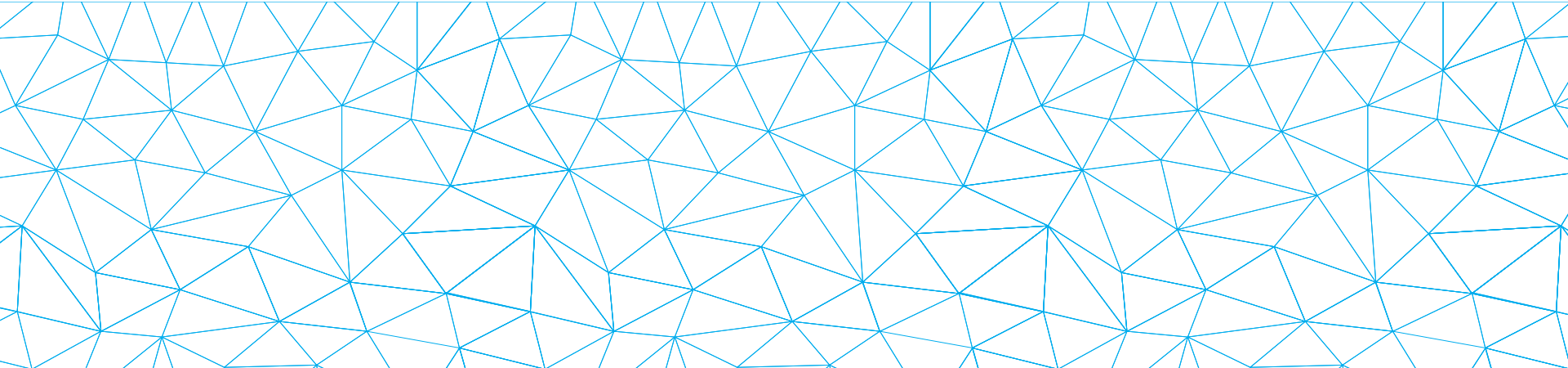




TANDEMLAUNCH

THE PAST, PRESENT AND FUTURE OF HDR

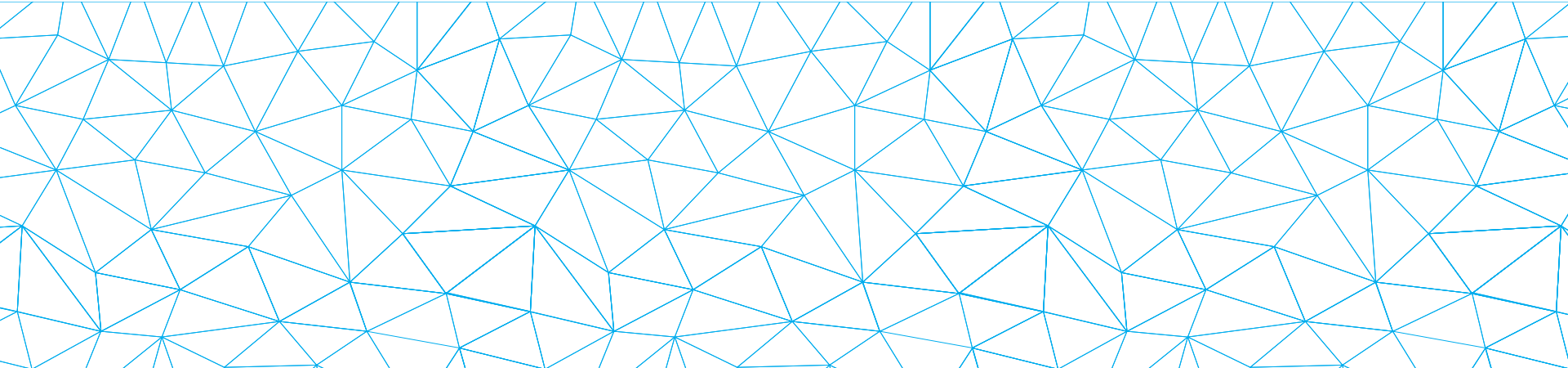






TANDEMLAUNCH

DEFINING HDR



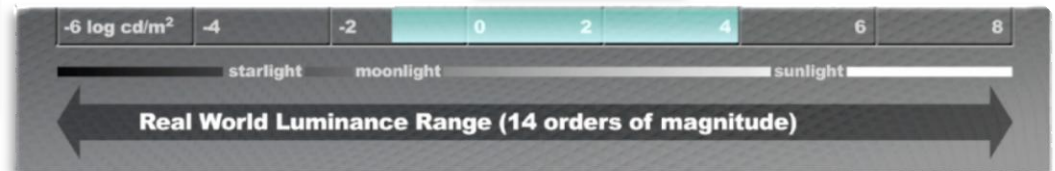
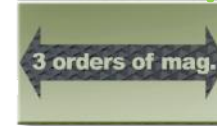
HUMAN VISUAL SYSTEM



Simultaneously Visible Dynamic Range



Conventional Displays



- Vast dynamic range available to human viewers
- Conventional displays deliver only a tiny fraction of it (today more than in 2000)

VIEWER PREFERENCES



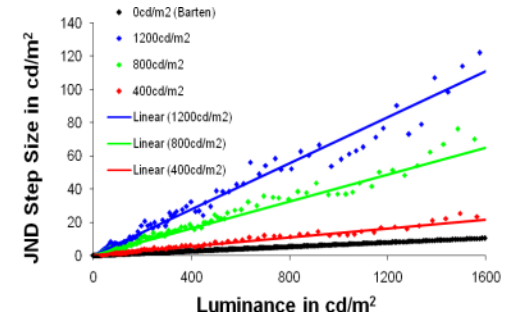
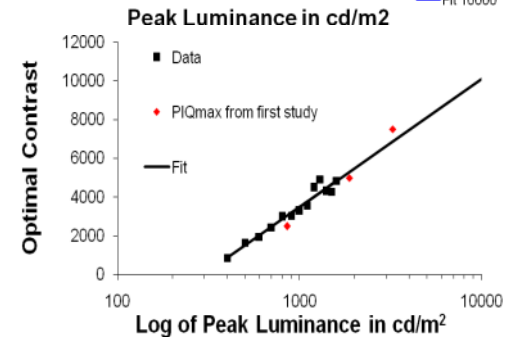
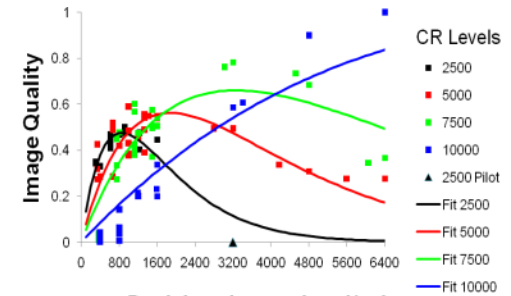
People prefer increased Luminance as long as Contrast remains high



People have “optimal” Contrast for different Luminance levels



People can distinguish far more than 255 steps depending on ambient lighting



A CLASSIC HDR SCENE



- Luminance levels in excess of 3,000 candela/m²
- Dark regions of <math><0.1</math> candela/m²
- Greater than 8 bit image depth in source data

CONVENTION DISPLAYS

Source Image in
False Colour Map

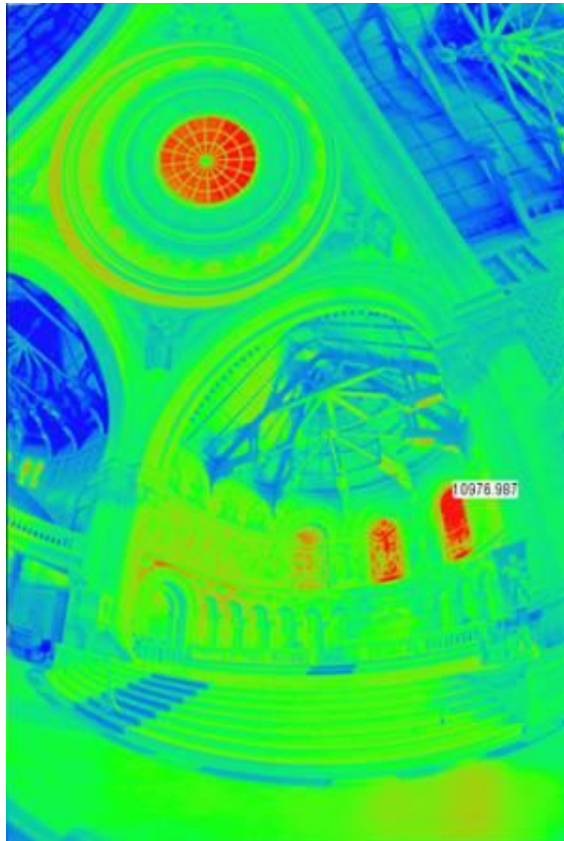
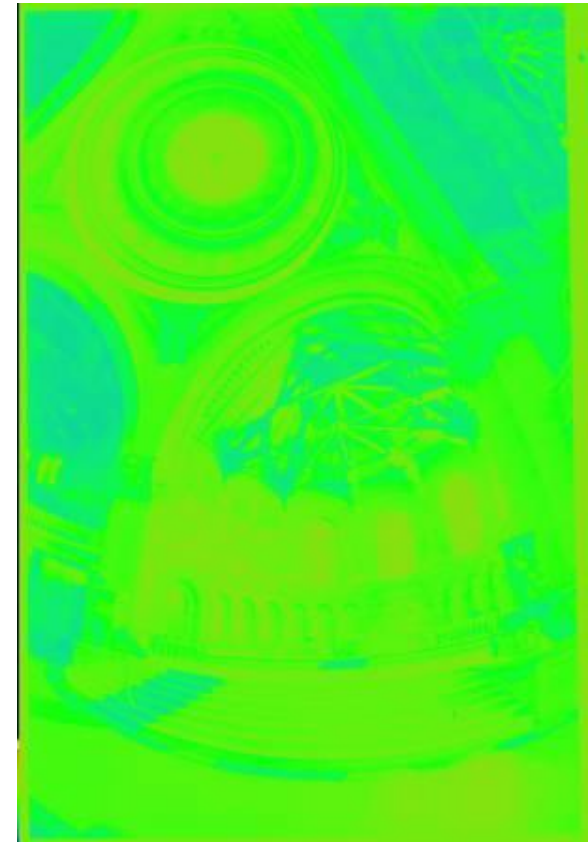


Image as Displayed on
Conventional Display

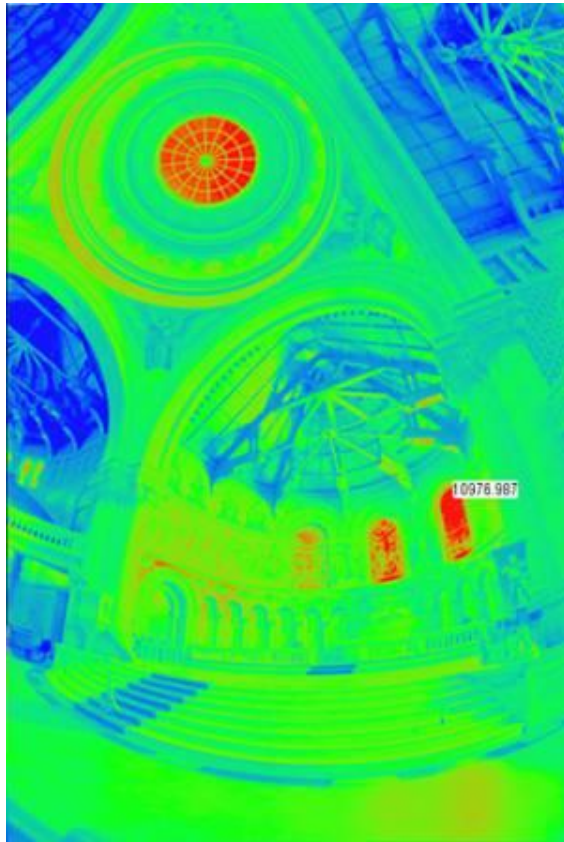


Cd/m²

1687.023
533.483
168.702
53.348
16.870
5.334
1.687
0.533

HDR DISPLAYS

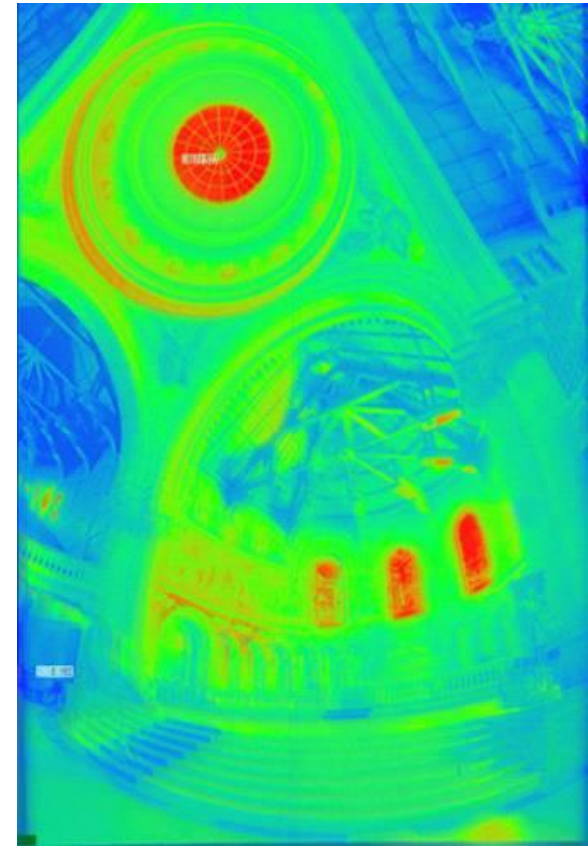
Source Image in
False Colour Map



Cd/m²

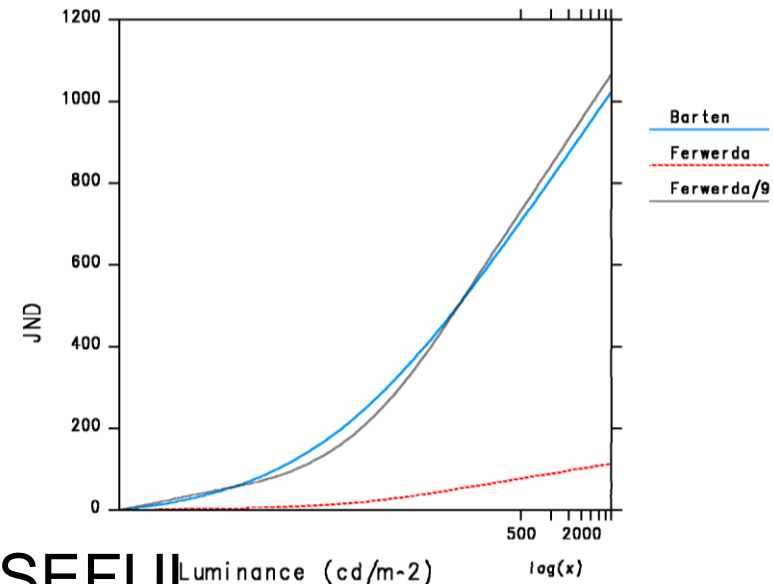


Image on HDR
Display



DEFINING DYNAMIC RANGE

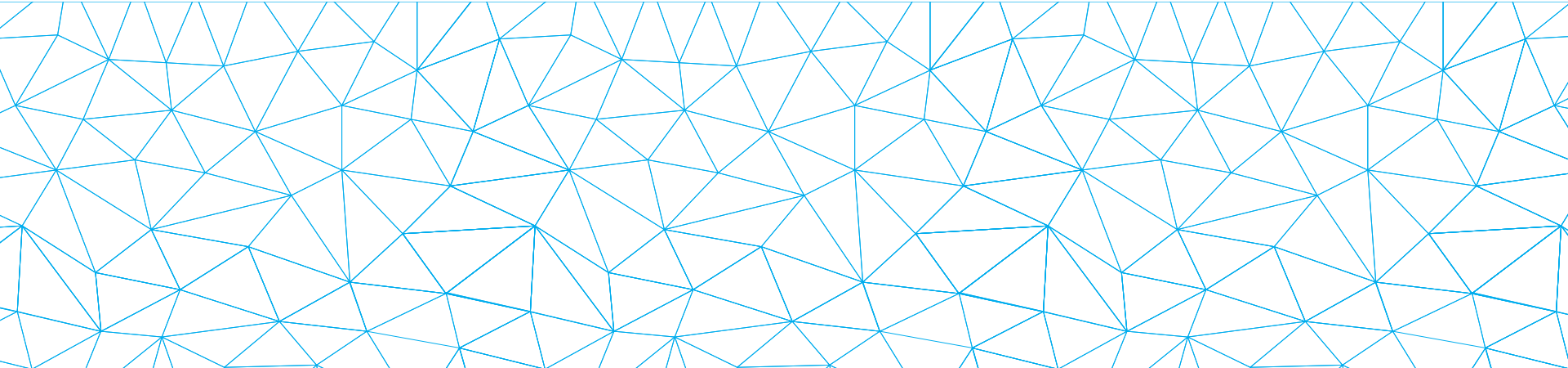
- ▶ DEVICE CONTRAST
- ▶ PEAK LUMINANCE
- ▶ AMPLITUDE RESOLUTION
- ▶ RESPONSE CURVE
- ▶ EASY TO QUOTE BY STORES
- ▶ FOCUS ON PERCEPTUALLY USEFUL
- ▶ ACHIEVABLE JND (SIMILAR TO “% NTSC” FOR GAMUT)
- ▶ INCLUDE AMBIENT ILLUMINATION





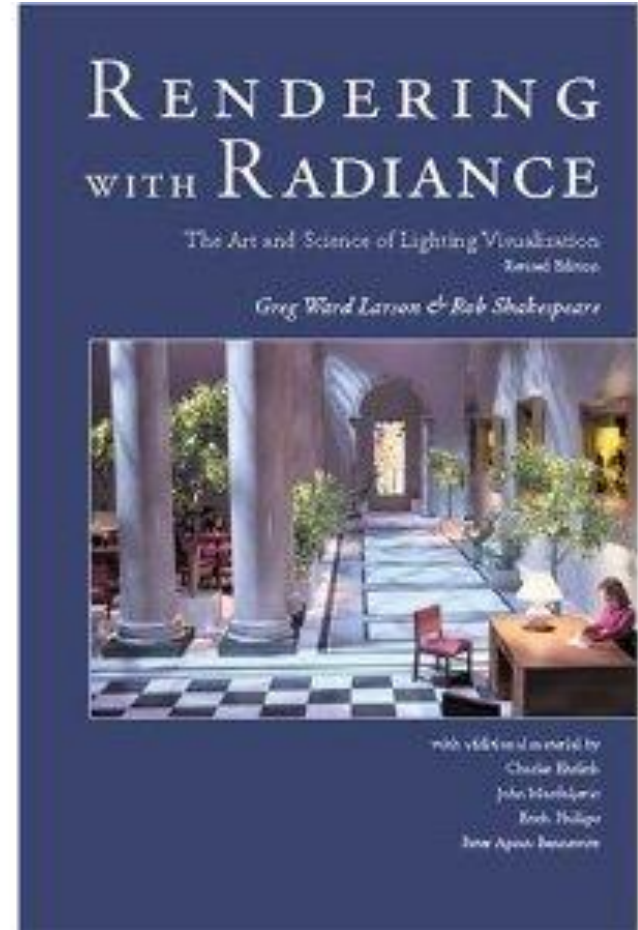
TANDEMLAUNCH

EARLY DAYS OF HDR



RADIANCE & .HDR

- ▶ RADIANCE IN 1985-1994
- ▶ .HDR (*RGBE*) & Log-Luv TIF



Ward, G., "[The RADIANCE Lighting Simulation and Rendering System](#)," *Computer Graphics*, July 1994.

Larson, G.W., "[LogLuv encoding for full-gamut, high-dynamic range images](#)," *Journal of Graphics Tools*, 3(1):15-31 1998.

SPHERES & MOVIES

- ▶ GLOBAL ILLUMINATION
- ▶ UNCANNY VALLEY IN SIGHT



LIGHTING EVALUATION



Physical Test Room Configuration at NRC Lighting Quality Group

STANDARD OFFICE LUMINAIRE IS ~10-20X BRIGHTER
THAN ANY COMMERCIAL DISPLAY ON THE PLANET

STANDARD OFFICES/HOMES HAVE DYNAMIC
RANGES EXCEEDING COMMERCIAL DISPLAYS BY
OVER 100X

SPACES ARE DESIGNED LIKE THIS FOR A REASON.

BUILDING HDR DEVICES

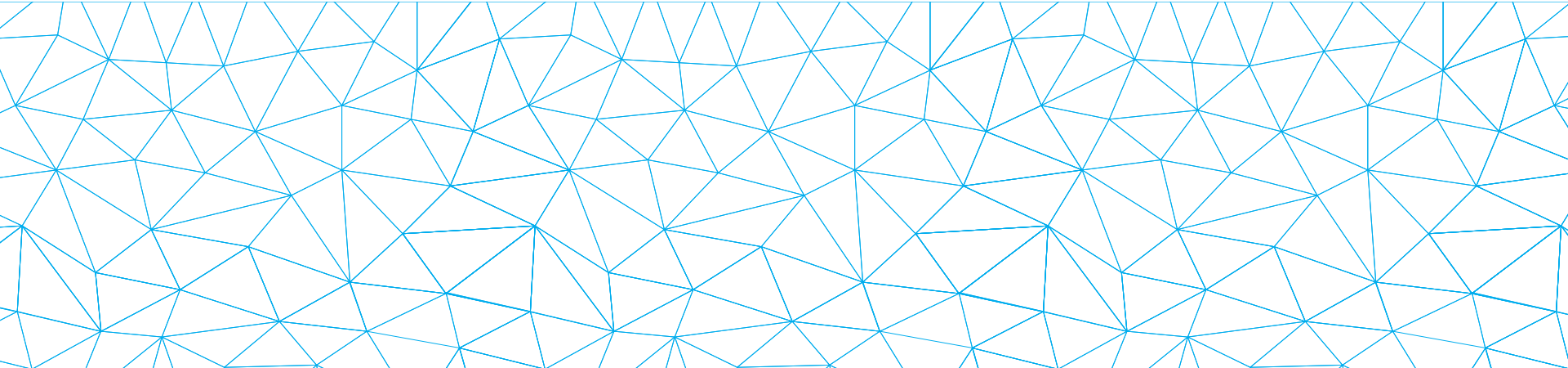
- HIGH LUMINANCE (>5X CONVENTIONAL)
- HIGH CONTRAST (>100X CONVENTIONAL)
- HIGH AMPLITUDE RESOLUTION (>14-BIT)
- DEPLOYMENT IN CURRENT ENVIRONMENT
- CONSUMER AFFORDABLE FOR MASS MARKET





TANDEMLAUNCH

THE EARLY STEPS



THE SPARKING MIX



OPTICS
TOLERANCE

ALGORITHMS

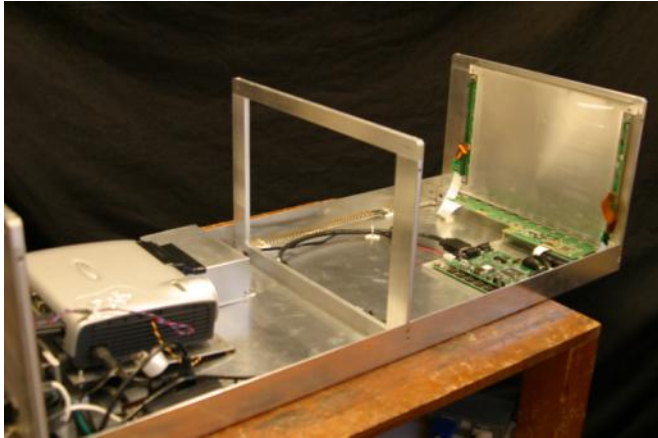
HDR

VENTURE

THE BASIC IDEA



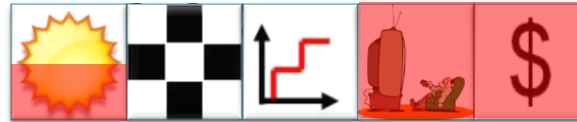
BASIC DUAL MODULATION DESIGN



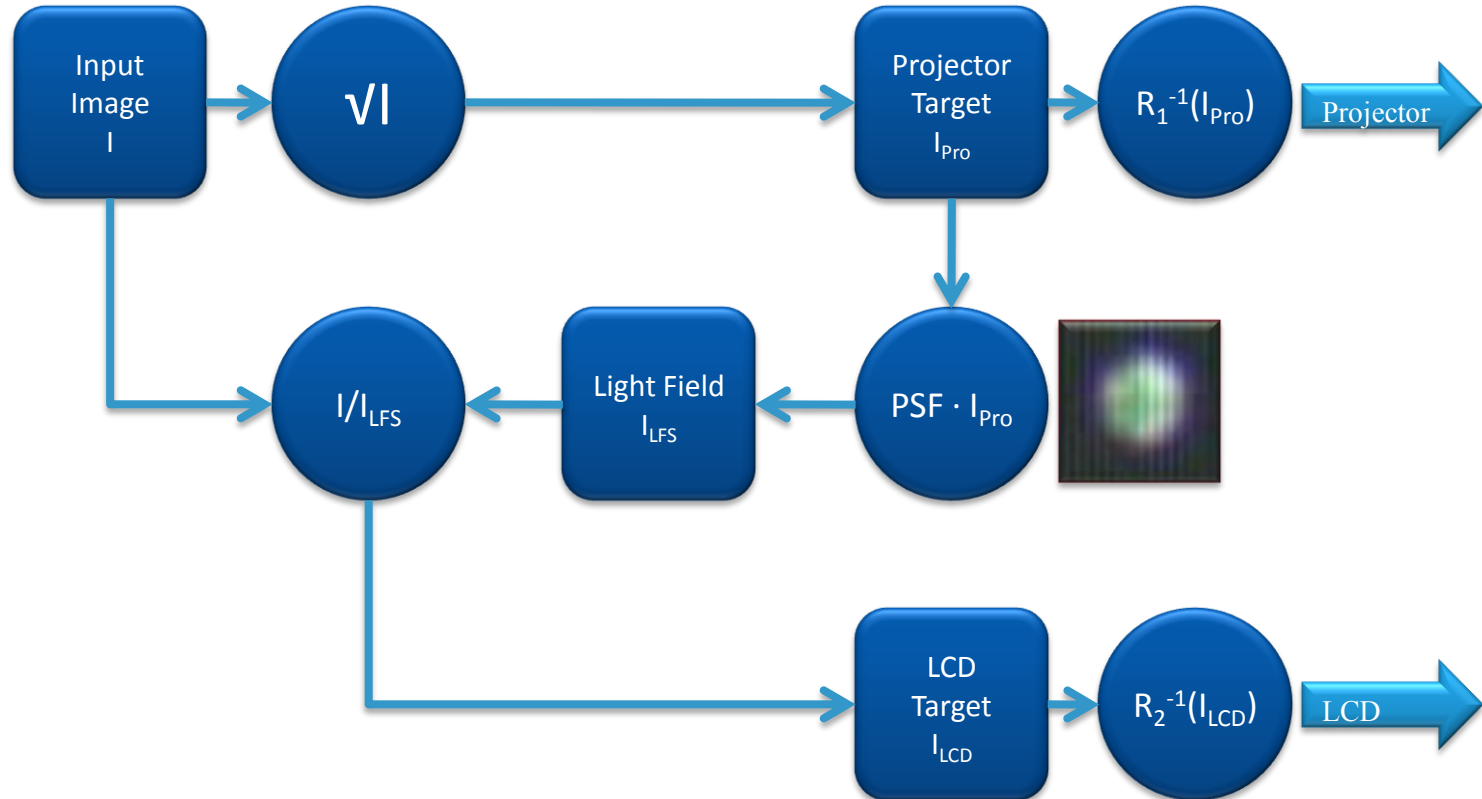
- ▶ MONOCHROME PROJECTOR
- ▶ CONVENTIONAL LCD
- ▶ COLLIMATING OPTICS



- ▶ BASIC CORRECTION



BASIC DUAL MODULATION DESIGN



COMMERCIAL RECEPTION



WHAT WE SOLD

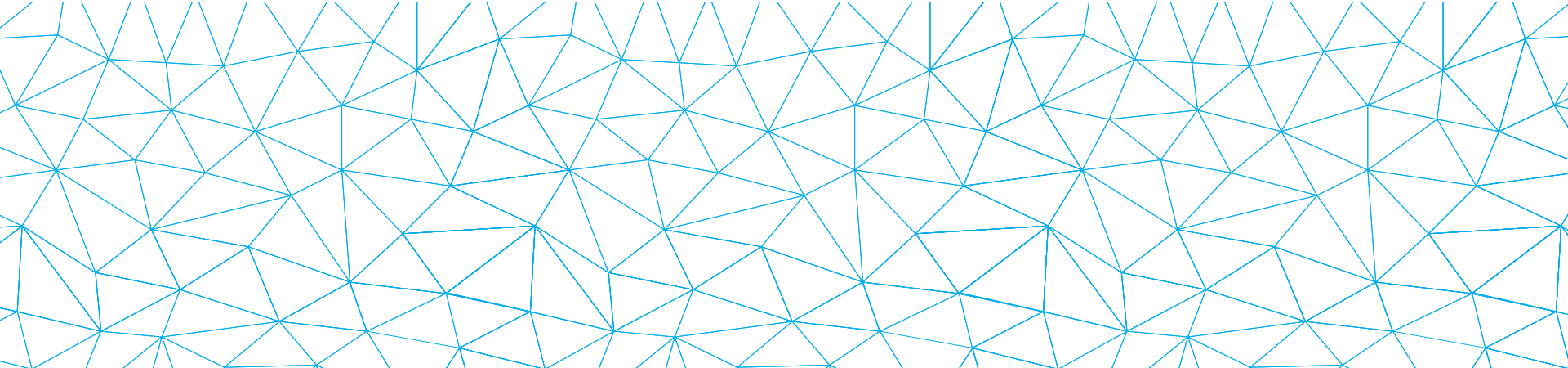


WHAT WE SHIPPED...

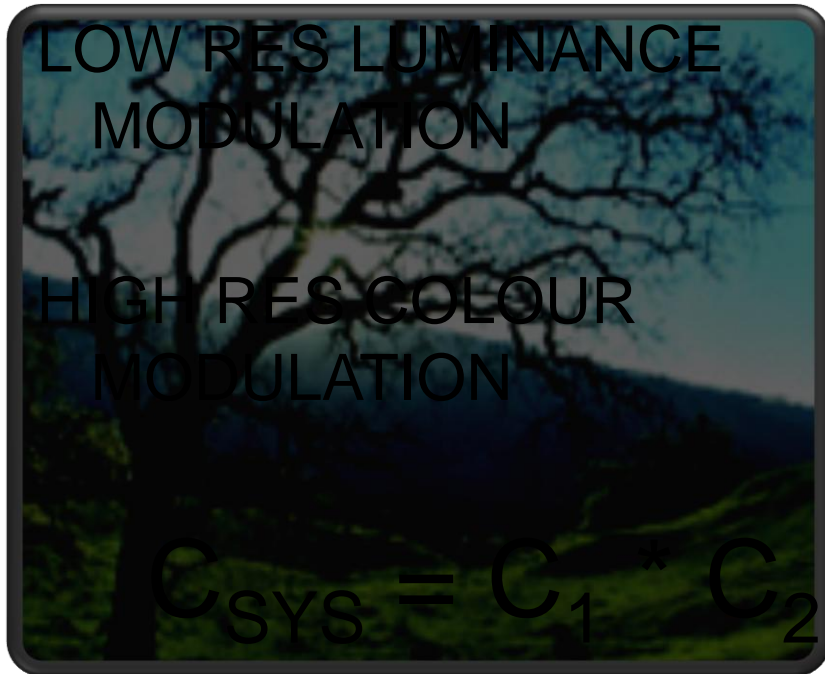


TANDEMLAUNCH

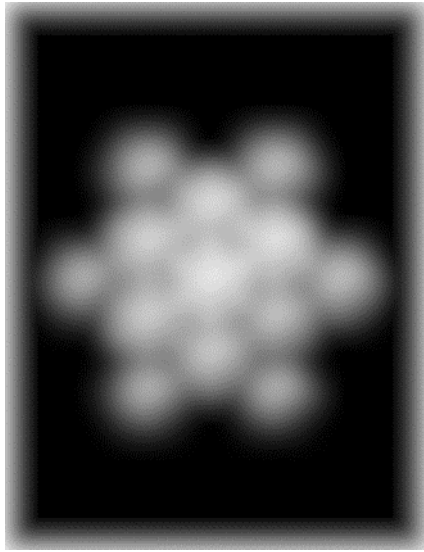
BRIGHTSIDE BECOMES REAL



THE BASIC IDEA 2.0

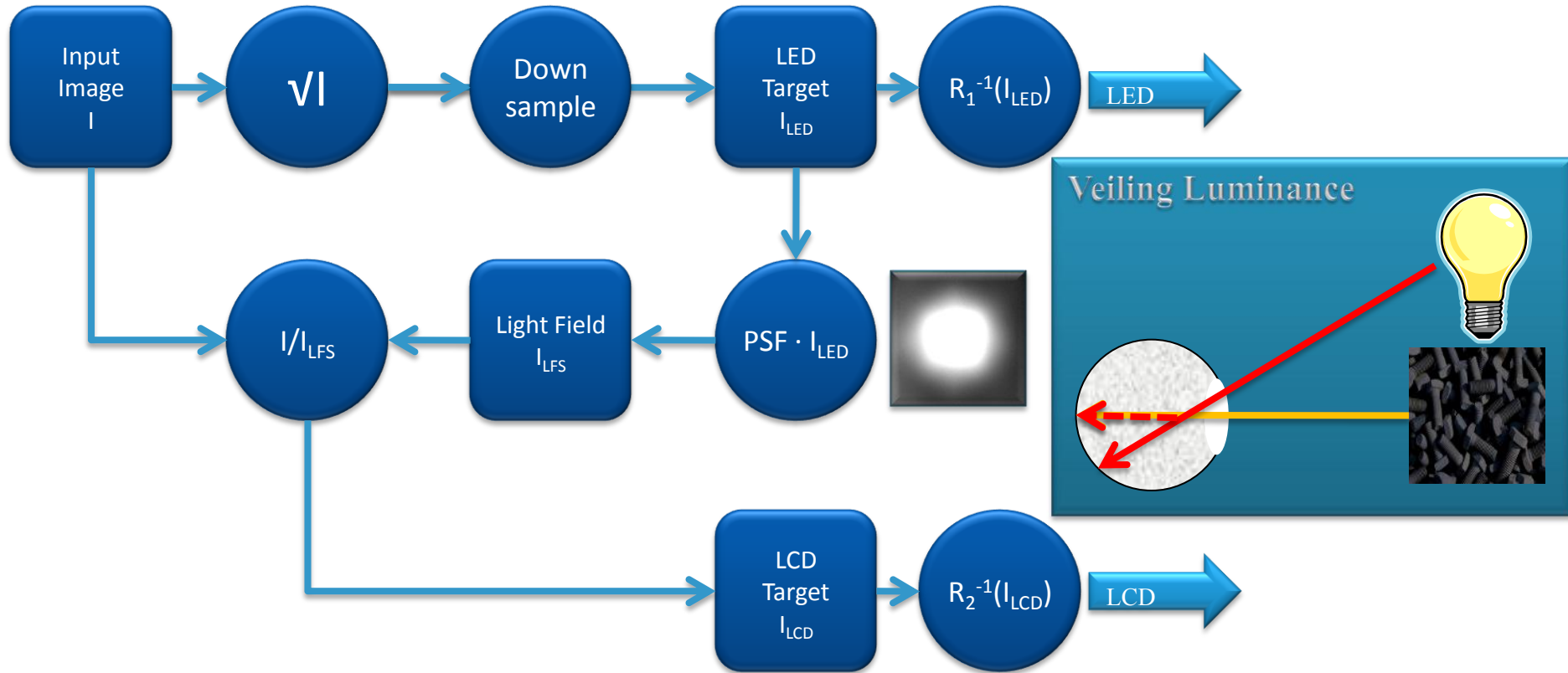


THE FIRST LOCAL DIMMING DISPLAY



- ▶ 3,000cd/m² PEAK LUMINANCE
- ▶ “INFINITE” CONTRAST (~20,000:1 9PT ANSI)
- ▶ ~2,000 INDIVIDUAL HAND-SOLDERED LED

LOCAL DIMMING ALGORITHM



LOCAL DIMMING





BRIGHTSIDE™
Est. 1986 Dynamic Range

Atlas

BRIGHTSIDE


BRIGHTSIDE

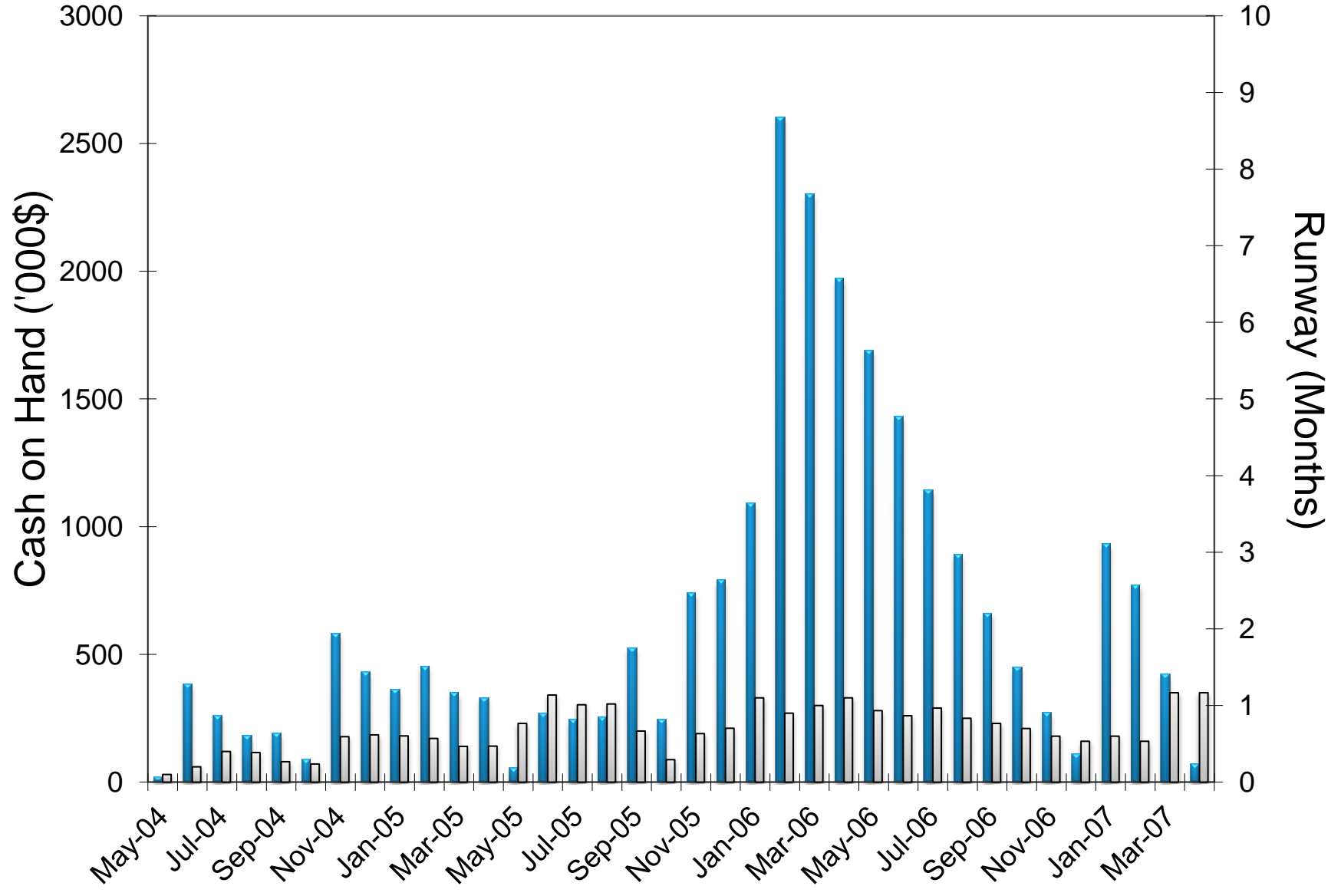
Display
Data & Process
130
1201



Informational cards on a stand.

Informational card on a stand.

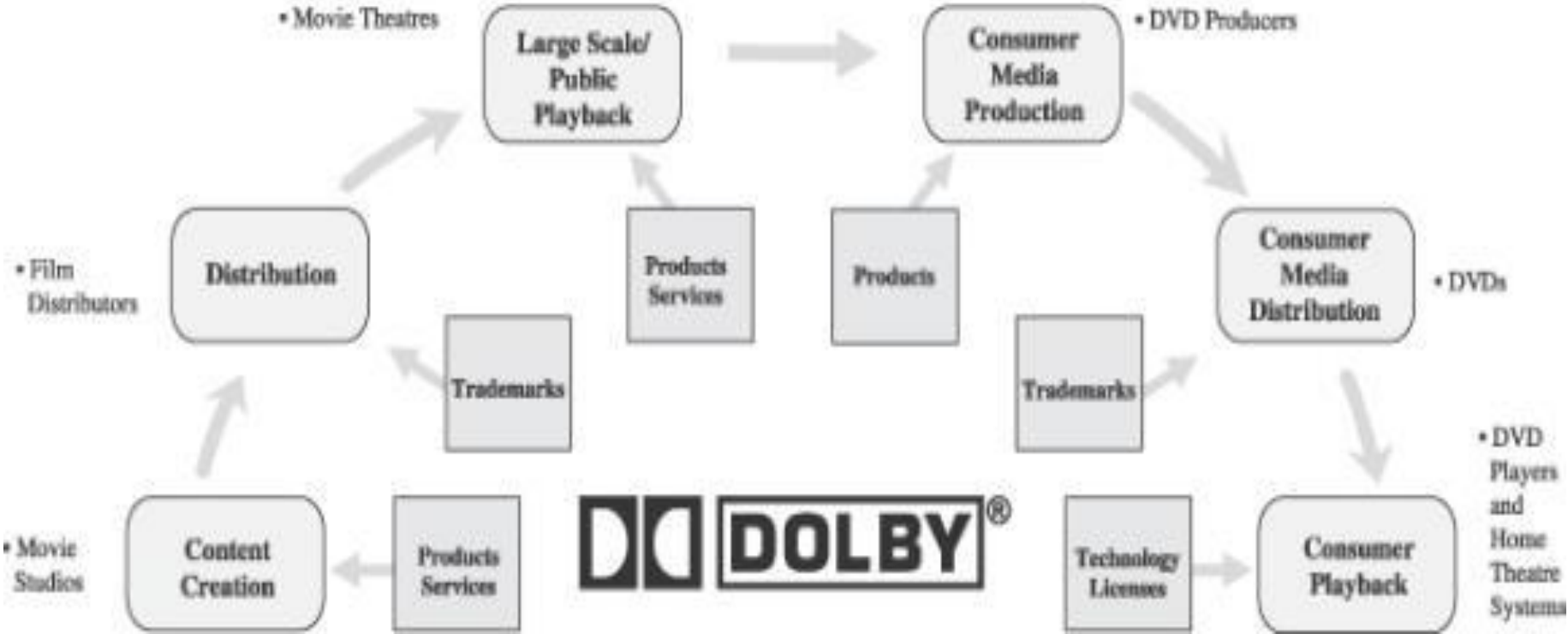
■ Cash on Hand ■ Burn — Runway



EXIT STRATEGY

Professional

Consumer





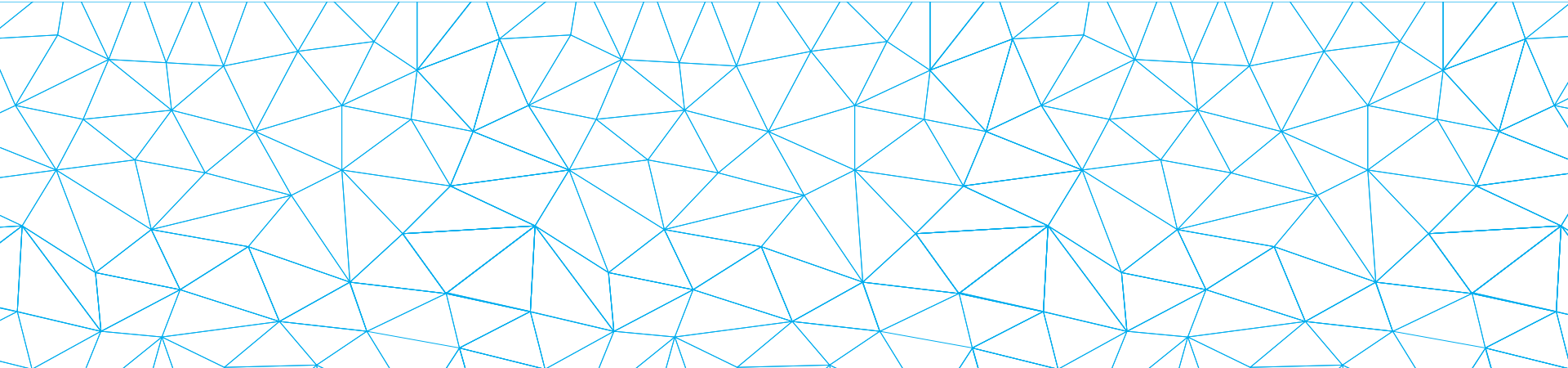
 DOLBY

entertainment.next

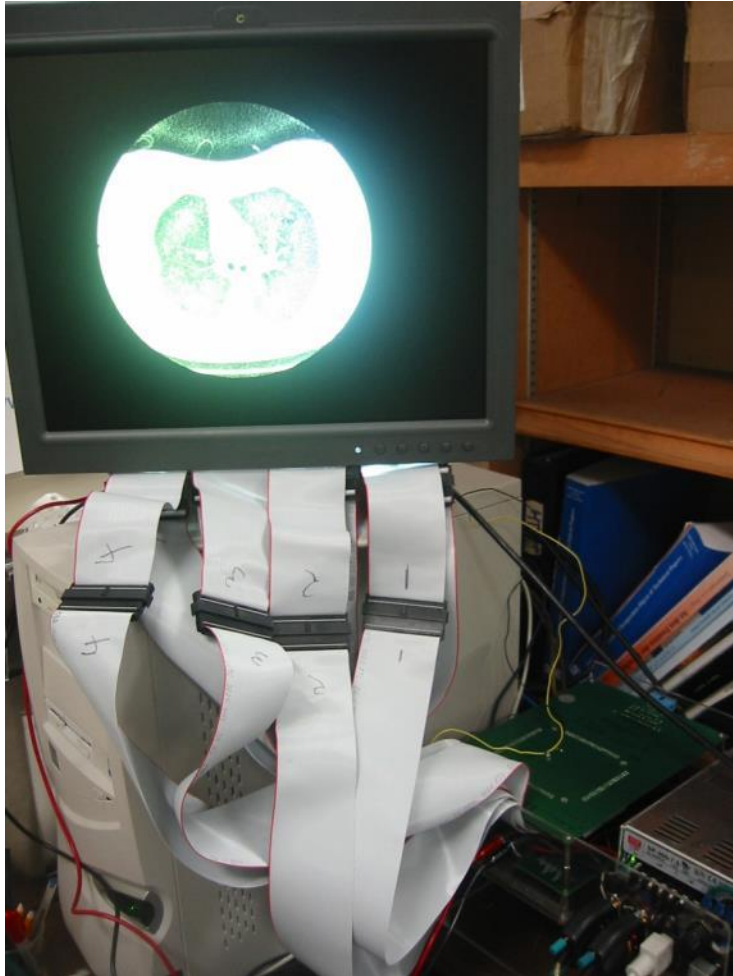


TANDEMLAUNCH

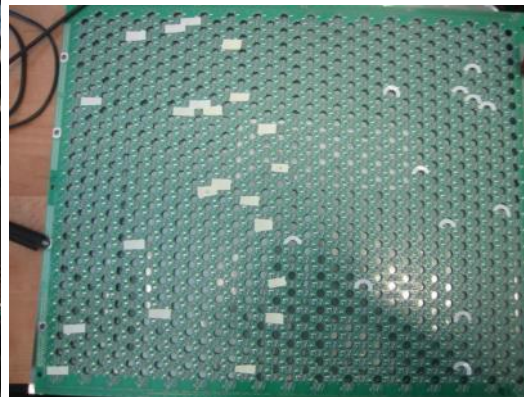
STUFF THAT WAS HARD THEN (BUT EASY NOW)



LED CONTROL & ASSEMBLY



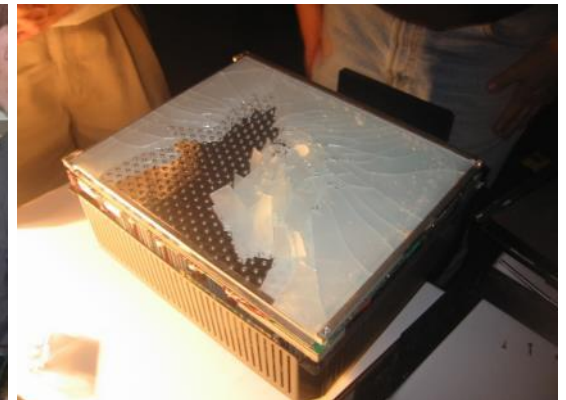
- ▶ NO DRIVERS FOR HB LED
- ▶ HIGH FAILURE RATE
- ▶ NO WAVE SOLDERING
- ▶ VERY HIGH CURRENTS
- ▶ NO EFFECTIVE BINNING



POWER & THERMAL MANAGEMENT



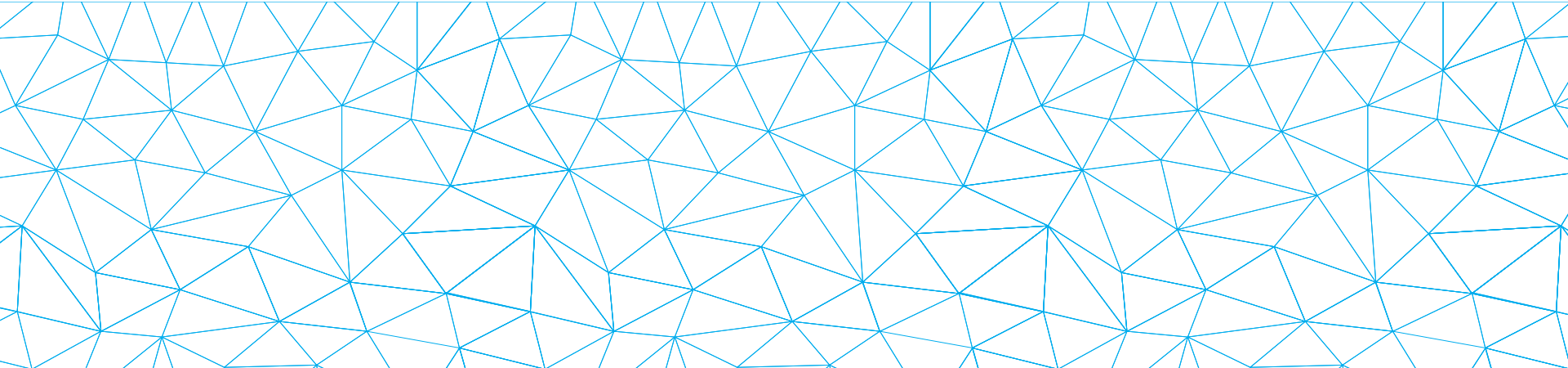
- ▶ 2,200W PEAK LOAD
- ▶ ~400A POWER SYSTEM (5V LED)
- ▶ LIQUID COOLING
- ▶ THERMAL STRAIN ON OPTICS
- ▶ MENTAL STRAIN ON USER...



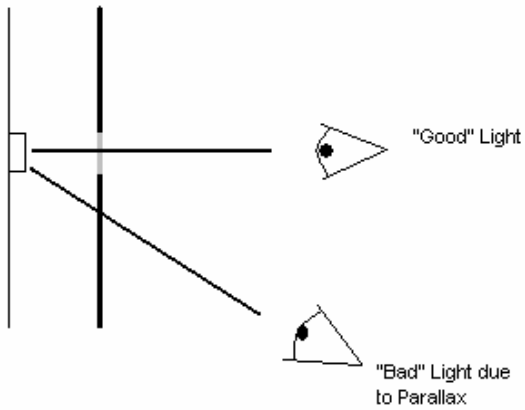
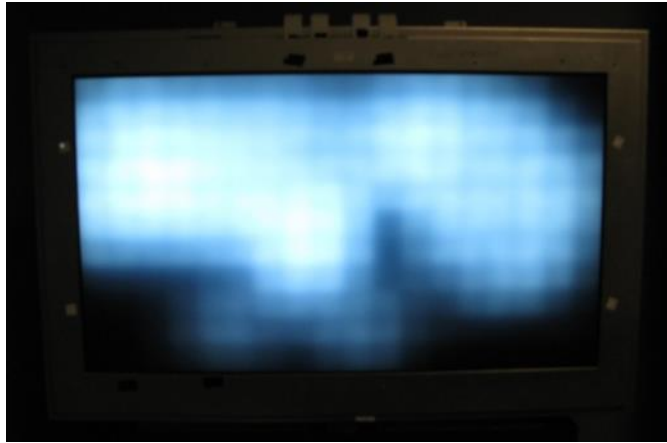


TANDEMLAUNCH

STUFF THAT WAS HARD THEN (AND STILL IS)

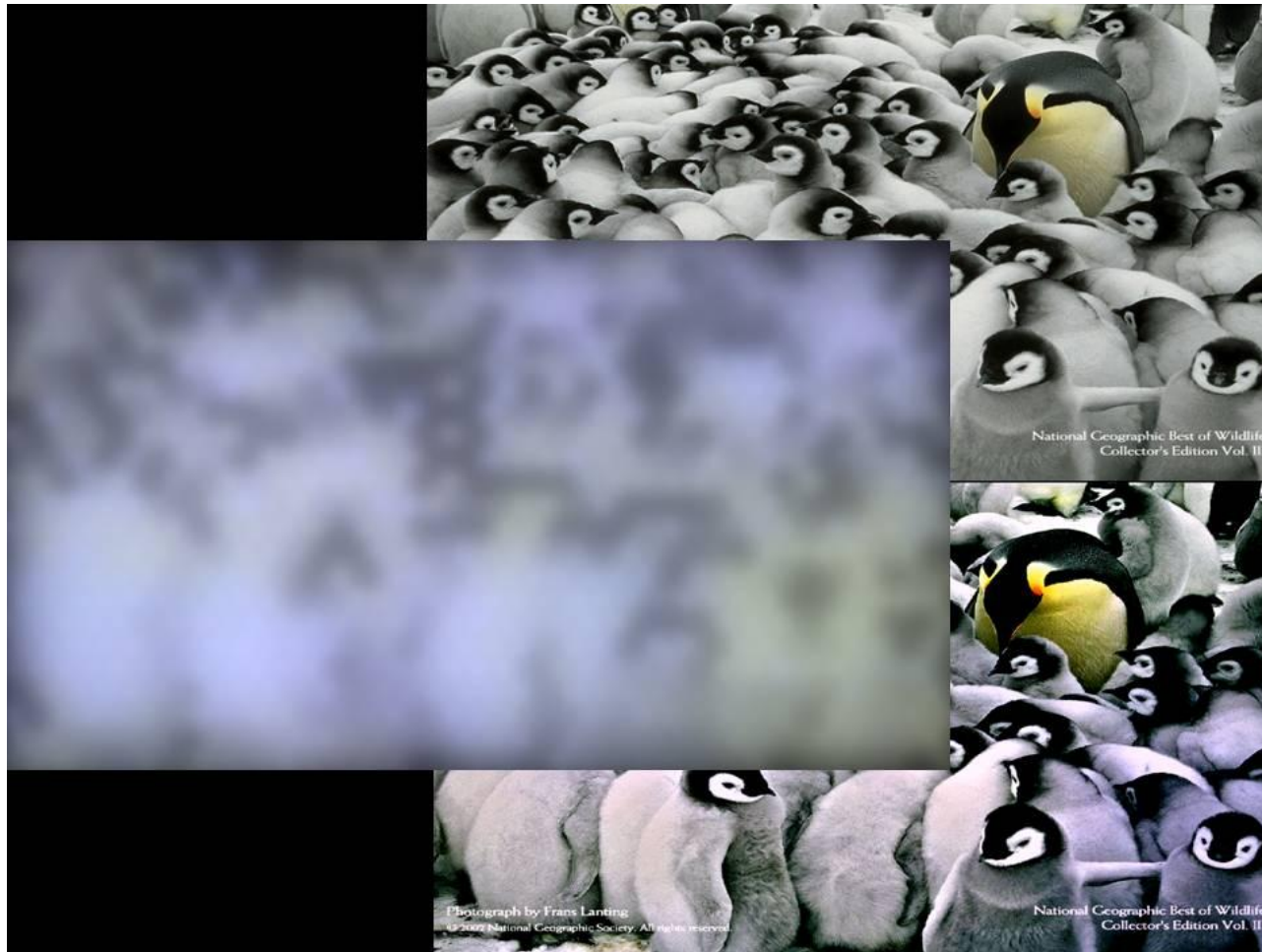


LED PSF MANAGEMENT



A Ballestad, T Wan, H Li, H Seetzen "Metrics for Local-Dimming Artifacts in High-Dynamic-Range LCDs-Local-dimming LCDs exhibit qualities and artifacts that cannot be captured by common ...", in *Information Display* 2007

INTERNAL COLOR MANAGEMENT



Helge Seetzen ; Samy Makki ; Henry Ip ; Thomas Wan ; Vincent Kwong ; Greg Ward ; Wolfgang Heidrich ; Lorne Whitehead; [Self-calibrating wide color gamut high dynamic range display](#). Proc. SPIE 6492, Human Vision and Electronic Imaging XII, 64920Z (February 12, 2007); doi:10.1117/12.720875.

EXTERNAL COLOR MANAGEMENT

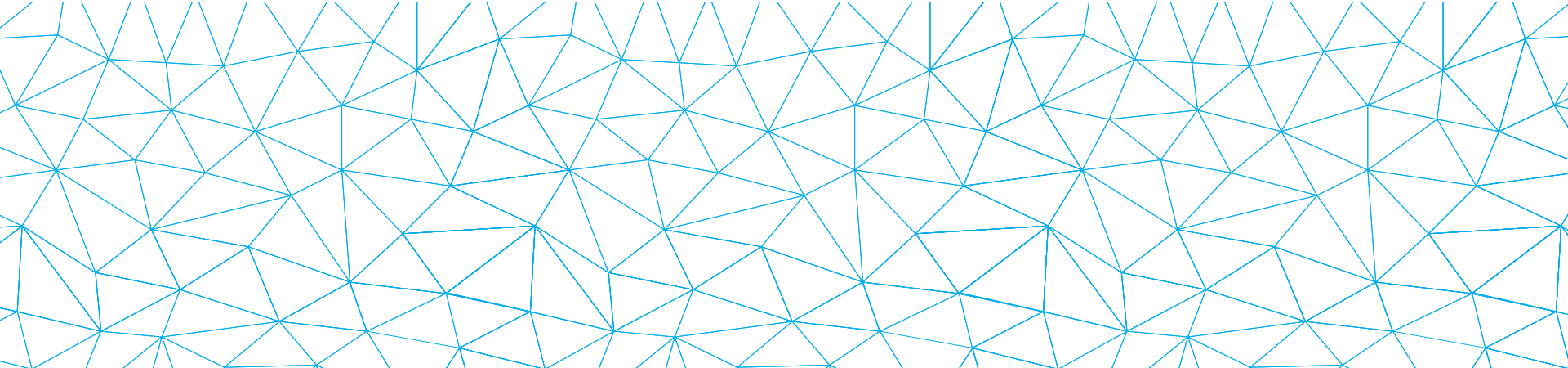
- ▶ GAMUT EXPANSION (“WIDTH”)
- ▶ GAMUT EXPANSION (“HEIGHT”)
- ▶ 3D GAMUT STANDARD NEEDED
- ▶ NO CLEAR OBJECTIVE CHOICES
- ▶ WILL BE FOUGHT ENTIRELY IN POLITICAL ARENA (STANDARDS)



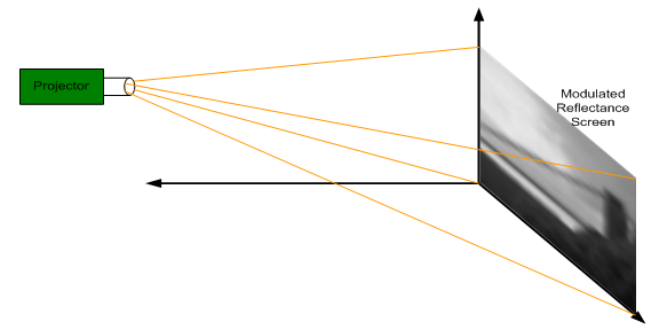
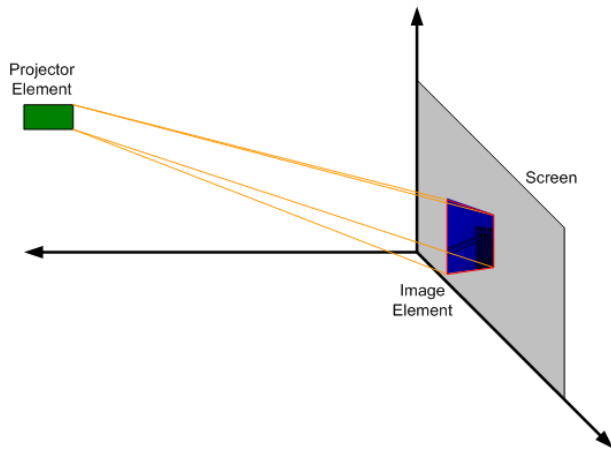
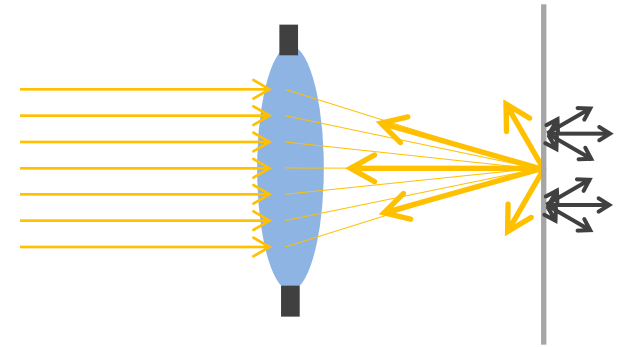
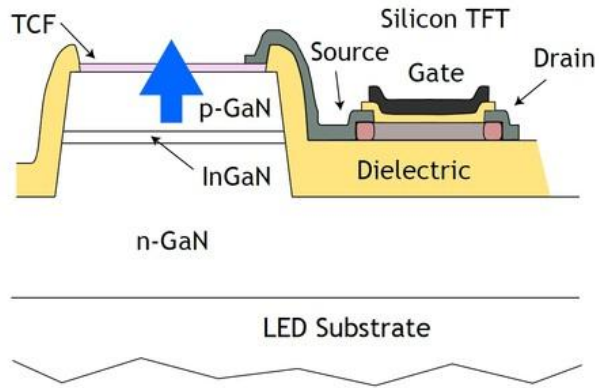


TANDEMLAUNCH

NEXT STEPS FOR HDR



BEYOND LOCAL DIMMING LED TV

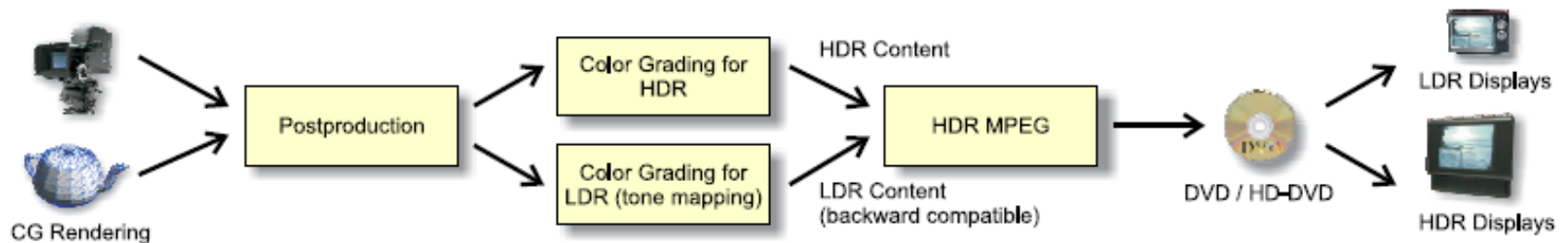


HDR ENCODING

- ▶ NUMBER OF BITS PER PIXEL
 - Minimize bits without sacrificing perceptual quality
- ▶ COLOR GAMUT COVERAGE
 - Perceptually uniform CIE (u',v') and future-proof gamut
- ▶ DYNAMIC RANGE MAGNITUDE
 - Real world about 14 orders of magnitude
 - Instantaneous human vision about 4-5 orders of magnitude
 - Min-Max needs to be a meaningful range for human vision
- ▶ LUMINANCE QUANTIZATION STEP SIZE
 - 1% is about threshold of human perception

HDR TRANSMISSION

- ▶ GOOD COMPRESSION (DESPITE LOW REDUNDANCY)
- ▶ BACKWARD COMPATIBILITY (EXCEPT IN SPECIALIZED OFFERINGS)
- ▶ FULL LUMINANCE AND COLOUR RANGE (IF POSSIBLE)



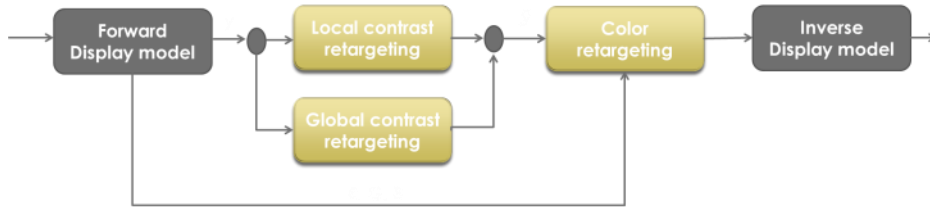
- ▶ BUSINESS ELEMENTS WILL INFLUENCE THIS AREA SIGNIFICANTLY

Ward, Greg, and Maryann Simmons, "[JPEG-HDR: A Backwards-Compatible, High Dynamic Range Extension to JPEG](#)," Proceedings of the Thirteenth Color Imaging Conference, November 2005.

Ward, Greg, "[A General Approach to Backwards-Compatible Delivery of High Dynamic Range Images and Video](#)," Proceedings of the Fourteenth Color Imaging Conference, November 2006.

Ward, Greg, Maryann Simmons, "[Subband Encoding of High Dynamic Range Imagery](#)," First Symposium on Applied Perception in Graphics and Visualization (APGV), August 2004.

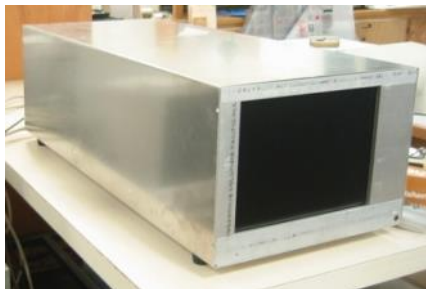
SMART IMAGE MANAGEMENT



- ▶ LOW LUMINANCE CONDITIONS
- ▶ HIGH LUMINANCE CONDITIONS
- ▶ ENVIRONMENTAL CONSIDERATION (INCL. MOBILE)
- ▶ LDR/MDR/HDR TRANSITIONS
- ▶ REPLACING TRADITIONAL FIXED-POINT SOLUTIONS

Rempel, Allan G., M. Trentacoste, H. Seetzen, D. Young, W. Heidrich, L. Whitehead, G. Ward, "[Ldr2Hdr: On-the-fly Reverse Tone Mapping of Legacy Video and Photographs](#)," *ACM Trans. Graph. (special issue SIGGRAPH 2007)*, August 2007.

Trentacoste, Matthew, W. Heidrich, L. Whitehead, H. Seetzen, G. Ward, "[Photometric Image Processing for High Dynamic Range Displays](#)," *Journal of Visual Communication and Image Representation*, Special Issue on High Dynamic Range Imaging, 2007.





LET'S MAKE THE FUTURE. TODAY.

