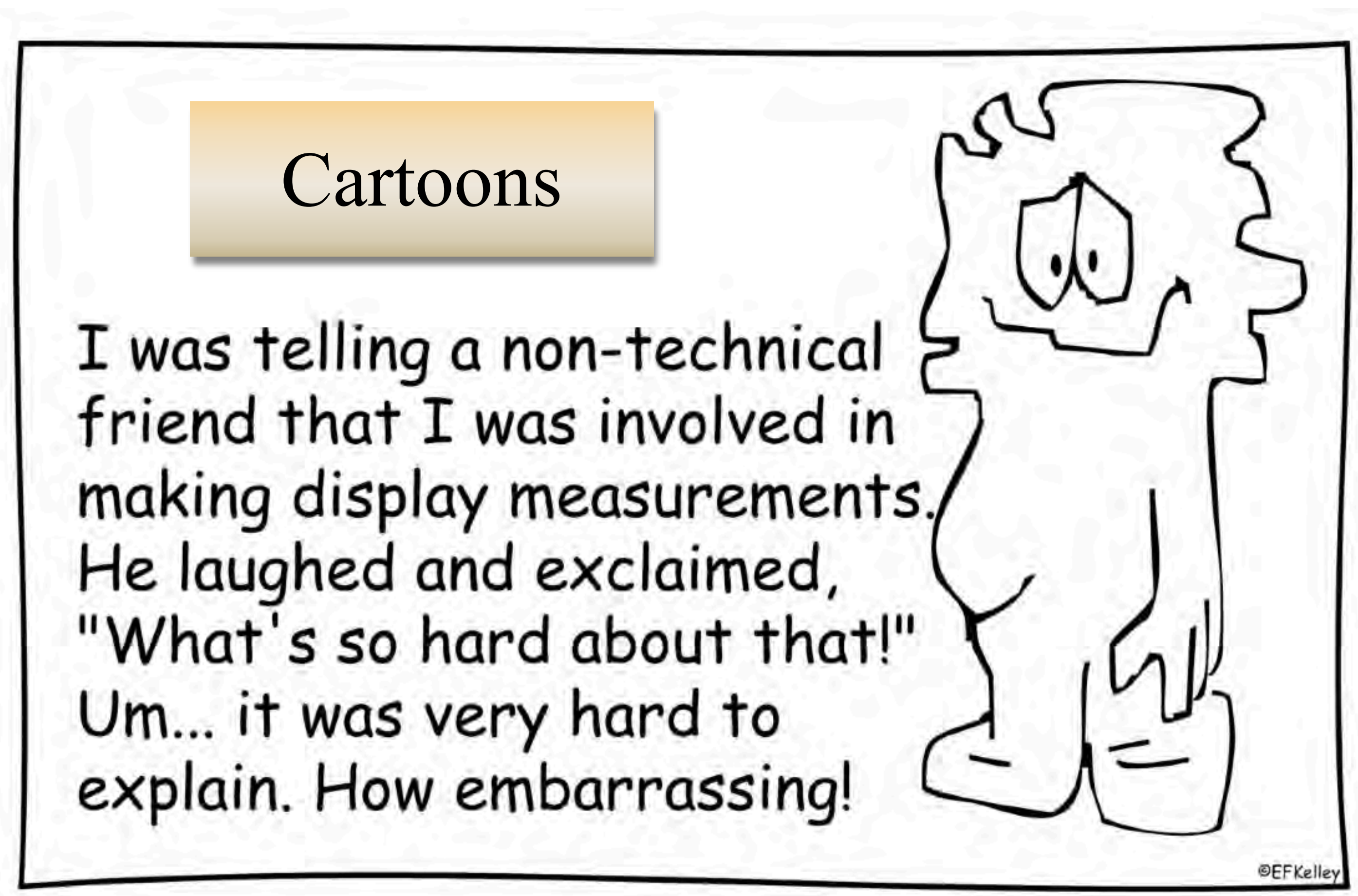



- Introduction, alignment targets, images for adjustment of controls and making measurements.

# Typical setup - LMD (Light Measurement Device)



# Cartoons for Levity


*Cartoons are done by the ICDM editor Ed Kelley*

# Templates

- Reporting templates and smart templates are planned.

**Information**

Serial Number: ______________

Resolution: ______________

Size: ______________

| Specifications | Luminance & Chrominance Uniformity | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | White | | | | | Black | |
| White | | | | | | | | |
| x: 0.283 ~ 0.343 | Point | Y (cd/m²) | *x* | *y* | CCT | du'v' | Y | CR |
| *y*: 0.299 ~ 0.359 | 1 | | | | | | | |
| Luminance | 2 | | | | | | | |
| Typ: 300 cd/m² | 3 | | | | | | | |
| Min: 250 cd/m² | 4 | | | | | | | |
| Uniformity | 5 | | | | | | | |
| Maximum = 25% | 6 | | | | | | | |
| Chromaticity | 7 | | | | | | | |
| Red | 8 | | | | | | | |
| *x*: 0.610 ~ 0.777 | 9 | | | | | | | |
| y: 0.250 ~ 0.385 | Ave | | | | | | | |
| Green | Min | | | | | | | |
| *x*: 0.1830 ~ 0.3130 | Max | | | | | | | |
| y: 0.58 ~ 0.8100 | %Unif | | | | | | | |
| Blue | %Unif = 100 x (Max -Min) / Max | | | | CR = White / Black | | | |

| Specifications | | Center of Screen Basic Measurements | | | | | |
|---|---|---|---|---|---|---|---|
| *x*: 0.0930 ~ 0.1700 | | | | | | | |
| y: 0.0400 ~ 0.1000 | | Y (cd/m2) | *x* | *y* | CCT | CR | Gamut |
| Dimming Range | White | | | | | | |
| 3:1% | Red | | | | | | |
| Contrast Ratio | Green | | | | | | |
| Typ: 1000:1 | Blue | | | | | | |
| Min: 700:1 | Black | | | | | | |
| CCT | CR = White / Black | | | | | | |
| Typ: 6500K | : Center point for uniformity | | | | | | |
| 6000K ~ 7200K | : Calculated values | | | | | | |

| GAMUT AREA DETERMINATION | | | | | | |
|---|---|---|---|---|---|---|
| ICDM spreadsheet - Reference IDMS Section 5.18 Gamut Area | | | | | | |
| **Part 1 - Ref Gamut** | *Do not modify part 1 unless you want a different reference gamut.* | | | | | |
| | Red | | Green | | Blue | |
| **sRGB Gamut** | xR | yR | xG | yG | xB | yB |
| | 0.64 | 0.33 | 0.3 | 0.6 | 0.15 | 0.06 |
| | u'R | v'R | u'G | v'G | u'B | v'B |
| | 0.4507 | 0.5229 | 0.1250 | 0.5625 | 0.1754 | 0.1579 |
| **Reference Gamut Area**: $A_r$ = | 33.238 | % of visible gamut | | | | |
| **Part 2 - Measured Gamut:** | *Enter your new values in the bordered cells below.* | | | | | |
| | Red | | Green | | Blue | |
| Enter measured *xy* values here } | xR | yR | xG | yG | xB | yB |
| | 0.7080 | 0.2920 | 0.1700 | 0.7970 | 0.1310 | 0.0460 |
| Or enter meas *u'v'* values here } | u'R | v'R | u'G | v'G | u'B | v'B |
| | 0.5566 | 0.5165 | 0.0556 | 0.5868 | 0.1593 | 0.1258 |
| **Measured Gamut Area**: A = | 57.276 | % of visible gamut | | | | |
| **Measured Gamut Area relative to the reference gamut:** | | | | | | |
| G = | 1.723 | | | | | |

*Figure 10: Example of a reporting template in planning to supplement release of ICDM2*

- Complete analysis method and math

Section 5.20: CCT WHITE-POINT VALIDATION

Determine Δ*u*'*v*' for a measured *u*'*v*' point or CCT in proximity to the Planckian Locus

$$u_{\text{locus}} = \frac{\frac{1.28641 t^2}{10^7} + \frac{1.54118 t}{10^4} + 0.860118}{\frac{7.08145 t^2}{10^7} + \frac{8.4242 t}{10^4} + 1.}$$

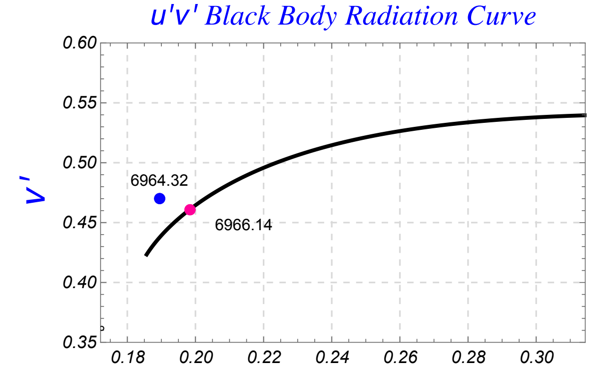
$$v_{\text{locus}} = \frac{\frac{6.30723 t^2}{10^8} + \frac{6.34209 t}{10^5} + 0.476098}{\frac{1.61456 t^2}{10^7} - \frac{2.89742 t}{10^5} + 1.}$$

$$\text{duv} = \sqrt{\left(u_{\text{locus}} - \text{ue}\right)^2 + \left(v_{\text{locus}} - \text{ve}\right)^2}$$

$$t2 = \frac{\left(146413. u_{\text{locus}} + 59239.9\right) v_{\text{locus}}^2 - 179737. u_{\text{locus}} \left(u_{\text{locus}} + 0.0149665\right) v_{\text{locus}} + 51869.9 \left(u_{\text{locus}} - 0.182722\right) u_{\text{locus}} \left(u_{\text{locus}} + 0.579256\right) - 926}{\left(0.5574 u_{\text{locus}} - 3.4864 v_{\text{locus}} + 1.1148\right)^3}$$

| White Point Δu'v' Analysis | | |
|---|---|---|
| Item | Measurement | Value |
| u' (Measured) | 0.1894 | – |
| u' (Measured) | 0.47 | – |
| Item | Calculations | Value |
| CCT (Measurement) | 6964.32 | K |
| $u_{\text{locus}}$ | 0.198305 | – |
| $v_{\text{locus}}$ | 0.46087 | – |
| CCT (locus) | 6966.14 | K |
| Δu'v' | 0.0127539 | – |

*u'v' Black Body Radiation Curve*



# ICDM Members from Many Fields

- Display Metrology organization of hundreds of display evaluation and related specialists in the field
  - Display Metrologists
  - Engineers
    - Display
    - Electrical
    - Mechanical
  - University Professors
  - Color scientists and specialists
  - Human Vision Scientists
  - Psychologists
  - Physicists
  - Chemists

# Basic Philosophy

- ICDM does not say what is good or bad, or what passes or fails
  - We leave that to other organizations like VQEG or ISO
- ICDM does not specify thresholds or limits of acceptance
  - With a few rare exceptions
- Rather, ICDM says how to evaluate the performance of a display

# ICDM Display Metrology Standard, version 2 now in progress

**The ICDM Standard was released June 1, 2012**

- IDMS Release version 1.03a
- **Free PDF download**
  - [*www.icdm-sid.org*](http://www.icdm-sid.org)

**Now work is ongoing for ICDM Standard version 2.**

- ICDM2
- Release date 2018 or 2019



Downloaded over 48,000 times, likely the most widely used display metrology standard yet produced.

# ICDM Membership

- https://www.icdm-sid.org
- ICDM Welcomes those involved with display evaluation as members — Free
  - Two options
  - -1- Active membership list,
    - Receive all main email
    - Participate at any level when the subject matter and your schedule allow.
  - -2- Interest membership list,
    - Receive only periodic updates and summary of ICDM activities
    - Lower expectation of participation
    - Watch what is going on in the ICDM
- ICDM membership allows membership also in any workgroups or subcommittees.

# Workgroups of the ICDM

| ICDM Workgroups and Chairs, as of July 8, 2018 | | | | |
|---|---|---|---|---|
| **Workgroup** | **Title** | **Short** | **Members** | **Workgroup Chair** |
| 1 | Specification Reform | wg1 | 28 | Joe Miseli<br>Chris Chinnock, Co-Chair |
| 2 | JNDs | wg2-jnd | 8 | Andrew Watson |
| 3 | HDR (Chapter 20) | wg3-hdr | 69 | Joe Miseli |
| 4 | File Formats | wg4-formats | 17 | Thierry Leroux |
| 5 | Color Volume | wg5-colorvol | 46 | Karl Lang<br>Johan Bergquist, Secretary |
| 6 | Glossary / Terminology | wg6-terms | 21 | Candice Elliott |
| 7 | Video Test Patterns | wg7-vidpatts | 12 | Florian Friedrich |
| **Workgroup Interest/Observer List** | | | | |
| 3a | HDR Interest/Observer list | wg3-interest | 21 | Joe Miseli |

# Subcommittees of the ICDM

## ICDM Subcommittees and Chairs, as of July 8, 2018

| Ver2 | Chapter Title | Members | Subcommittee Chair |
|---|---|---|---|
| 1 | Introduction | -- | Ed Kelley (Chair by default) |
| 2 | Templates, Composite Metrics, & Suites | -- | Ed Kelley (Chair by default) |
| 3 | Set of Displays & Apparatus | -- | Ed Kelley (Chair by default) |
| 4 | Visual Assessment | -- | Joe Miseli (Chair by default) |
| 5 | Fundamental Measurements | 24 | Ed Kelley |
| 6 | Gray- & Color-Scale Measurements | -- | Don Gyou Lee |
| 7 | Spatial Measurements | 62 | Ed Kelley |
| 8 | Uniformity Measurements | -- | Jens Jensen |
| 9 | Viewing Angle-Measurements | -- | Thierry Leroux |
| 10 | Temporal Measurements | 29 | Mike Wilson |
| 11 | Reflection and Transmission Measurements | 21 | John Penczek |
| 12 | Motion Artifacts | -- | Andrew Watson |
| 13 | Physical & Mechanical Measurements | -- | Joe Miseli (Chair by default) |
| 14 | Electrical Measurements | -- | Joe Miseli (Chair by default) |
| 15 | Front Projector Measurements | -- | Karl Lang |
| 16 | Front Projector Screen Measurements | -- | Joe Kane |
| 17 | 3D & Stereoscopic Displays | -- | Adi Abileah |
| 18 | Touch Screens and Surface Displays | -- | -Open- |
| 19 | VR/AR/HUDs/Near-Eye-display | 27 | Tom Lianza |
| 20 | HDR (See Workgroup 3 below) | 69 | Joe Miseli |
| 21 | Automotive Displays | 34 | Michael Becker |
| 22 | Medical Imaging Displays | 15 | Paul Bo Zhang |
| 23 | Color Metrology | 45 | Kenichiro Masaoka<br>Kyung-Jin Kang,Co-Chair |
| -- | Appendices | -- | Ed Kelley (Chair by default) |

# Chapter 4 - Visual Assessment



## 4. VISUAL ASSESSMENT

Especially during warm up of the display it is a good time to visually inspect its performance. Here are a few ways that its quality can be assessed visually. A variety of patterns are employed to make these assessments. Although the ICDM supplies patterns in different formats for these and other purposes, companies make software that will provide such patterns to perform this kind of assessment, where the software tailors the pattern to the display by reading its pixel array electronically.

During the 20-minute warm up period (or whatever period is required for warm-up) certain subjective observations can be made. Also, any controls on the DUT can be set to provide the best images or patterns commensurate with the use of the display and its task setting (consistent with the manufacturer's specifications, if they cist or apply)—see the previous chapter on setup of the display.

The sections on subjective evaluations allows for a visual check to determine the presence of certain display conditions or anomalies and give guidelines to help determine the level of seriousness of problems. With the exception of the Saturated Colors (§ 4.1), presence of any of these conditions is usually undesirable and degrades the quality of displayed video or the appearance of the display. Some displays will have some of these characteristics, and some will not.

All of the tests are made by human visual observation with no measurement equipment, unless specifically stated within a test. There may be visual enhancement aids, such as magnifiers or optical filters, which can assist the evaluations. It is important to note that visual testing infers looking for visual problems which may or may not be present rather than measuring performance as is done for the regular testing sections of this standard. Saturated Colors (§ 4.1) is the exception. For color displays, the colors are expected to be present. Absence of the colors or video artifacts on the way the colors are displayed would suggest a serious problem. It is recognized that subjective evaluations depend upon the observer. For example, some people exhibit a much greater sensitivity to flicker than others. These evaluations are intended to flag the most obvious problems.

Should any of the tests of this section not be completed during the warm-up interval, they may be tested at any time thereafter. It is assumed all tests in this section are immune to warm up time, and that the order of the tests is during warm up is not a factor. Should any of these tests be deemed to dependent upon warm up time, they should be conducted after proper warm up time has been achieved.

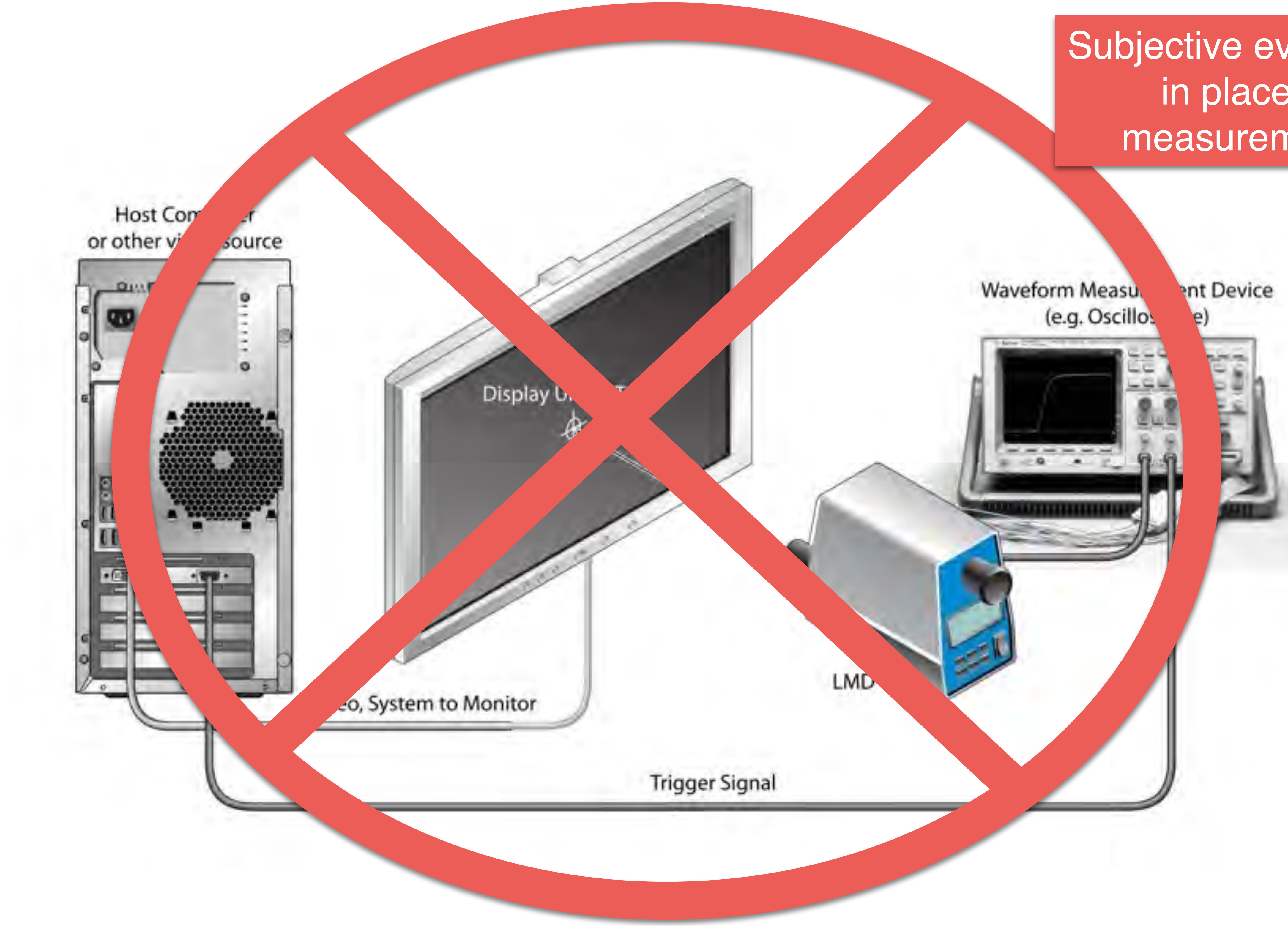

VISUAL ASSESSMENT

# Chapter 4 - Visual Assessment

- An opportunity for standardizing subjective display evaluation methods.
- Version 2 of the ICDM standard is in development.
- Chapter 4 - Visual Assessment
  - Does not require instrumentation for display evaluation.
  - It is for evaluation of displays by subjective methods.
  - Any way to evaluate a display without making measurements with light measurement equipment could be part of that chapter in the standard.

# Chapter 4 - Visual Assessment

Subjective evaluation in place of measurements



# Chapter 4 - Visual Assessment

VISUAL ASSESSMENT

## 4.1 SATURATED COLORS

Use the color bar pattern to determine the presence of all saturated and primary colors. No measurements are made, so only the presence of the colors is observed, not an assessment of how well the colors are reproduced. The full-screen color bar pattern is intended for visual assessment of the general color performance of a display. All colors are saturated to enable minimum difficulty in visually assessing presence of color and relative saturation as per an adequate color gamut. The full-screen color gamut is measured in § 5.1.4.

The full-screen color bar pattern (Fig. 1) is a sequence of vertical bars that show the three saturated primary colors, three secondary, black, and white. The color order (from left to right) is white, yellow, cyan, green, magenta, red, blue, and black—this assumes an RGB color scheme. Their order represents video content luminance from maximum on the left, to minimum, on the right. Their heights are full screen with widths of 1/8 of the total horizontal video size.

**Use of Color Bars:** There are a number of uses for which the color bar pattern will serve to check:

- the saturated-color (full gamut) and black-and-white performance of the DUT
- to assure all primary and secondary colors are displayed
- to assure all colors are in the correct order
- of proper signal path arrangement, including wiring and cabling
- the color purity, saturation, and hue
- the spatial color separation
- of signal path performance for adequate color response capability
- to assure that all saturated colors can be displayed without overlap or other spatial degradation
- to assure all colors are distinct from each other
- to assure there are no color dependencies or characteristics of the DUT that vary from one color to another.


***Fig. 1.*** *Color bar pattern from RGB primaries.*

**Reporting:** Report in the comments sections of the reporting templates any problems with the appearance of normally displayed color bars, such as missing colors, wrong colors, problems at the transition points between colors, or color artifacts, etc.

## 4.2 COSMETIC DEFECTS

While displaying alternately a white and black full screen, inspect the DUT for cosmetic defects. These are imperfections of the display surface or its packaging that are visible on the external surface that detract from the display's value such as the following examples (not a complete or required list):

- cuts
- dents
- smears
- gouges
- scratches
- bubbles
- pullouts
- cracks
- bumps
- misalignment of parts
- stains on components
- other …

Report description of any unacceptable cosmetic defects on the reporting sheet in the comment section along with any other appropriate information such as position, type of defect, size, and shape. Note: This section does not include pixel defects that are handled separately in § 4.4 nor does it include mura (nonuniformities on the display surface) dealt with in § 4.3.

VISUAL ASSESSMENT

# Chapter 4 - Visual Assessment

## 4.7 ALTERNATING PIXEL CHECKERBOARD

Display an alternating-pixel checkerboard pattern and look for clarity of black and white individual pixels. If the black pixels are gray or the white pixels are noticeably gray or both, it could indicate problems in some of the circuits or the generating signal. Report any inadequacies in the Comments Section of the reporting form.

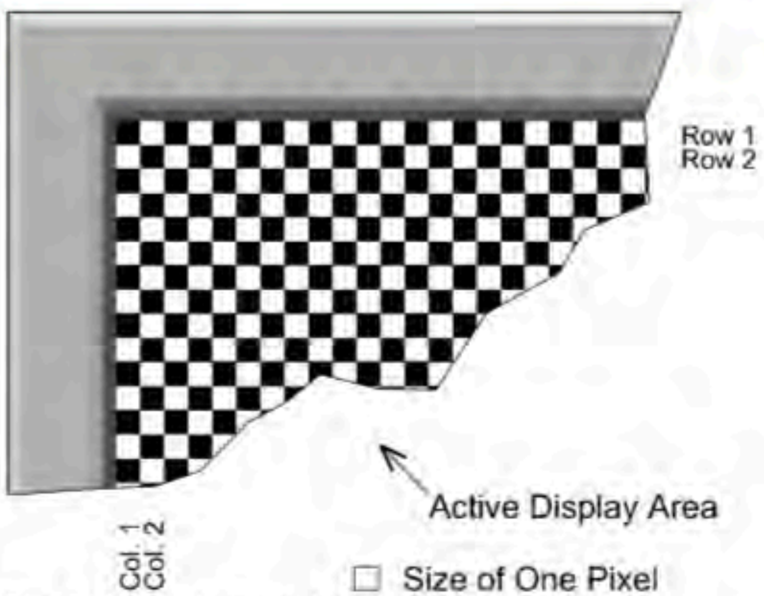


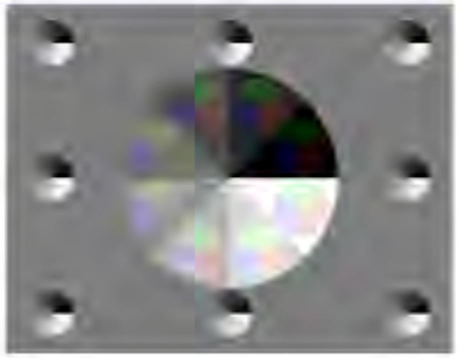
**Fig. 1.** Alternating pixel pattern.

**DISCUSSION:** An alternating pixel pattern is a series of on-off-on-off... pixels (e.g. white-black-white-black...) where each successive row is the inverse of the row above it. Such a pattern is the same as a checkerboard pattern in which the size of the checkers is reduced to one pixel. A compliment or inverse alternating pixel display may also be used whereby the two patterns can be compared.

Alternating pixel patterns produces the highest frequency video (equal to ½ the pixel clock rate), and pixel clarity on the DUT is representative of the display's ability to reproduce the highest frequency video signal. Such a pattern tests the DUT sensitivity to rise/fall times and frequency capabilities of the video system (generated video and transmission path). Some find that this pattern also enables them to check for pixel defects as well; any pixel which is continually fixed at a certain luminance level or color will often stand out better when observed surrounded by all black or white pixels.

## 4.9 COLOR & GRAYSCALE INVERSION

The pattern CINV01 is designed to reveal both color and gray-scale inversions and both color inversions, rotations, and confluences. See the appendix, § A12 Color and Gray-Scale Inversion Target. It is available on a DVD-ROM (if supplied in the printed version) or at http://www.icdm-sid.org/downloads.



## Example of new Subjective Test methods to be in chapter 4 of version 2 of the ICDM standard

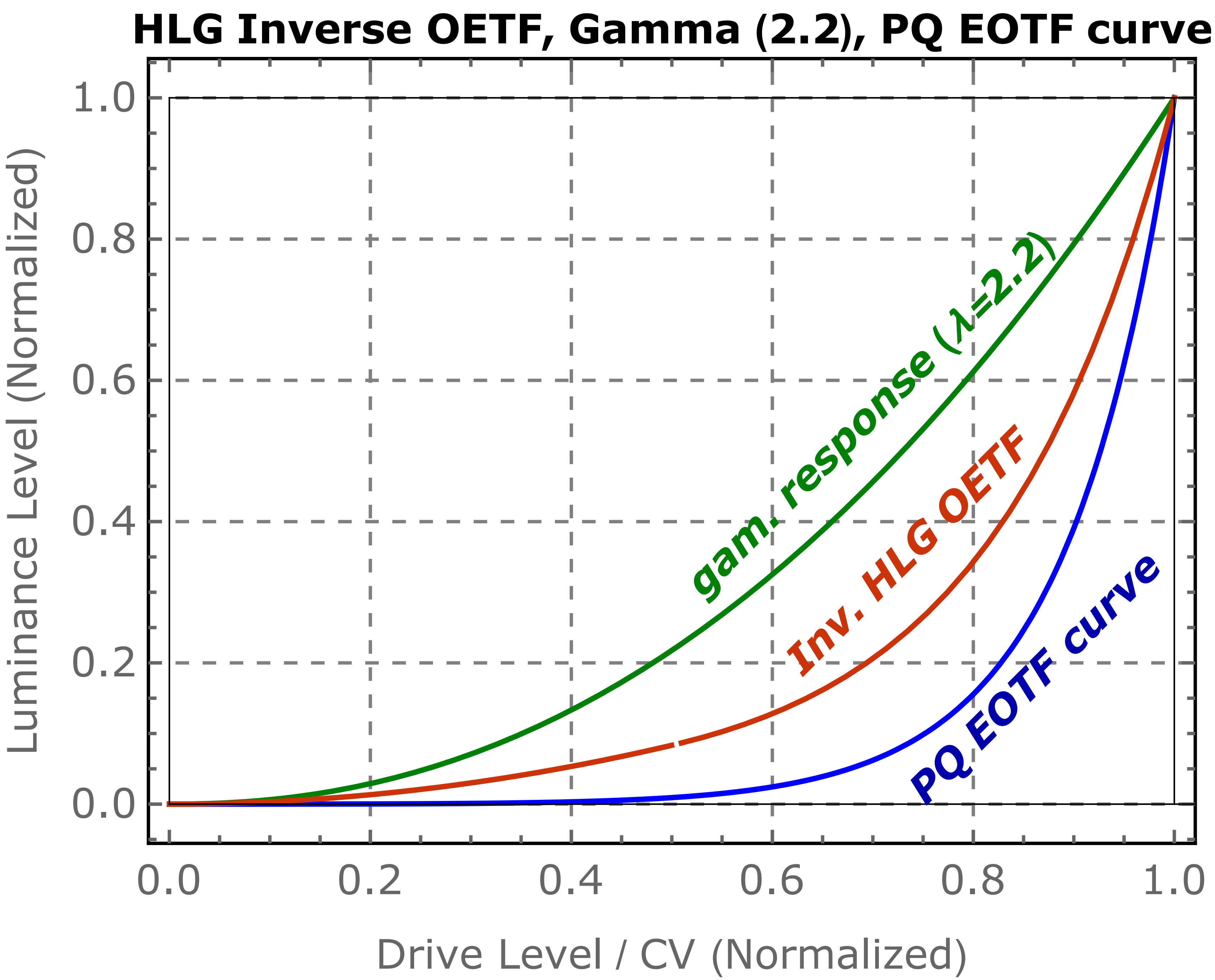
# HDR

High Dynamic Range

HDR Displays — Changing the way the world is seen

# Transfer Characteristics of HDR Displays

## HDR for displays is controlled EOTFs to replace gamma curves




HDR: PQ (Perceptual Quantizer) EOTF Based on SMPTE ST 2084:2014, shown in blue

More bit depth in the dark regions, where the eye is more sensitive.

HDR HLG (Hybrid Log Gamma) EOTF based on BBC & NHK / ARIB STD-B67 and ITU BT.2100, shown in red

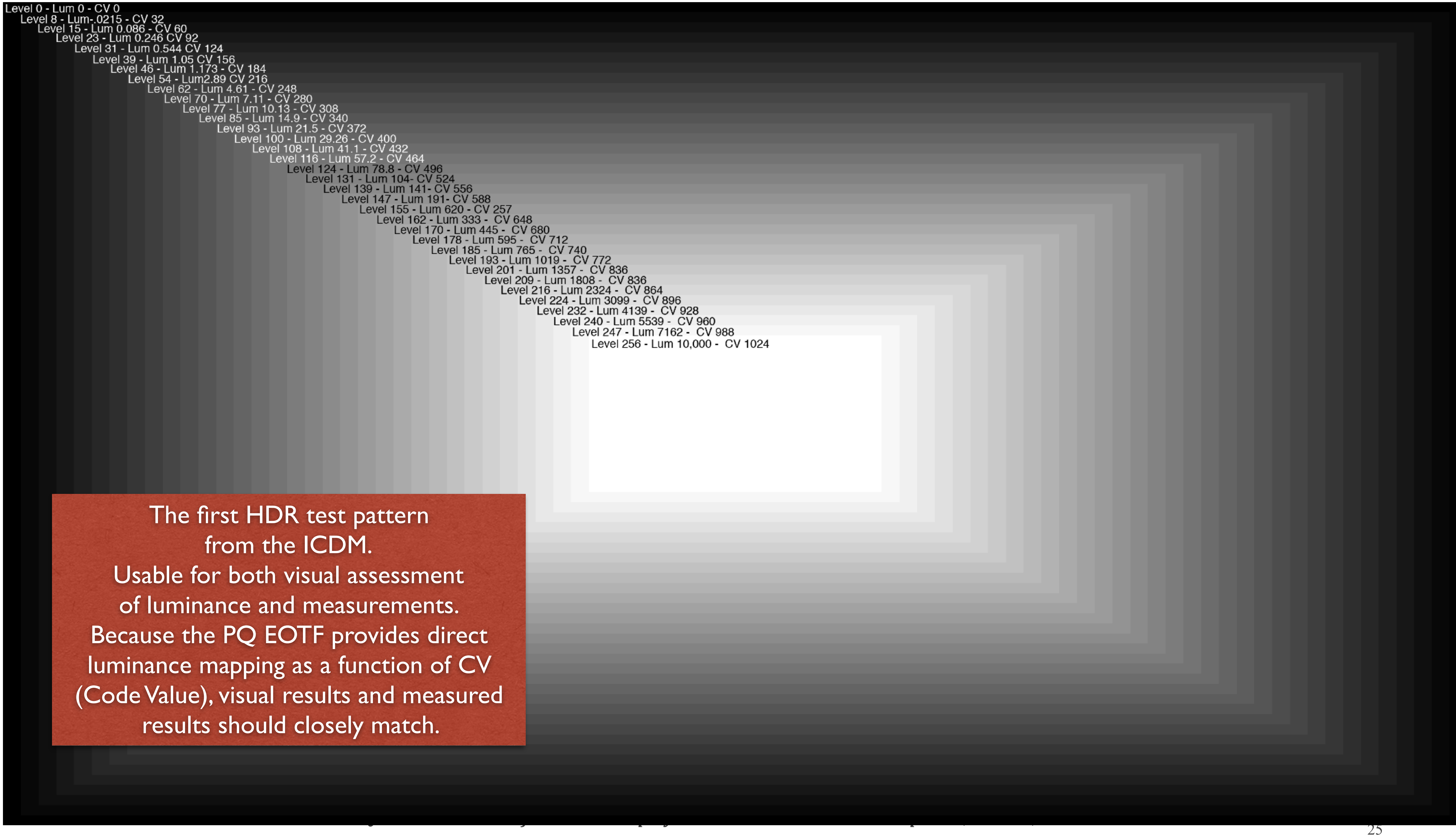
Traditional gamma curve found in CRTs up to non-HDR (or SDR) displays today, shown in green.

Joe Miseli
JVM Research

# EOTF HDR Test patterns

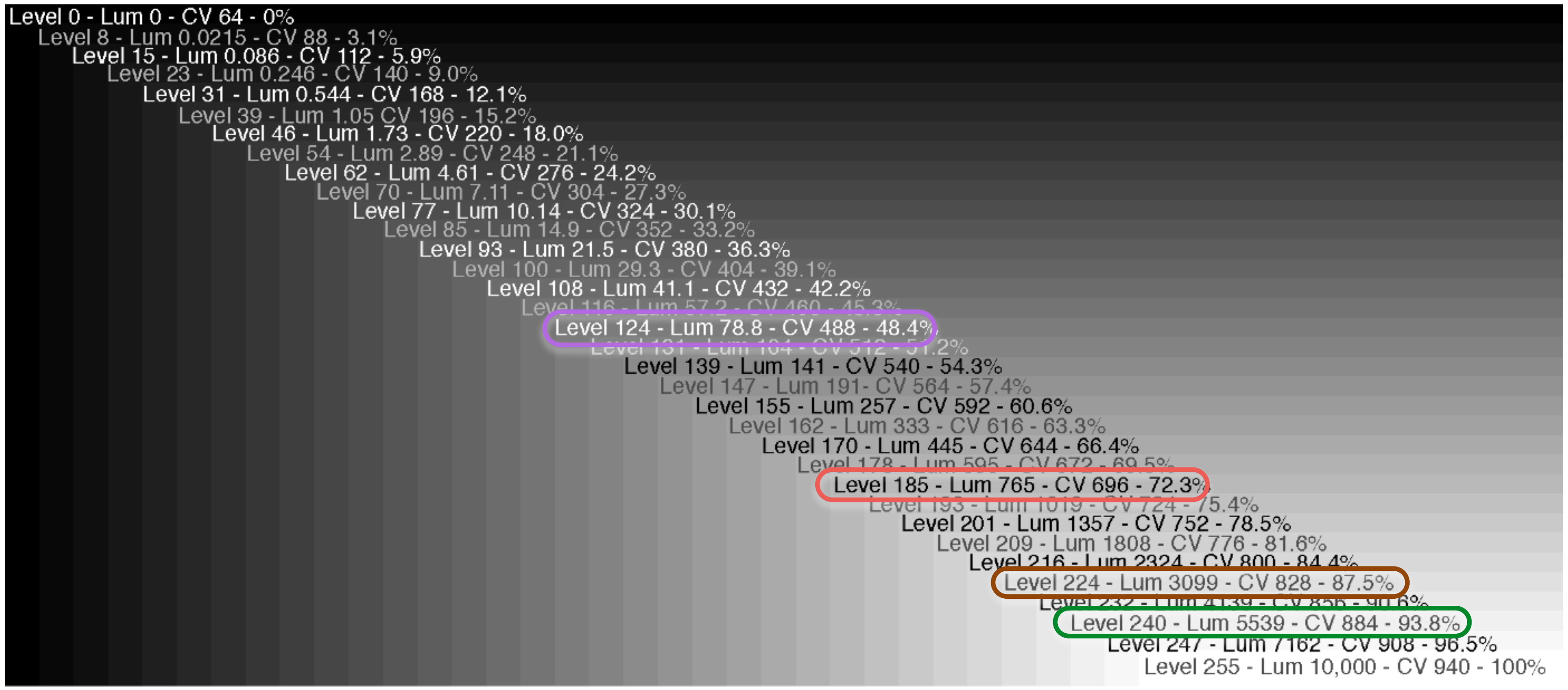
- All HDR test patterns from the ICDM are videos
  - Often sequences of test images, but encoded properly with HDR metadata
  - With audio to help identify the expectations of the content and otherwise clarify the task being done
  - Most is for measurement with LMDs
  - But for chapter 4, they are primarily intended for visual assessment
  - One example follows

# EOTF HDR Test pattern




The first HDR test pattern from the ICDM. Usable for both visual assessment of luminance and measurements. Because the PQ EOTF provides direct luminance mapping as a function of CV (Code Value), visual results and measured results should closely match.

# Absolute values via the EOTF curve

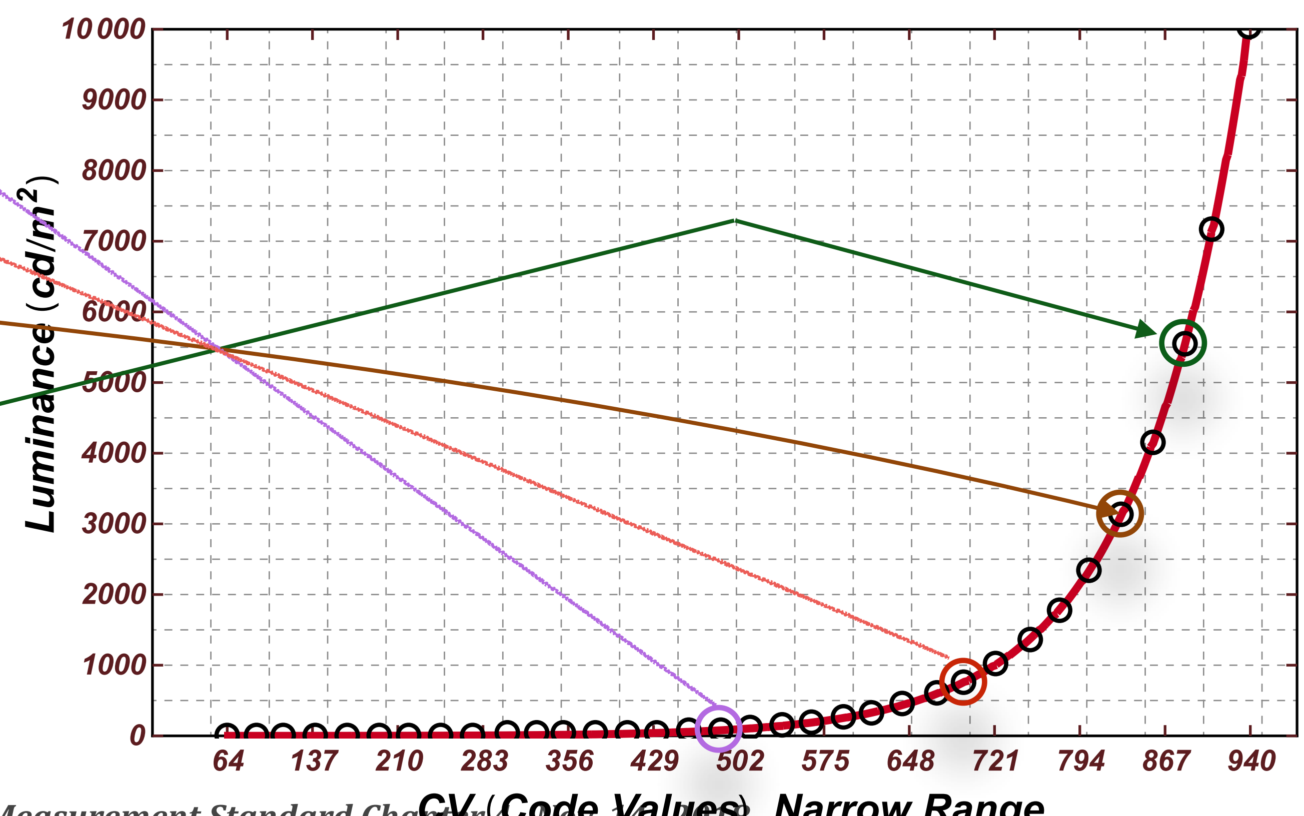



Level 124 - Lum 78.8 - CV 488 - 48.4%

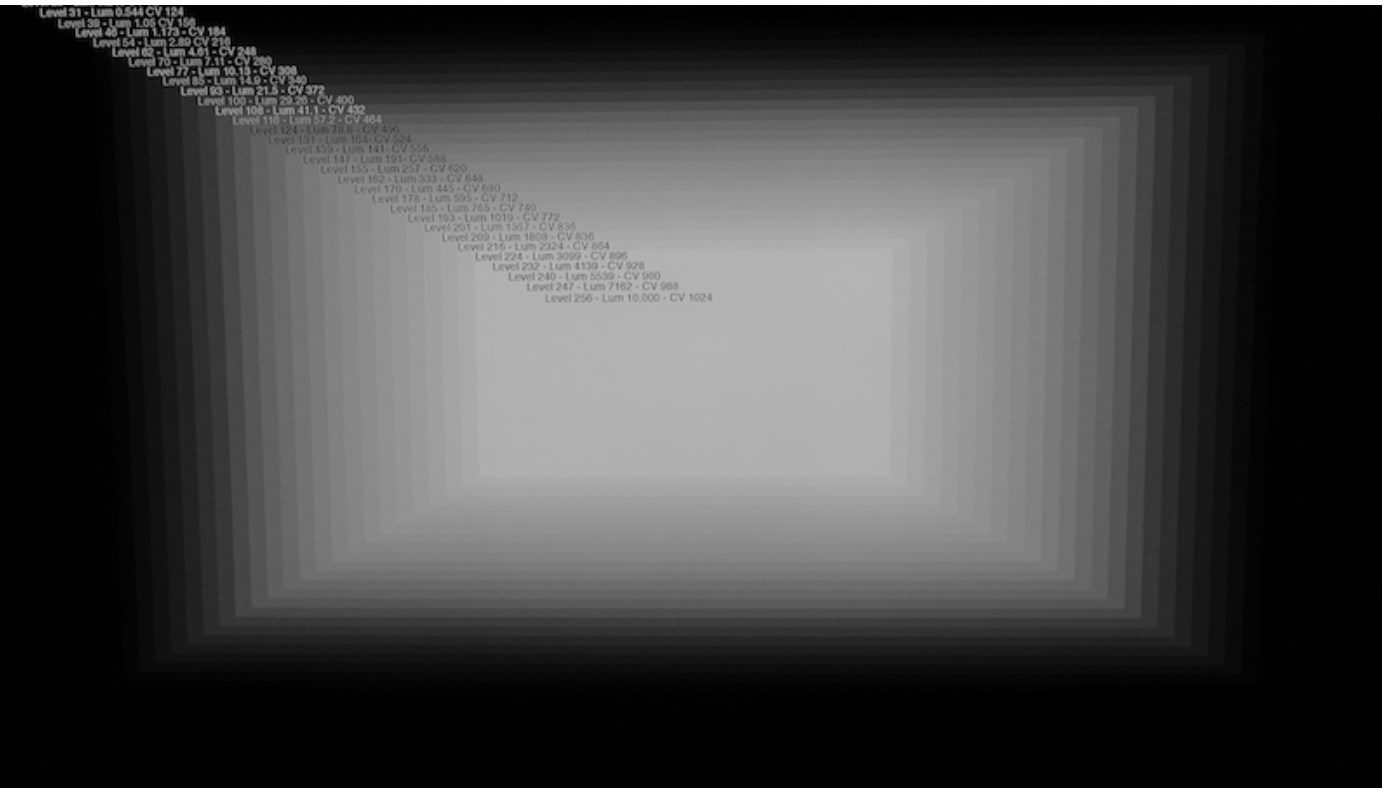
Level 185 - Lum 765 - CV 696 - 72.3%

Level 224 - Lum 3099 - CV 828 - 87.5%

Level 240 - Lum 5539 - CV 884 - 93.8%



# EOTF HDR Test pattern in test

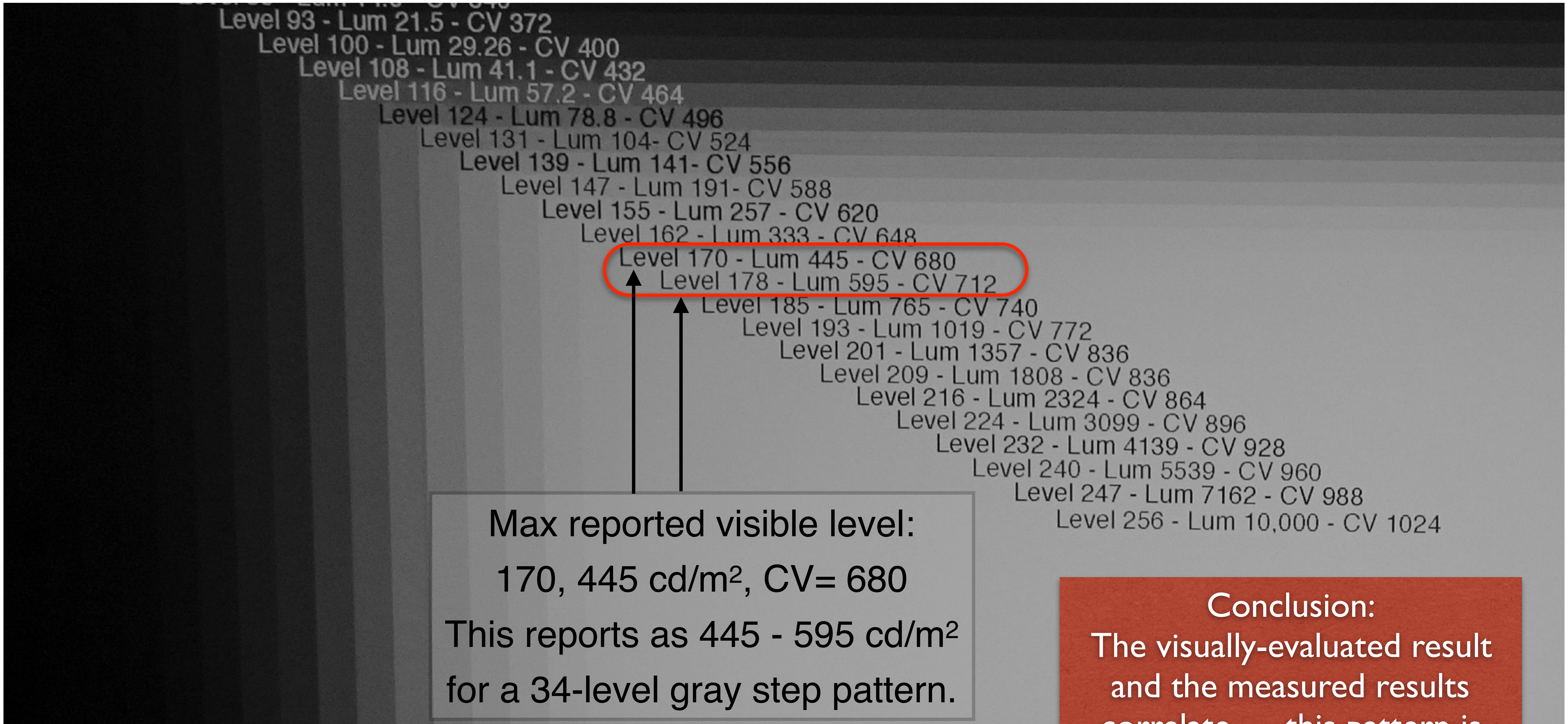




34-level pattern photo in non HDR mode

34-level pattern photo in HDR mode

# Absolute values via the EOTF curve



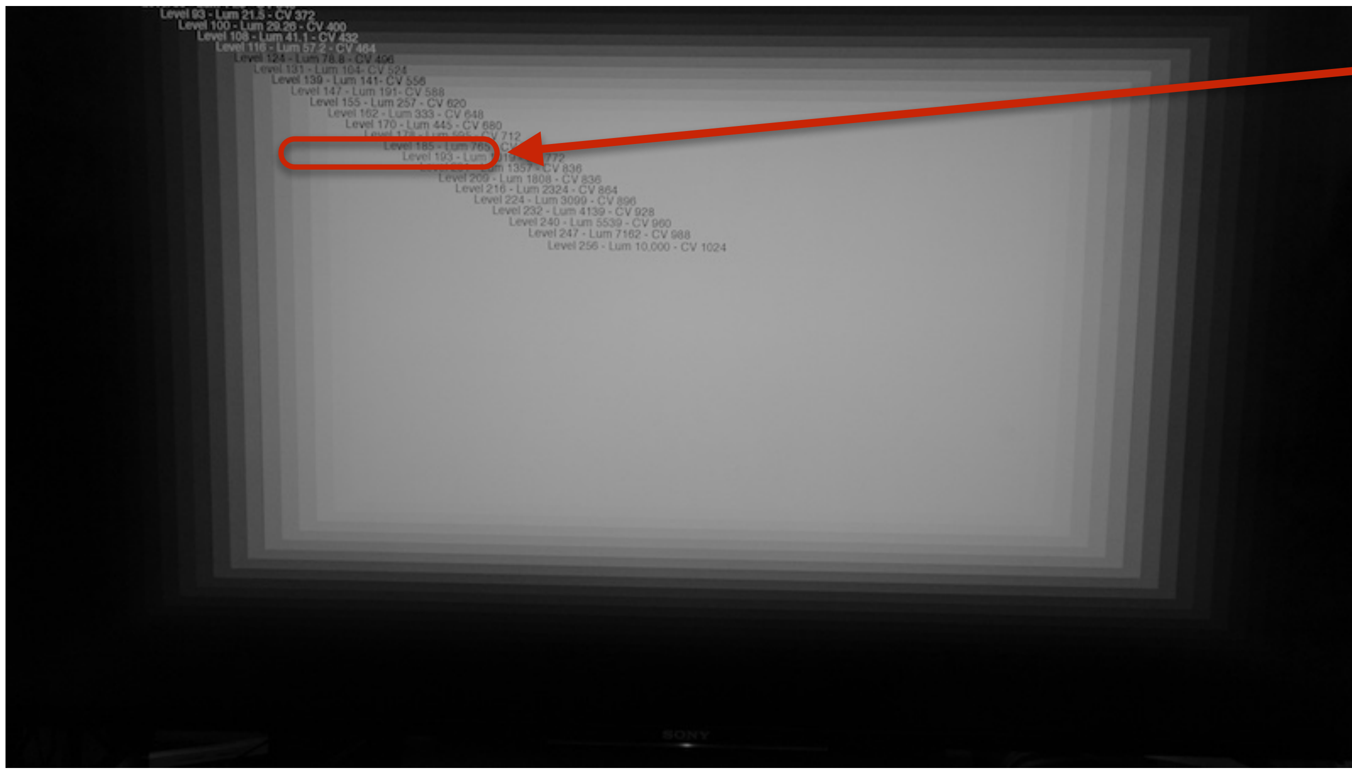

Max reported visible level:
170, 445 cd/m², CV= 680
This reports as 445 - 595 cd/m²
for a 34-level gray step pattern.

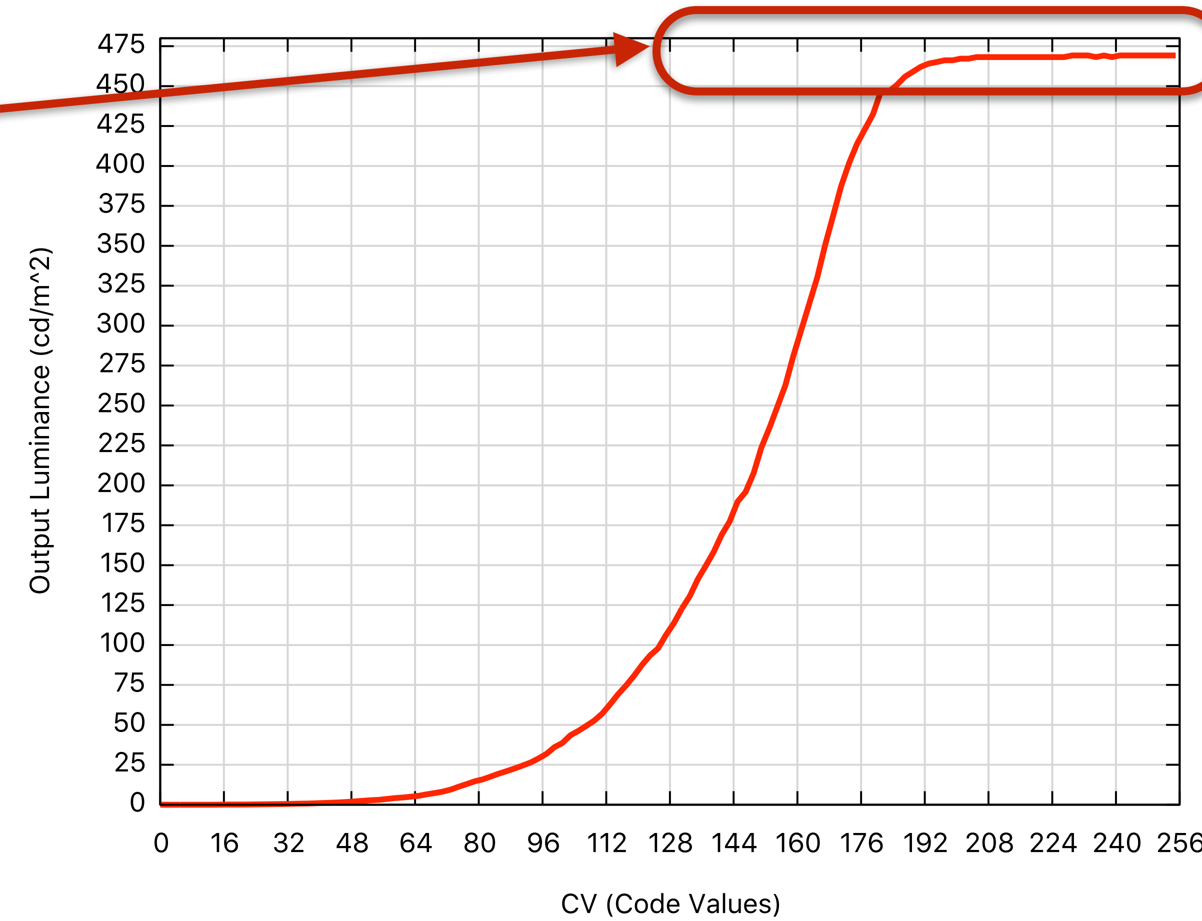
Actual measured level
471.3 cd/m²

Conclusion:
The visually-evaluated result and the measured results correlate — this pattern is suitable for both visual and measured analysis for HDR displays.

The EOTF curve defines the maximum luminance mapping of the display when running in HDR mode. The maximum level is sometimes called the clipping level.

# EOTF HDR Test pattern in test






**34-level pattern photo in HDR mode**

**34-level pattern photo EOTF plot**

The 34-band gray scale pattern matches the plotted EOTF curve maximum luminance mapping of the display when running in HDR mode.

# Summary - Chapter 4 - Visual Assessment

- An opportunity for standardizing subjective display evaluation methods
- Version 2 of the ICDM standard is in development.
  - It will include up-to-date display methods and needs, like HDR, Medical Displays, AR/VR, Color Volume, automotive displays, more color standardization, and much more.
- Chapter 4 - Visual Assessment
  - Does not require instrumentation for display evaluation.
  - It is for evaluation of displays by subjective methods
  - Quality assessment and subjective-related metrics
  - Any way to evaluate a display without making measurements with light measurement equipment could be part of that chapter in the standard.
- If you have a method you would like to have standardized, then the ICDM standard version 2 offers a potential path for you to consider, where it would be available to thousands of people for potential use.

# Display Metrology Standardization Work

# ICDM

## International Commi… …splay Metrology

**VQEG … nal Presentation**

**…ember 14, 2018**

**…ogle, Mountain View, CA**

# End of Presentation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