Color Correction and Gamut Monitoring
Agenda

- Color Correction & Gamut Monitoring
- Introduction to Spearhead Display
- Introduction to LQV Display
- Content Quality Assurance
Basic Anatomy of the human vision system

- **Physical part/elements**
  - Eye, Lens and Retina
    - Rods
      - Sensitive to Blue-green light
      - Used for vision under dark-dim conditions.
    - Cones
      - 3 Types of Cones
        Sensitive to either
        long wavelengths of light (red light)
        medium wavelengths of light (green light)
        short wavelengths of light (blue light)
  - Optic nerve

http://webvision.med.utah.edu/index.html
Color Model – developing color spaces

- CIE 1931 XYZ color space with 2% observer is still foundation of most color models
- Trichromatic stimulus (color value)
- Lightness decreases towards not shown third dimension
- Saturation increases towards edges
What could go wrong?
Gamut Compliance

- **Color Not Correct**
  - Company logo/brand incorrect color in commercial or graphic.
  - Format conversion caused clip of color in change from one color space to another

- **Color Balance**
  - Overall image appears washed out
  - Image appears to dark
  - Cameras incorrectly balanced produced different look from scene to scene

- **Composite Gamut Error**
  - Over saturates transmitter causes broadcast distortion.
**Color Correction**

- **Primary Color Correction**
  - Focuses on Overall color correction of image.

- **Secondary Color Correction**
  - Focuses to enhance specific areas or components of the image.
  - Are used to “change“ colors after shooting
  - Mostly used to enhance the “message“ of an image by highlighting areas, changing the tonal range of a particular area etc.
  - Key areas: Skin tone, sky, grass. Making it look real
Impact of Distortions on Different Color Spaces

A signal can be legal in one color space but not valid when converted to another.

- **A** - Legal RGB
- **B** - Converted to Legal Color Difference
- **C** - Distorted Color Difference
- **D** - Converted back to RGB

Distances are represented from 0.0 to 0.8.
RGB and YPbPr Color space.

- YPbPr color cube shows Parallel-Piped of RGB colors
- Certain YPbPr values when converted to RGB will fall outside the allowed range and will be out of Gamut
Gamut monitoring - The traditional way RGB domain

![Diagram of Gamut monitoring in the RGB domain with maximum and minimum gamut annotations.](image-url)
How the *Diamond* Display is constructed

![Diagram of Diamond Display construction](image)
Gamut monitoring — *Diamond* display

### Gamut Limits

- **High**: 735 mV
- **Low**: –35 mV
- **Area**: 1 %

### Configuration Menu

- **Selectable Gamut Thresholds**
  - Diamond High: 735 mV
  - Diamond Low: –35 mV
  - Diamond Area: 1 %
  - Reset Diamond Defaults: Press SEL
Diamond Display - Live Signal Gamut Errors Blue
Diamond Display - Live Signal Gamut Errors

High: 735 mV
Low: -35 mV
Area: 1%

Split-Diamond
Diamond Display - Live Signal Gamut Errors
Diamond Display – Live Signal Corrected Gamut

High: 735 mV
Low: -35 mV
Area: 1%

Split-Diamond
Diamond Display – Camera Balancing

White Outer Apex

Black Center

White Outer Apex

Split-Diamond

High: 735 mV
Low: -35 mV
Area: 1%

Color and Gamut Monitoring
Diamond Display – Camera Balancing Red Error

Deviation from center indicates color balance error
Black Offset in Red Channel

Deviation from vertical indicates color balance error
In this case a Red Gain Error

High: 735 mV
Low: -35 mV
Area: 1 %

Split-Diamond

Color and Gamut Monitoring
Diamond Display – Camera Balancing Live

- Keep signal within graticule
- Adjust luma in vertical axis
- Black balance in center of display
- Remember color component axes

High: 735 mV
Low: -35 mV
Area: 1%
New Spearhead Display
Can we make a new display that has metrics of Saturation, Value and Lightness?

Premise:
1) For gamut limit testing we are interested in the max and min values of R, G, and B.
2) Artistic metrics like Value and Saturation are functions of both max and min of R, G, and B.

![Diagram of RGB gamut space and rotated monochrome axis](image)
New Spearhead Display
(Color Lightness, Saturation and Value)

\[ Y(i) = \frac{\max(i) + \min(i)}{2} \]

Spearhead triangular RGB Gamut space:
\[
\begin{align*}
\max(i) & = \text{maximum of } r(i), g(i), b(i); \\
\min(i) & = \text{minimum of } r(i), g(i), b(i); \\
& \text{in mV.}
\end{align*}
\]

The space is bounded by 3 lines:
1) the vertical line (monochrome) where \( \max(i) = \min(i) \),
\[
\text{i.e. } Y(i) = \max(i) = \min(i), \ X(i) = 0;
\]
2) the line of all possible 100% Saturated colors where \( \min(i) = 0, \max(i) = 0..700 \text{mV} \)
\[
\text{i.e. } Y(i) = \frac{\max(i)}{2}, \ X(i) = \max(i),
\]
\[
\text{or graphically the } y = x/2 \text{ line;}
\]
and
3) the line of all possible 100% Value colors where \( \max(i) = 700 \text{mV}, \min(i) = 0..700 \text{mV} \)
\[
\text{i.e. } Y(i) = \frac{700 \text{mV}}{2} + \frac{\min(i)}{2}, \ X(i) = 700 \text{mV} - \ \min(i),
\]
\[
\text{or graphically the } y = -x/2 + 700 \text{mV}
\]

Note: All valid rgb values \((r(i), g(i), \text{or } b(i) \text{ within the range } 0..700 \text{mV})\) are contained within the Spearhead triangular gamut space. All invalid (or illegal) rgb values \((\min(i) < 0, \text{or } \max(i) > 700 \text{mV})\) are outside the Spearhead gamut space. Adjustable gamut limit detector thresholds are indicated as graticule markers (i.e. -0.5% and 105%).
How to Make Gamut Measurement Using Spearhead.

- Select one of the tiles 1, 2, 3 or 4
- Select Gamut button
- Push and Hold Gamut to bring up the menu
- Use arrow keys or general knob to select Spearhead display.
Rainbow (variable Hue) Test Pattern
Rainbow Pattern with SMPTE Pb/Pr Hue rotation (RGB gamut error)
Rainbow Pattern with Color Corrector Green Gamma Adjustment Error
Spearhead for Content Quality Control (RGB gamut limits)

- Fold Diamond Horizontally and Vertically to form Spearhead
- The Spearhead display indicates Out-of-Gamut RGB components (triangle boundary)
- Spearhead also indicates how much the Signal is OVER Saturated or OVER Value (or BOTH) so that we can see what has to change to correct the signal back into gamut.
- This way a better trade-off of reducing Saturation or Value (or both) without affecting the Hue can be accomplished with the least compromise in artistic quality.
Using Spearhead with a Color Corrector

Adjust Setup
Adjust Chroma
Adjust Gamma and gray-scale tracking
Adjust RGB Gain
Push back to monochrome line with RGB gamma controls
Adjust RGB Black Level
Image with Gamut error in Blacks and RGB Gain
Image after Color Correction using Spearhead Display
Image Enhancement using Spearhead Display

Before

Limited to 75% Value

100% Value utilizing full gamut space

No negative blacks

After

Limited to 75% Value

Negative black level
Luma Qualified Vector
Construction of Vector Display

50% Lightness Vector plane

Cy
Magenta
Cyan

Color and Gamut Monitoring
Luma Qualified Vector Display

- Allows User to define luma slice of vector display
- Selectable upper and lower limits
- Allows user to select low, medium and high ranges to isolate certain luma regions.
How to Configure LQV on WFM8300

- Select Vector display
- Push and Hold VECTOR for menu
- Select LQV
- Enter Upper & Lower threshold
Color Correction Tools

- Color Correction tools allows for adjustment of Highlights, Mid Tones, Shadows
- LQV can be set up within 3 different tiles to show these specific regions
Using LQV on WFM8300

- Each Tiles can be configured with different threshold
  - High, Medium & Low
Luma Qualified Vector Limits

Color and Gamut Monitoring
Image Enhancement Using LQV

- Threshold can be set to isolate black region
- Allows user to focus on black region to remove color offset
  - Upper limit 51mv
  - Low limit -51mv
- Set threshold to isolate flesh tones
  - Upper limit 500mv
  - Low limit 400mv
Composite Gamut Monitoring
Understanding the *Arrowhead* Display

**Luma Limits**

- Upper Luma+Chroma
- Lower Luma+Chroma

**Luma**

- 103.0 %
- Y Low: -1.0 %
- Y High: 103.0 %
- Y Area: 1 %

**Arrowhead**

- Y+C Low: -24 IRE
- Y+C High: 120 IRE
- Y+C Area: 0 %

**SDI Input A**

- Ref: Internal

**Comment Gamut Error**

**Tektronix**

ID: WFM7120

Audio Input: AES A
Graticules available for both PAL & NTSC

- PAL Graticule
  - Keep trace within graticule

- NTSC Graticule
  - Keep trace within graticule
Arrowhead Display – Live Signal

- Keep trace within graticule limits of Arrowhead
- Adjust Luma and black level controls for vertical adjustment
- Adjust Chroma controls for horizontal adjustment
Arrowhead Display vs Pseudo Composite– Live Signal

- Keep trace within graticule limits
- Saves having to view Waveform and Vector displays
Content Quality Assurance
Tape QA

- Video Session and Error Log provide a simplify the QA process
  - After program has been edited
  - QA of Incoming program
  - QA of Duplication

- Video Session
  - Provides summary of video

- Error Log
  - Reports errors based on Alarm settings
  - Provides log related to timecode
  - Allows easy navigation to errors
Video Session

- Provides Summary of Video signal during session
- Simple indication of Gamut Errors
- Lower case letters indicate values go below threshold
- Capital letters indicate value exceeds threshold
- In this case
- Lower r,g,b & l indicate values are below threshold for this SMPTE bars test signal
Error Log

- Provides log of errors
  - Related to timecode
  - Internal time of day
- Simplifies QA process
- Log can be printed
  - via network interface

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<tr>
<th>Error Status</th>
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<td>5/4/2011</td>
<td>16:38:00</td>
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Arrow Left – Previous, Right – Next, Up – First, Down – Last.
Conclusion

- Important to ensure Gamut compliance
- Tektronix Diamond and Spearhead displays can aid in RGB gamut adjustments
- Tektronix Arrowhead display is suitable for Composite Gamut adjustments
- Luma Qualified Vector allows users to isolate specific color components based on Luma limits.