MEGAPIXEL
VISUAL REALITY

Megapixel Technology Overview

Calibration Metadata

Spring 2021

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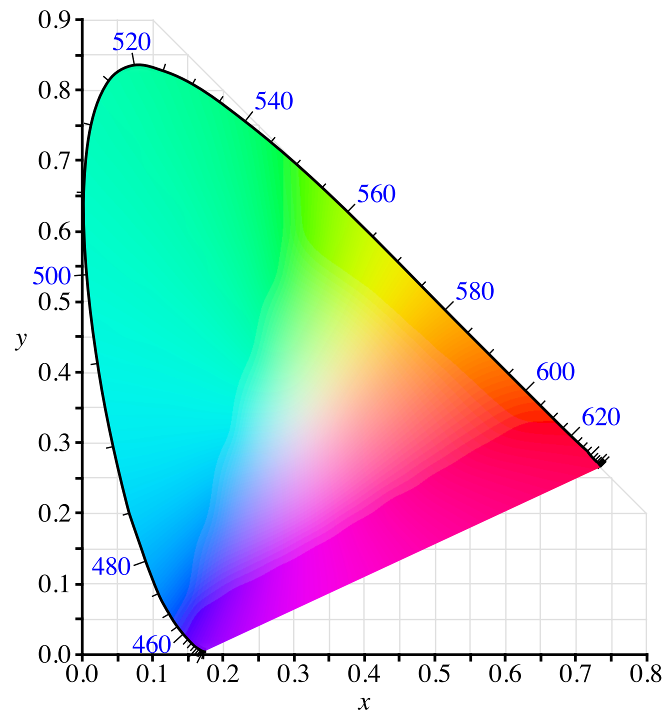
Background

Calibration technology for LED displays has existed for decades. With recent improvements in LED color gamuts along with the increased usage of HDR, there is now a greater end-user focus on color accuracy and calibration. Companies are marketing "new techniques" for calibration of LEDs, however today's best-practice calibration methodologies have been in use for years and have not changed significantly in the last decade.

Over the past several years in an effort to drive down production time and cost, manufacturers have devised ways to calibrate a display using precomputed data requiring less sophisticated control systems. Unfortunately, this deviation from best-practice methodologies has also yielded a significant sacrifice in image quality.

Megapixel VR's approach has always been to capture and store the most data possible in order to give a product the best performance with future-proof flexibility. In this whitepaper, we will explain the differences between various calibration data storage methods, why they are important, and how they are used over time.

C.I.E. 1931 Chromaticity diagram



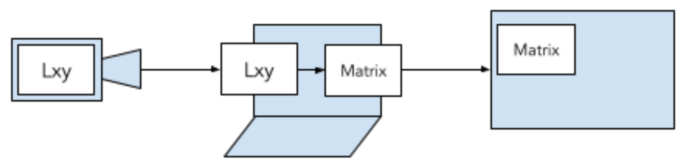
Raw vs. Precomputed Data

How data is measured and stored is one of the biggest differentiators between LED processing systems and displays. Today, many companies only store precomputed correction data in LED modules rather than storing raw measurement data. While working with precomputed correction data reduces the amount of storage and processing required within a tile, it creates many inherent limitations of which users are often unaware.

What are the differences between storing raw measurement data and precomputed correction data? Think of it in terms of a parametric math equation where the raw data is input for the variables. It is faster and easier to simply have one solution precomputed, however this makes it difficult to later adjust one of the input variables when only the output of the equation is stored. It is far more flexible to have the variables and full math equation available for solving different problems.

The increased processing power in the Megapixel PX1 receiving card provides the capabilities for working directly with raw data instead of the limitations of precomputed data.

Storing Precomputed Coefficients

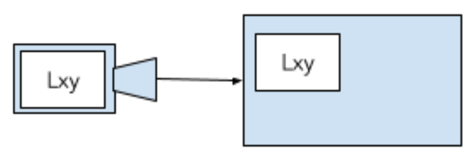


Precomputed (Rec.709) matrix stored per pixel:

0.5428	0.1895	0.0294
0.0650	0.8109	0.0044
0.0134	0.0686	0.8482

For each possible gamut required, an additional matrix must be calculated and stored on the LED tile.

Storing Raw Measurement Data



Raw measurement data stored per pixel:

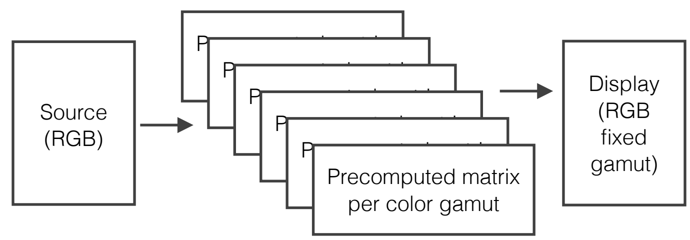
	L	x	y
R	146.7	0.7105	0.2877
G	403.7	0.2295	0.7241
B	35.4	0.1353	0.0514

L is for the luminance for a given xy chromaticity coordinate on the C.I.E chart.

In a typical color pipeline, the stored correction data is used to populate a correction matrix. Source RGB pixels are provided by an upstream input, processed through the correction matrix, and the resulting RGB values are used. There are a number of variables that go into this correction matrix, including those which compensate for per-pixel uniformity and color space differences. By precomputing the solution, which essentially creates one correction matrix, these variables become locked and extremely difficult to change.

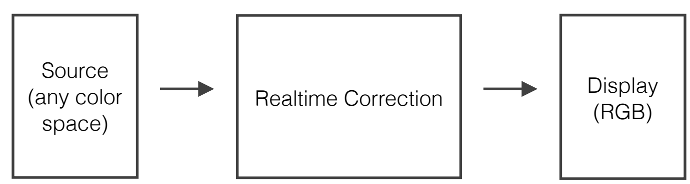
Some vendors work around this problem by providing several different correction matrices, or "calibration banks," to support different gamuts. At the time of manufacturing, there would be computations generated for a REC709 bank, a REC2020 bank, and other custom precomputed calibration banks.

Color Pipeline for Precomputed Data



New precomputed coefficients required for each future gamut. Re-calibration required for future color gamuts.

Color Pipeline for Raw Measurement Data



Any incoming color space can be accommodated within HELIOS, and any output gamut can be achieved with a mathematical formula in real-time.

If the original variables (i.e. the raw measurement data) are available, then it becomes possible to recompute the correction matrix "on the fly" for any desired color space. This allows for scenarios in which gamuts can be dynamically adjusted, or completely changed to another target, such as DCI-P3, without requiring additional tools or external processing.

Measuring and storing the raw values characterizing the LEDs requires more processing power in the display device, but provides greater flexibility and capabilities.

LED Tile sample measured data *(one pixel per row)*

Pixel		Red				Green				Blue			
Col	Row	Lv	Cx	Cy	λ	Lv	Cx	Cy	λ	Lv	Cx	Cy	λ
0	0	146.7	0.7105	0.2877	633.7	403.7	0.2295	0.7241	539.0	35.4	0.1353	0.0514	467
1	0	131.8	0.7096	0.2852	636.4	420.9	0.2217	0.7239	537.6	32.4	0.1386	0.0459	465.2
2	0	134.6	0.7136	0.2838	637.4	432.0	0.2173	0.7317	537.1	35.8	0.137	0.0479	466
3	0	144.1	0.7054	0.2894	632.6	432.3	0.2236	0.7271	538.0	34.4	0.1378	0.0452	465.3
4	0	133.2	0.7083	0.2874	634.2	370.0	0.2258	0.7292	538.5	27.6	0.1374	0.0451	465.4
5	0	139.7	0.7096	0.2879	633.6	414.7	0.2132	0.7338	536.4	33.2	0.1369	0.0473	465.9
6	0	142.5	0.7099	0.2856	635.8	433.8	0.2243	0.7287	538.2	32.6	0.1383	0.0426	464.7
7	0	139.1	0.7071	0.2876	634.1	436.0	0.2207	0.73	537.6	32.1	0.139	0.0451	465

λ = wavelength

Although tile pixels are predominately made of RGB pixels, there are other more exotic color compositions such as RGBW or RGCB. For these pixel compositions, it is extremely beneficial to have the raw measurement data to achieve unique color mix adjustments.

Real-time Correction Per Pixel

$$X = \frac{L}{y}x$$
$$Y = L$$
$$Z = \frac{L}{y}\left(1 - x - y\right)$$
$$XYZ_D = XYZ_M \; . \; TRA$$

	L	x	y
R	146.70	0.7105	0.2877
G	403.70	0.2295	0.7241
B	35.40	0.1353	0.0514

Raw pixel measurement

0.5428	0.1895	0.0294
0.0650	0.8109	0.0044
0.0134	0.0686	0.8482

Correction matrix computed "on the fly" for desired gamut

	L	x	y
R	106.32	0.6400	0.3300
G	357.58	0.3000	0.6000
B	36.10	0.1500	0.0600
W	500.00	0.3127	0.3290

Resulting desired gamut as measured on LED tile (e.g, Rec709)

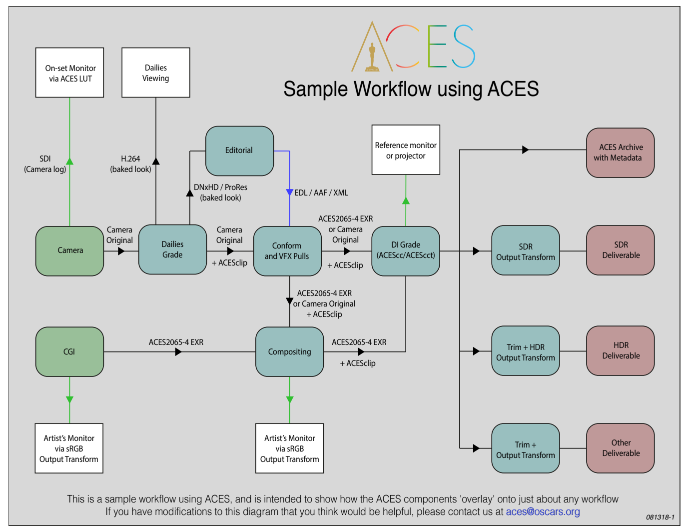
While storing raw measurement data requires more memory allocation than the precomputed approach, it is the best insurance for future-proofing a display when it comes to supporting new formats. Similar to the ACES (Academy Color Encoding System[1]) workflow which represents the complete color volume, storing the raw measurement data in the tile allows for new color gamut implementations on existing LED displays in the future without requiring recalibration.

This also aligns with Megapixel's philosophy of maintaining accuracy by preserving data and processing when and where it is needed. By preserving the video signal all the way through the entire chain, the native output gamut of the LED tile itself is changed, not simply altering the lower bit-depth signal feeding it.

Of course, the technique of utilizing raw data is not at all new. The team that founded Megapixel has designed, manufactured, and installed products that store raw measurement data in this fashion for more than 15 years. Storing raw data is not a magical new technology – it has always been the most technically correct way to store calibration data and is considered an industry best practice.

ACES Workflow

Sample workflow using ACES



[1] https://en.wikipedia.org/wiki/Academy_Color_Encoding_System

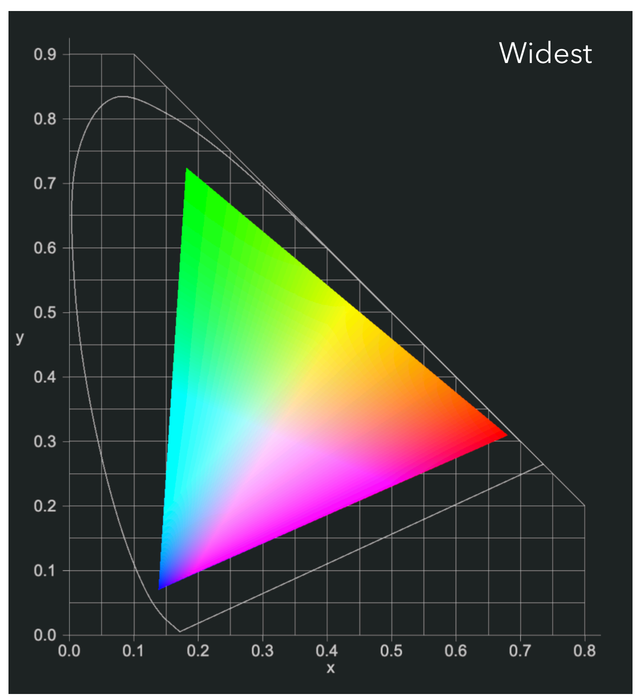
Dynamic Color Gamuts

One of the main principal advantages of having raw metadata stored in the LED modules themselves is to enable dynamic color gamut retargeting. This means the system can dynamically change the color gamut between current standards like REC709, DCI-P3, REC2020, and others. It also allows for creating custom gamuts on the fly; this is especially useful for on-camera tuning. In these environments, it is necessary to tune the display system specifically to the camera sensor and create a common workflow for color grading.

For other applications, the most vivid display is desirable with the widest possible gamut that the tiles can emit. This can be accomplished by analyzing all the raw measurements and determining the widest gamut reachable by all pixels in all the connected tiles.

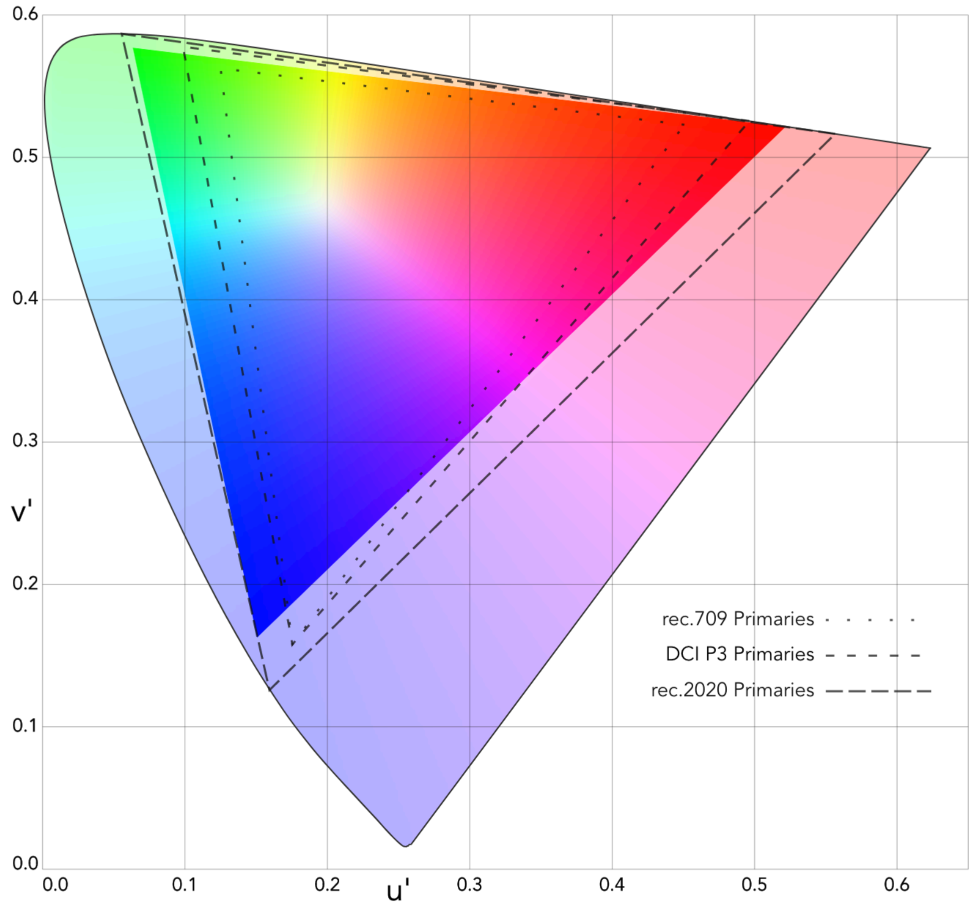
Color Gamut Manipulation

Example ROE Ruby LED tile

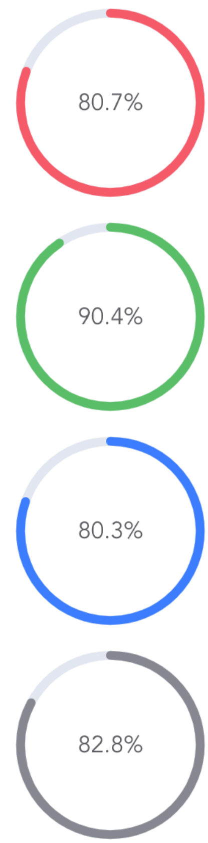


ROE Ruby Calibration Report 2020-02-14

CIE u'v' Chromaticity Diagram



ITU Rec.2020 Coverage



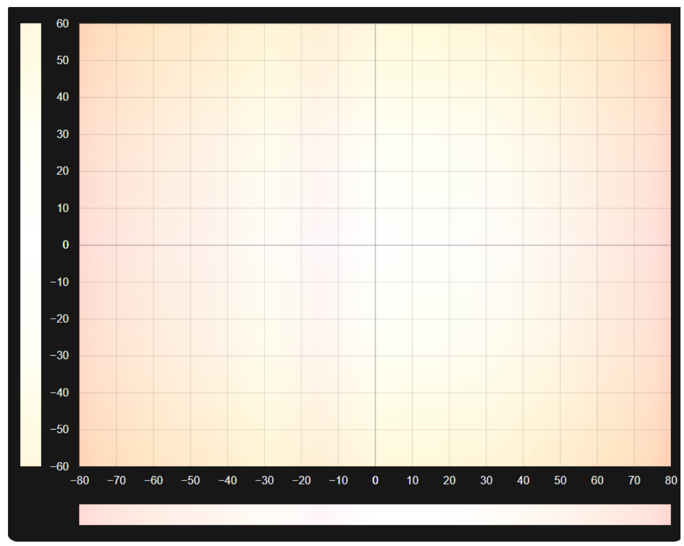
Color Standard		Red	Green	Blue	Total
ITU Rec. 2020	Primary Saturation	90.7%	93.4%	89.7%	
	Gamut Area	80.7%	90.4%	80.3%	82.8%
DCI P3	Primary Saturation	108.0%	117.1%	99.4%	
	Gamut Area	106.9%	136.3%	107.5%	113.6%
ITU Rec. 709	Primary Saturation	127.0%	142.9%	99.4%	
	Gamut Area	138.6%	195.3%	117.9%	142.6%

** Gamut percent coverages in Megapixel's ColorVis calibration report are calculated as the area covered by a quadrilateral for each primary. For example, the blue calculation is performed as an area calculation for the region bounding from white to blue to cyan to magenta. The saturation of the primary is represented by the length of the line drawn for that gamut.*

Off-Axis Color Metadata

An exclusive Megapixel feature is to capture each tile's off-axis color performance during the calibration process. Tiles are typically measured and calibrated for viewing from a single, head-on vantage point. However, when viewed off-axis, tiles tend to exhibit significant color shift due to the physical LED arrangement or shader occlusion. This color shift is especially problematic for large screens with different vantage points and virtual production volumes that may have different camera angles relative to the display. Color consistency and accuracy are critical in these applications. Using the off-axis metadata, Megapixel has proprietary solutions that allow for correcting off-axis performance in real-time.* This gives cameras in virtual production environments a uniform, color shift free canvas. To the right is an example of an off-axis correction plot showing color shift measurements as the tile angle varies by +/- 80 degrees horizontal range and +/- 60 degrees of vertical range.

Off-Axis Color Performance



Example off-axis simulation from tile metadata

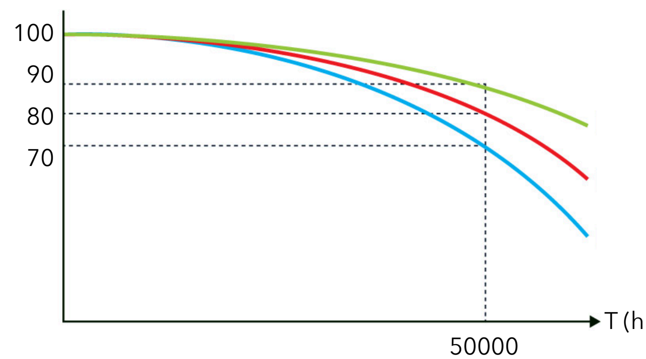
**Patent pending*

Virtual Aging

In addition to storing raw measurement data, Megapixel also stores environmental metadata such as tile temperature, ambient temperature, and humidity. Each tile also stores its total runtime. Combining this metadata allows for uniformity compensation over time while reducing the need to perform frequent recalibration.

Screens often operate at +/-10C from the temperature at which they were originally calibrated, which can dramatically affect overall color temperature. This is the reason operating environment is critical for maximum performance as well as having a processing system that is capable of compensating for these effects.

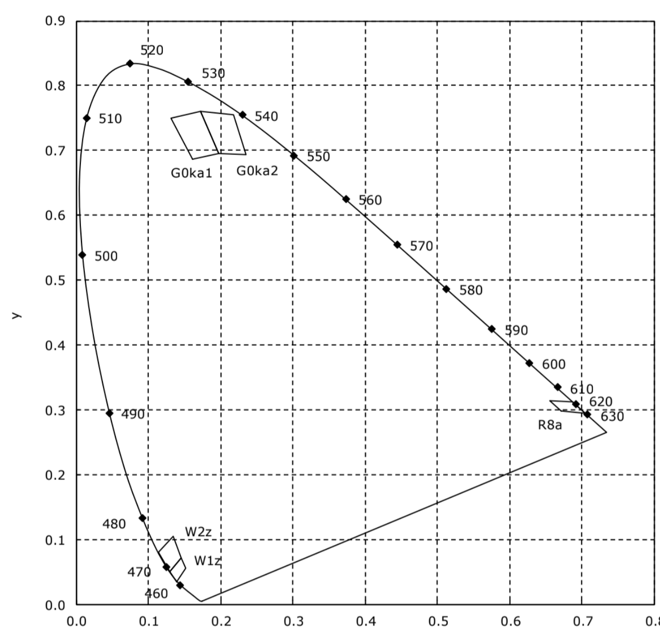
LED Output Over Time



Batch Matching

Calibration is often seen as the tool that can fix any problem in matching tiles between batches. Because of physical differences in the LEDs and current-limiting resistors used for a given batch of LEDs, it is not always possible to address all differences in calibration, yet having the raw data allows the system to recalculate and match gamuts for the tiles within a given screen.

Example LED Binning (CIE1931)



Recalibration

Recalibrating tiles outside of a controlled factory environment rarely produces results as good as the original calibration. Factory calibration is typically done in a light-sealed tunnel with tightly controlled environmental conditions to consistently produce the best results. Tiles often undergo recalibration to compensate for aging or to match new color targets, however with our comprehensive raw measurement data and metadata storage we dramatically reduce the need for this process. Chromaticity changes very little over an LED package's lifetime, and degradation occurs mostly in relative luminance. If panels need recalibration later in life outside of a controlled environment, it can be accomplished by simply adjusting module chromaticity and gains, rather than requiring full-fledged, per-pixel re-measurements. Megapixel's HELIOS platform has tools that enable fast and easy corrections on-site to make these adjustments.

Photo Research
PR-670 Spectroradiometer

Calibration Data Storage

Where should all of the metadata be saved? Many display manufacturers store data on the receiver card or HUB PCB of a tile. In most tile designs, LED modules connected to this component can be replaced, resulting in the stored data no longer matching the appropriate LED module location. This results in the cumbersome need to re-upload calibration data to accommodate replacement of an LED module. Therefore, Megapixel always advocates for storing metadata directly on the LED module/PCB itself. This ensures all modules always carry their own metadata, no matter their installed location. Megapixel offers reference schematics and layout files to our manufacturing partners to ensure they use the correct memory type and size on each LED PCB.

Megapixel Kelvin LED Tile

Data stored on each module

Build vs. Buy

Calibration equipment for processing platforms varies widely. We considered the choice of "build vs. buy" seriously. Some manufacturers go to great effort and expense to package cameras into proprietary calibration systems despite the fact that the instrumentation market is already mature with extremely accurate and trusted tools.

Megapixel believes that it makes little sense to divert resources to reinvent the calibration equipment supply chain. A proprietary system becomes expensive to maintain and can quickly lag behind the industry without constant updates and additional equipment investment.

We use the best-of-breed imaging systems available in the market. Just as the HELIOS Platform adopts high-reliability, resilient IT infrastructure for data distribution, we chose to utilize ColorSpace Technology in our calibration process. ColorSpace is solely focused on calibration cameras for professional displays and has a wide range of cameras, lenses, and sensors. Additionally, many LED manufacturers already own this equipment.

At Megapixel, we focus our efforts on superior image processing technology to give customers the best display performance.

Calibration Equipment

ColorSpace PM-30

Fluke Infrared Camera

About Megapixel VR

Megapixel is an innovative technology partner dedicated to delivering fast-tracked, customized, state-of-the-art LED displays and processing to the world's leading artists and architects.

Our unrivaled team of engineers and designers consistently delivers the most unique and breakthrough LED solutions to market, helping our visionary clients bring their ideas to life in ways that inspire a sense of wonder and make the seemingly impossible possible. With over 200 patents and award wins from Live Design, the Emmys, and the Oscars, we endeavor to always be at the forefront of digital displays and technology for which we set the bar as the industry standard.

We provide superior product design development, manufacturing expertise, and successful deployment to deliver unsurpassed visual performance for any project and look forward making the world's next iconic projects a reality.

Visit www.megapixelvr.com for more information on HELIOS.

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Jeremy Hochman
CEO & Innovator
20 years experience
LED Video Design & Manufacturing

Previous

- Executive Director R&D, VER
- Director of Product Management, Barco
- Founder, Element Labs *(acquired by Barco)*

Major Product Accomplishments

- All VER / Revolution Display LED systems
- Barco C-Series
- Element Labs COBRA tile
- World's first creative mapping software (RasterMAPPER)

Keith Harrison
COO
30+ years experience
LED Video Operations

Previous

- Executive Director LED, VER
- Managing Director, PSL Los Angeles
- Managing Director, Gearhouse Los Angeles

Major Project Accomplishments

- MGM Macau – Spectacular, Theater, Exterior
- Radio City Music Hall, NYC
- Coldplay "A Head Full of Dreams" Tour