



# Adaptation of Bridge System Graphical User Interfaces (GUIs) to Promote Dark Adaptation

*Presented by*

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# The Case for Design Guidance

- Many bridge systems have attempted to address Graphical User Interface (GUI) brightness, but with limited success
- Dark Adaptation needs and limitations exceed those of normal night operations
- Existing approaches are generally ineffective at:
  - Controlling overall luminance output
  - Balancing luminance and contrast needs
  - Proper use of color as an attentional draw or for categorization






































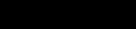
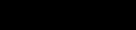
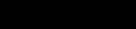


# Challenges for Design in Dark Adaptation

- Designing for Dark Adaptation is not the same as creating a “Night Mode”
  - Dark Adaptation has stricter luminance standards than a typical night mode
  - Need to reduce overall light output while maintaining sufficient contrast for readability and element distinction
- Existing standards (e.g. MIL-STD-1472) have criteria for dark adaptation and for readability which are in direct conflict
  - Dark Adaptation standards required all elements to achieve 0.03 cd/m<sup>2</sup> luminance
  - Minimum color contrast required for readability was 4.5:1
    - Color contrast is actually the contrast of luminance between foreground and background color
  - Any text that achieved luminance standards violates readability standards
    - E.g. Insufficient contrast between foreground (text) and background
- Using color and software by themselves was insufficient for reaching dark adaptation goal
- Decision was made to create a color palette with distinct colors that showed improved luminance control over standard night modes, and using hardware / physical mitigation to get the rest of the way

# Dark Adaptation Color Palette

- The color palette shown here was created to provide design and development teams color options that are more compatible with a dark adaptation environment
- Regarding the colors shown here:
  - No color has a contrast ratio more than 8.5:1, assuming a black background color
    - Using black as a standard background color allows for a more global control of luminance
  - “Baseline” color was based on common industry standards, with each being dimmed or lightened to achieve a particular contrast level.
  - Limiting each color to four contrast levels allows for visual distinction and categorization within colors while still retaining existing color-use familiarity

	Category	Contrast Ratio (x:1)	Color Swatch	Hex	RGB
White	Baseline	21.00		FFFFFF	255 255 255
	Very High	8.52		A5A5A5	165 165 165
	High	4.49		747474	116 116 116
	Medium	2.52		4E4E4E	78 78 78
	Low	1.23		1C1C1C	28 28 28
Red	Baseline	5.25		FF0000	255 0 0
	Very High	8.50		FB8080	251 128 128
	High	4.50		EA0000	234 0 0
	Medium	2.51		A10000	161 0 0
Yellow	Low	1.23		420000	66 00 00
	Baseline	19.55		FFFF00	255 255 0
	Very High	8.55		ABAB00	171 171 0
	High	4.48		787800	120 120 0
	Medium	2.52		515100	81 81 0
Orange	Low	1.25		1F1F00	31 31 00
	Baseline	10.63		FFA500	255 165 0
	Very High	8.47		E49300	228 147 0
	High	4.52		9F6900	159 105 0
	Medium	2.49		6B4600	107 70 0
Green	Low	1.25		291B00	41 27 00
	Baseline	4.08		008000	0 128 0
	Very High	8.45		00C000	0 192 0
	High	4.52		008800	0 136 0
	Medium	2.49		005B00	0 91 0
Blue	Low	1.25		002400	00 36 00
	Baseline	2.44		0000FF	0 0 255
	Very High	8.44		9A9AFF	154 154 255
	High	4.47		5D5DFF	93 93 255
	Medium	2.50		0A0AFF	10 10 255
Brown	Low	1.25		000075	00 00 117
	Baseline	3.30		964B00	150 75 0
	Very High	8.50		C09F7D	192 159 125
	High	4.51		936D46	147 109 70
	Medium	2.47		61482E	97 72 46
Purple	Low	1.26		271C11	39 28 17
	Baseline	2.22		800080	128 0 128
	Very High	8.51		FF64FF	255 100 255
	High	4.47		CD00CD	205 0 205
	Medium	2.51		8D008D	141 0 141
	Low	1.26		3D003D	61 0 61

# Palette Validation: Readability Testing

- **Goal:**
  - Determine if contrast levels of color text need to be adjusted in order to have similar readability as white text.
  - Particularly important under low lighting conditions.
- **Methods:**
  - Evaluated minimum contrast needed to read word in five text colors using adaptive staircase procedure (2 down: 1 up).
    - Threshold = contrast level.
    - Stimulus = 8-letter word displayed for 3 sec against black background.
    - Text color: white, red, green, blue, and yellow.
  - Conducted at three different levels of brightness.
    - Low: white = 0.03 cd/m<sup>2</sup>; text size = 30 arcmin
    - Medium: white = 0.1 cd/m<sup>2</sup>; text size = 30 arcmin
    - High: white = 0.25 cd/m<sup>2</sup>; text size = 15 arcmin
  - Data collected for seven participants in dark environment.
  - Calculated difference in minimum legible contrast between white and the color text for each participant.

	9.0	White	Red	Green	Blue	Yellow
<b>Very High</b>	8.5	White	Red	Green	Blue	Yellow
	8.0	White	Red	Green	Blue	Yellow
	7.5	White	Red	Green	Blue	Yellow
	7.0	White	Red	Green	Blue	Yellow
	6.5	White	Red	Green	Blue	Yellow
	6.0	White	Red	Green	Blue	Yellow
	5.5	White	Red	Green	Blue	Yellow
	5.0	White	Red	Green	Blue	Yellow
<b>High</b>	4.5	White	Red	Green	Blue	Yellow
	4.0	White	Red	Green	Blue	Yellow

Examples of five colors across contrast ratios

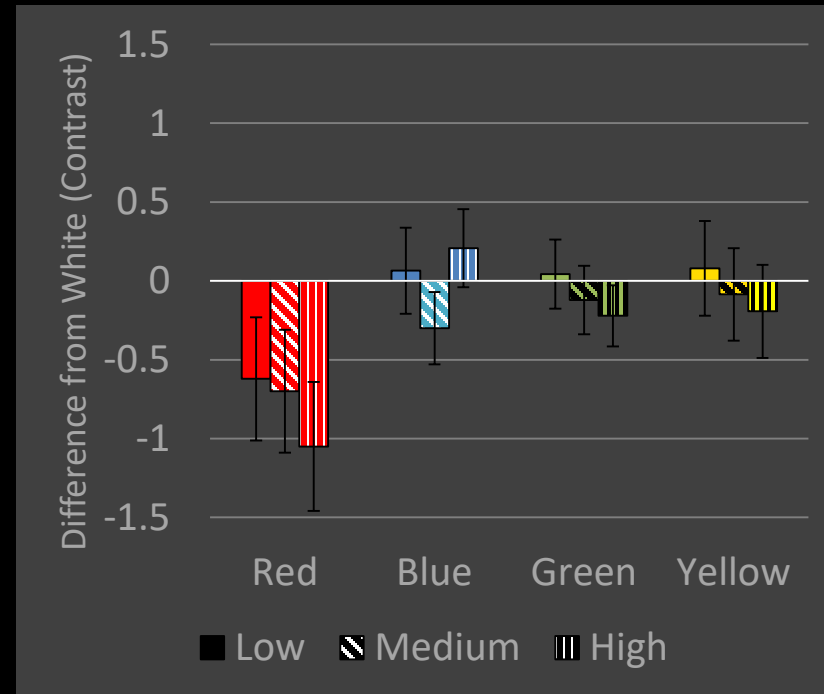
# Palette Validation: Readability Testing

- **Findings:**

- Green, blue, and yellow text could be read at similar levels to white.
- Red text could be read at lower contrast levels.

- **Conclusions:**

- WCAG contrast calculations remain useful at low lighting levels.
  - Corresponding color from dark adaptation palette should be used whenever possible.
  - If unique UI colors are required, WCAG contrast benchmarks should be used to control for contrast level.
- Red text, when displayed, should be legible at lower display brightness setting than the other colors.
  - Difference may vary based on display brightness.
  - Reducing relative brightness of red may result in reduced readability at brighter display settings (e.g., dusk or dawn).
  - Lower readability threshold may be desirable for red content.
- The contrast levels developed can be used at the low light conditions with consistent readability across text colors under monitor brightness setting.
  - No evidence that these colors would need higher contrast to be legible in dark environment.



Average Difference from White  
(error bars = standard error of the mean)

# Dark Adaptation Color Palette

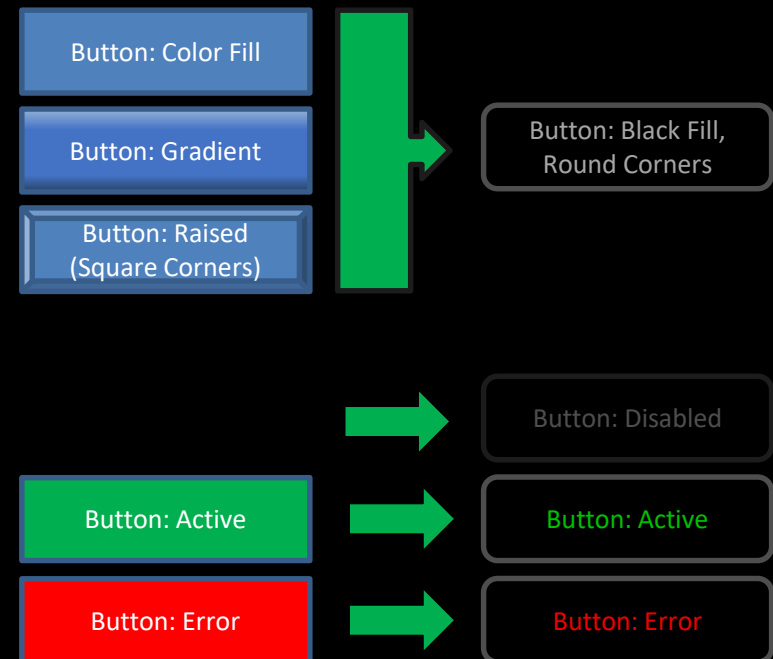
- Each GUI element (e.g. button, dropdown, etc.) or parameter of an element (e.g. default fill, active border color, etc.) is evaluated by design team along four different scales, each broken into three scores and values:
  - Size:
    - How much of the screen does this element take up compared to other elements?
    - Large (1pt), Medium (2pts), or Small (3pts)
  - Priority:
    - How important is this information to the user?
    - Low (1pt), Medium (2pts), or High (3pts)
  - Fidelity:
    - How much detail needs to be conveyed by this element to the user?
    - Noticeable (1pt), Recognizable (2pts), or Readable (3pts)
  - Dynamic properties:
    - Does the information change in its relationship to other elements on the GUI?
    - Neither content nor location change (1pt), content OR location change (2pts), or content AND location change (3pts)
- Total score is calculated and assigned a contrast category

Assigned Score Range	4-6	7-8	9-10	11-12
Category	Low	Medium	High	Very High

- NOTE – High Priority is not always the same as Very High Contrast
  - While highly correlated (especially in regards to text), other factors have equal weight when determining score

# General Rules and Guidance

- Certain aspects of the GUI can be adjusted to accommodate dark adaptation needs besides the contrast category assignment process.
- Buttons are a heavily used GUI element and as such are often a significant contributor to screen luminance
  - Avoid using 3D effects (e.g. gradient fills, drop shadows, etc.) or squared edges for selectable elements
    - 3D effects are less effective in low contrast and poor lighting
    - Use of rounded corners affords interaction
- Avoid using non-black background fills for buttons whenever possible
  - Button labels contribute less light pollution than the fill
  - If color is required, High or Very High Contrast colors are still readable on black background
  - Buttons that are disabled (or inactive) can be dimmed further to conserve luminance



# Example 1 - ASTAB

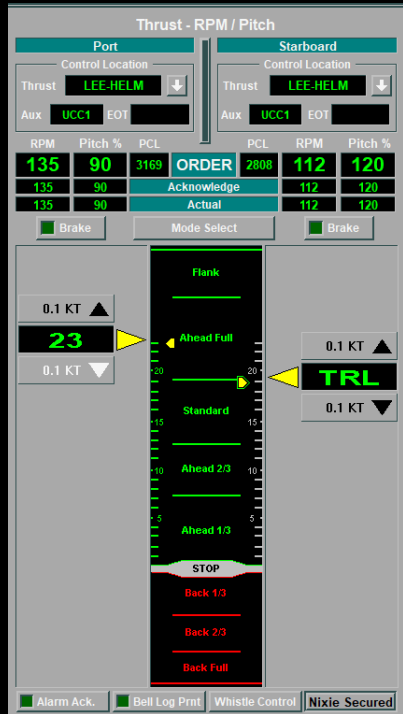
- ASTAB text assessed and rules / scores applied:
  - Labels scored as “High” due to non-dynamic nature and lower priority
  - Data scored as “Very High”
  - Background makes use of “use black wherever possible” rule for backgrounds
  - Button icons made “Medium” due to non-dynamic nature and lack of need for readability

The screenshot shows the ASTAB interface with a table of system availability data. The table has columns for 'System Avail Summary', 'Weapons', 'Phalanx', 'Port - Stbd', 'A/C', 'Contrast Ratio', 'Color Swatch', 'Hex', and 'RGB'. The rows are color-coded based on their contrast ratio and readability scores. A summary panel on the right shows the system status for various weapons and systems, with labels like 'ESSM', 'SM-2', 'SM-3', 'SM-6', 'Gun', 'Phalanx', 'Port - Stbd', and 'A/C'.

Before / After

The 'Before / After' comparison shows two versions of the summary panel. The 'Before' version has a dark background with light text, while the 'After' version has a lighter background with dark text, improving readability. The text in both panels is:
   
--- Weapons ---
   
ESSM : aaaa Harpoon : ffff
   
SM-2 : bbbb VLA : oooo
   
SM-3 : cccc
   
SM-6 : dddd
   
Gun : hhhh Phalanx: jjjj jjjj
   
Port - Stbd AA SU AS
   
OTST : jjjj jjjj A/C : 111 111 111

# Example 2 – Scoring the Throttle



	Size	Priority	Fidelity/ Detail	Dynamic	Score	Contrast
Labels	Small 3	Medium 2	Readable 3	Non 1	9	High
Inactive Text	Small 3	Medium 2	Recognizable 2	Non 1	8	Medium
Borders	Low 1	Low 1	Noticeable 1	Non 1	4	Low
Primary Readouts (Text)	Small 3	High 3	Readable 3	Content 2	11	Very High
Secondary Readouts (Text)	Small 3	Medium 2	Readable 3	Content 2	10	High
Knot Scale	Small 3	Medium 2	Noticeable 1	Non 1	7	Medium
Scale Indicator – Triangle	Medium 2	Priority 3	Noticeable 1	Location 2	8	High Medium
Scale Indicator – Home Plate	Small 3	Priority 3	Noticeable 1	Location 2	9	High



Assigned Score Range	4-6	7-8	9-10	11-12
Category	Low	Medium	High	Very High

# A Tool to Analyze the Brightness of UI Color Content

- Currently using image analysis capabilities in the R programming language to quantify brightness of color content within UI designs.
- Image Analysis Process:
  - Takes in an image file of the display mockup
  - Extracts the color information of each pixel and its frequency count in the image
  - Uses the RGB values to calculate color brightness of each pixel based on the WCAG color brightness formula\*
    - Defined as  $(0.299 \times R) + (0.587 \times G) + (0.114 \times B)$ , where R, G, and B are the 0-255 value of each color component
  - Calculates the average color brightness across all pixels in the entire image
- This tool quantifies how color content affects UI luminance levels independent of display hardware
- This tool can be used as an aid in the software design process and maintain goals towards effective night time UI designs such as:
  - Reduce/minimize the percentage of non-black pixels
  - Reduce overall display luminance
  - Provide adequate text contrast

\*Source for formula: <https://www.w3.org/TR/AERT>

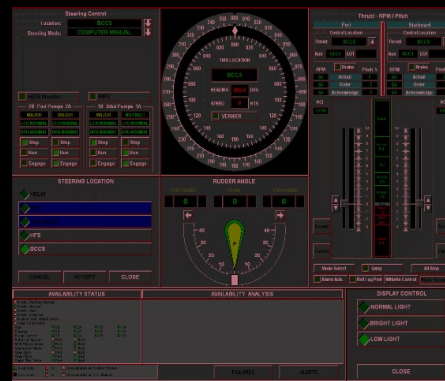
# A Tool to Analyze the Brightness of UI Color Content

- An example analysis utilizing the tool
  - Comparing both average color brightness and color contrast allows you to assess effectiveness of proposed UI content for night time use.
  - Mock ups that have a lower average brightness and same or better contrast levels will be more effective for both dark adaption and legibility at night.

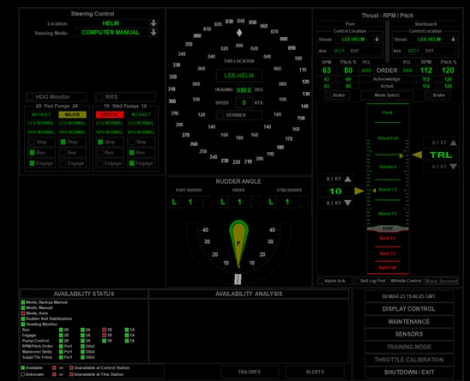
Normal Mode



Original Night Mode

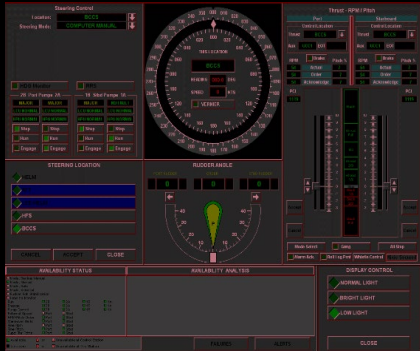


New Night Mode

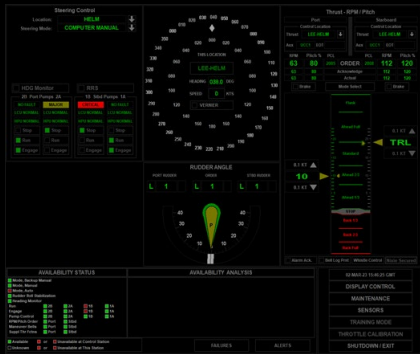


Average Brightness:	142.3	40.94	7.12
Green Readout:	15.3	2.86	8.54 to 4.52
Active Buttons:	2.35	4.36	4.49
Labels:	2.35	4.36	4.49

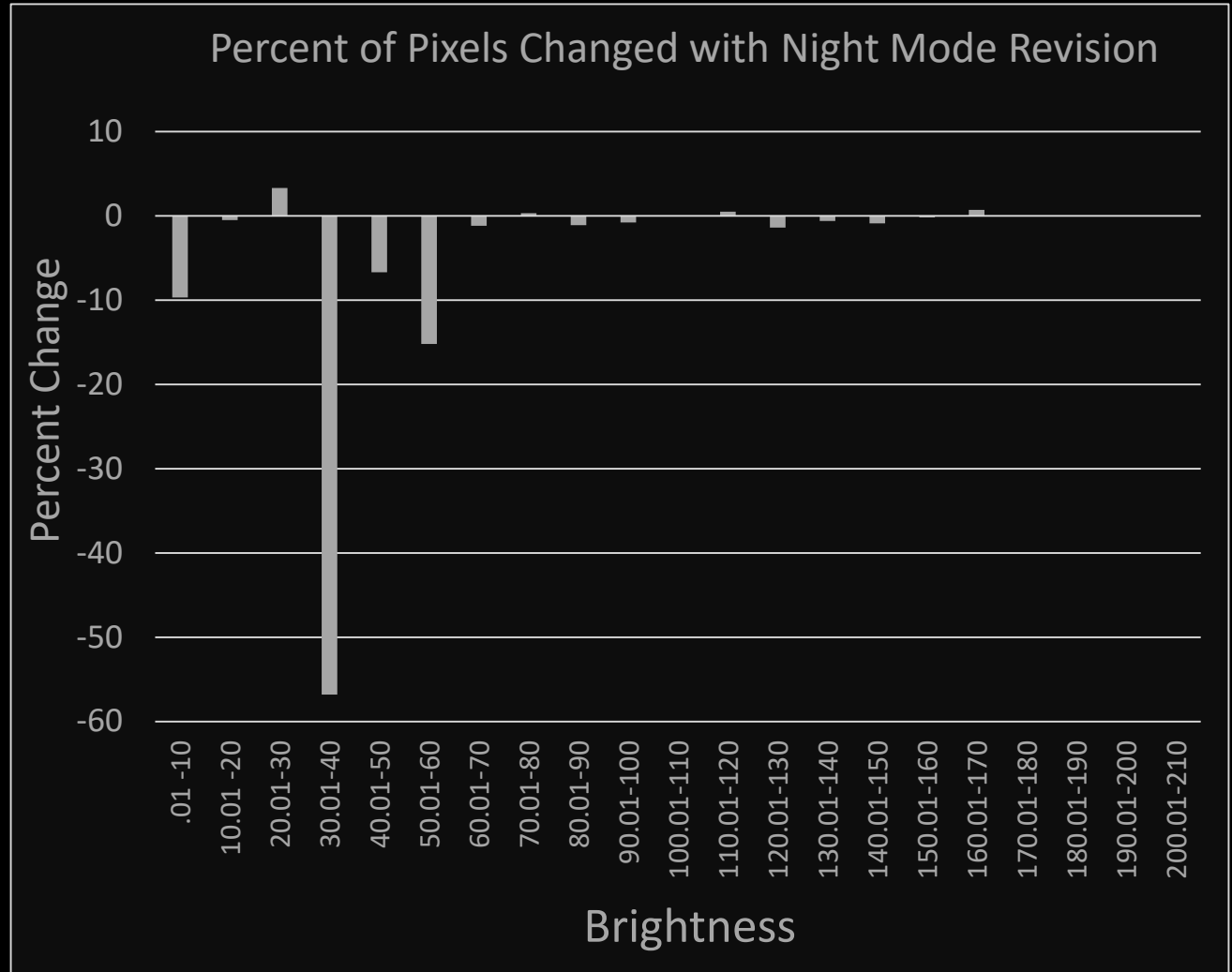
# A Tool to Analyze the Brightness of UI Color Content




Black Pixels: 5.2%



Black Pixels: 87.2%



# Closing Thoughts

- The methods and rules presented in the design guidance document are intended to provide best practices when designing / translating interfaces for dark adaptation
  - There will moments when the design team may be directed by either users or program needs to “bump” a score higher or lower depending on the context
  - Notice on Slide 10 that “Scale Indicator – Triangle” had a  next to the score.
    - This was due to a user-identified desire to have all the throttle indicators be at the same level and to err on the side of the brighter color
    - The triangles were bumped up a level in color to match the smaller “home plate” indicators
- Bumping up / down a contrast level is a perfectly acceptable practice, though should be used sparingly
  - If used too often, it can add luminance unnecessarily which is contrary to the purpose of the document
  - Remember that if everything is made more salient or distinct, then the effects will just cancel one another out
- Keeping within the palette provided will improve night adaptation use, and should be used in conjunction with usability testing and other human factors design principles