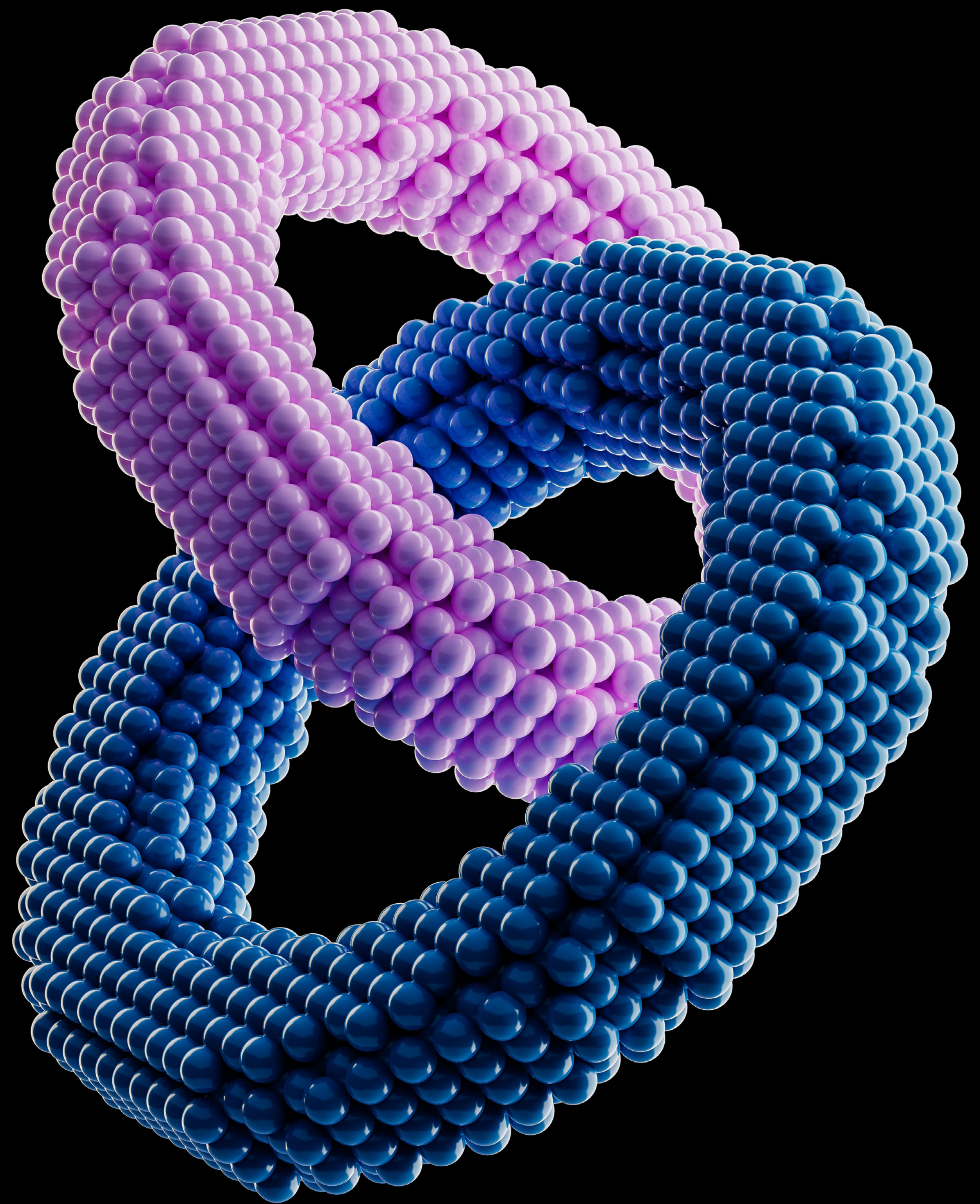


THE BROADCAST BRIDGE
Connecting IT to Broadcast

Virtual Production For Broadcast

Part 4 - Uniting The Physical & The Virtual

A Themed Content Collection from The Broadcast Bridge

Themed Content Collection

Contents

Series Overview

By Tony Orme. The Broadcast Bridge.

Virtual Production For Broadcast is a Themed Content Collection which serves as a reference resource for broadcast technologists. It covers the science and practical applications of all aspects of virtual production for broadcast.

Virtual Production is rapidly becoming the workflow of choice in cinematic and episodic TV production. With large-scale multi-location productions there are potential cost benefits but it is the versatility, creative scope and the improved efficiency it can bring to production spaces, that are the compelling forces driving adoption.

The basic principles of back projection and greenscreen have been with us for decades and are already commonplace in TV production, especially in news and sports, but the creative versatility of virtual production brings fundamental technical and creative differences. The technology and techniques of virtual production are also evolving very quickly and there is not yet a standard approach, with different teams establishing their own approach.

Virtual Production For Broadcast provides a deep exploration of the creative techniques, technology and workflow involved. It discusses what currently can and cannot be achieved, with a specific focus on the unique requirements of broadcast production.

It is essential reading for those evaluating incorporating virtual production technology into new studio design and exploring the creative benefits it can bring.

Virtual Production For Broadcast is a four part series:

All 4 parts are now available:

Part 1. The Foundations Of Virtual Production

Part 2. Planning, Virtual Worlds & Virtual Lighting

Part 3. Creative Image Capture

Part 4. Uniting The Physical & The Virtual

Image Based Lighting

By Phil Rhodes. *The Broadcast Bridge.*

Ensuring consistency of lighting between the virtual world and physical objects on set requires controlling production lighting based on image content.

Video walls are not generally sources of high color quality light. So, it's sometimes necessary to reinforce that light with conventional production lighting, though naturally, that lighting must react to changing conditions in the virtual world. Using a rendered image to control production lighting adopts the video game and CGI technique called Image Based Lighting.

One of the key advantages of virtual production is that the LED wall can be sufficiently powerful to cast light on real-world, foreground objects. Like a lot of virtual production techniques, though, interactive lighting is related to approaches which have been used since the dawn of cinema. Fire might be simulated with a flickering orange light, or the passing street lights of a night drive with conventional production lighting, moving past a car that's really stationary.

Image Based Lighting

Normally, that kind of lighting trick might be achieved with no more technology than someone hand-holding a light. Even before the availability of virtual production in the current sense, video displays had been used to cast light on a scene, particularly in 2013's Oblivion, where front-projected backgrounds were allowed to light entire scenes. At around the same time, Gravity used LED video wall panels, but not to create a convincing background image. The panels of the time lacked the necessary resolution, at least at practical screen sizes. Instead, the cast were surrounded by LED panels intended to cast convincing interactive light for spectacular, dizzying space scenes.

LED walls have now improved enough to provide both background images and interactive light. The result recalls image-based lighting which has long been used in video game and visual effects development, where a 360-degree photograph of a location is used to control the fall of light on objects. The LED wall does this by its very nature, but additional production lights can be controlled by the image rendered for a virtual production stage too. When there's a spectacular purple and amber sunset in the sky, overhead lighting might automatically turn purple and amber to match it, without needing an overhead video wall.

The Compromises Of Virtual Light

One reason we might want to use additional production lighting, as opposed to relying entirely on the LED wall, is color quality. Many people are familiar with color quality metrics such as CRI and TLCI. CRI was designed a long time ago to evaluate home and workplace lighting, and is often not a sensitive enough test for cinematography. Regardless how we measure, though, projected and LED video displays invariably score very poorly on all metrics of color quality, meaning that real-world subjects - particularly people - may not look as we would expect.

This happens because effectively all LED video walls are built using red, green and blue LED emitters. While they might seem to combine into white light, measuring the result with a color meter reveals that the light only looks white; it still has only three peaks of red, green and blue, as opposed to the continuous spectrum of (say) sunlight. No correction or calibration can solve this problem; it's the same issue which afflicts very low cost lighting intended for entertainment venues and live events, which may also have solely red, green and blue emitters. As a result, any object which reflects saturated colors other than bright shades of red, green and blue may appear muddy and poorly-illuminated.

Production Lighting

Production lighting may use red, green and blue LEDs, but it will also include other types. Commonly, white emitters use an underlying blue emitter to make a yellow-emitting phosphor glow, creating a more continuous spectrum. Many other configurations are found in quality production lighting. Many production lights have remotely-controllable color behavior, which may allow the color and brightness to be controlled automatically by video images in the same way as image-based lighting in a visual effects environment.

That can work for a single, point-source LED emitter, which might simulate sunlight, something LED walls often struggle to do. While bright, they can't generally produce a small spot of light that's bright enough to illuminate the scene as the sun would. Overhead lighting such as spacelights might change color to match a sky. Possibly the most advanced expression of image based lighting in virtual production, though, involves a technique which has sometimes been called pixel mapping. With pixel mapping, production lighting, sometimes in tube format, is made of individually-controlled pixels an inch or two square.

Assembling an array of tubes creates, in effect, a low resolution video display which can be controlled in much the same way as the LED wall itself. That can create more realistic reflections and more accurately simulates the complex fall of light on the scene, with excellent color quality, and in a way that has never been possible with conventional post production visual effects.

Connectivity & Control

Film and television production lighting invariably offers DMX as at least one of its supported control protocols. A simple DMX connection may be enough to control a single light intended to simulate, say, sunlight. Where a large array of pixel-mapped lights are used, the number of control channels needed quickly exceeds what's practical using conventional lighting control systems.

Some lighting control consoles are capable of working with video material in order to derive the control signals for the light from the image itself. In other circumstances, particularly where lots of pixel-mapped lighting is in use, a computer-based media server will be responsible for creating DMX control signals based on image content. Approaches which send DMX data over Ethernet connections are often used, especially on computer-based control systems, sometimes called media servers.

Details of the process for controlling any light using a video image varies depending on the specific hardware involved. Usually, there will be facilities to control a single light based on a single point in the video image, or to average an area of the image to control one or more lights. Pixel mapping means defining an area of the video to be displayed on the pixel-mapped lighting. That might mean scaling down the video, since the array of pixel-mapped lights will invariably be much lower effective resolution than the LED wall itself.

Color & Brightness

For all these techniques to be meaningful, the color of the light must match the color displayed on the LED wall. This is not always easy, since, as we've seen, the LED wall and the lighting devices, while both LED-based, generally don't use the same emitter types. The underlying technology is often very different.

Solving this problem means addressing two issues. The first is colorspace. Most people understand that a color image relies on red, green and blue components. A colorspace defines exactly what shades of red, green and blue we're using, which controls which shades are possible; for instance, there can be no blue that is a deeper blue than the blue emitter turned on, while the red and green are off. The colorspace used by video signals are generally specified in documents such as the ITU-T's Recommendation BT.709, among others.

The second issue is brightness encoding. Most production lighting is photometrically linear, so that movement of a control slider is (roughly) proportional to the number of photons that come out. To reduce exposure one stop we reduce the control signal by 50%. That's not how video gamma encoding works, for reasons connected to noise and the behavior of legacy display technologies.

Production lights intended to be part of image-based lighting setups may support various brightness encoding standards and colorspaces. Ideally, an LED video wall and the nearby lighting technology will all be capable of using the same standards, meaning that data can be extracted directly from the video and sent over DMX to the lights. In reality, that ideal may not always occur, and there may be some manual adjustment involved.

Image Sources

Image-based lighting must have images from which to derive its control signals. In most situations, two images appear at once on a virtual production display. First, the system establishes exactly where the camera is, where it's aiming, and how its lens is set up, and it renders a high-resolution image of the virtual environment onto the wall in the appropriate area. Second, the rest of the wall, which will not be seen directly on camera, is filled with a slightly simpler, static approximation of the surrounding area, intended to create appropriate reflections and fall of light on real-world foreground objects.

That static surround will generally be the source of data for image-based lighting, changing as the scene in general changes (and not, necessarily, reacting to the motion of the taking camera). This approach works well when a light is controlled by part of the image which appears on the LED wall. Some lights, however, might need to be controlled by information that isn't part of the LED wall image, such as a sky where there is no overhead LED wall. In this situation it is sometimes possible to ask the virtual production facility to render a specific video feed, from an upward-facing virtual camera, to create lighting control data.

In Practice

Image-based lighting has the potential to create interactive lighting effects which further enhance the already-impressive realism of virtual production. Particularly, the option to use conventional production lighting devices which are intended to produce light of high color quality can avoid the compromises of LED wall light, ideally creating a best of both worlds that's both convincing as an effects tool, and ensures foreground subjects always receive flattering, accurate light.

New RGBW LED Technology

By Phil Rhodes. The Broadcast Bridge.

New technology in the manufacture of LED video wall panels has the potential to bring improvements to how color is reproduced and to expand the creative options available within virtual production.

LED wall based virtual production relies heavily on a fairly new display technology. Most of the LED video wall panels used in current practice are related to designs intended for advertising, boardrooms and demo suites which can tolerate the cost of such a high performance display. Fantastic as they are, though, those installations are intended to look good to the eye. They weren't designed to look good on camera or behave as sources of light which are suitable for cinematography. It wasn't until very recently, in early 2023, that we began to see video wall panels specifically designed to address those concerns, and a few others.

Compare LED Lighting

Accurate, believable interactive lighting which reacts correctly to the environment is one way in which LED wall based virtual production separates itself from green screen, and a large part of how it produces such convincing results. The problem is that most video wall panels use the same configuration of LED emitters as the most basic lights which are intended for live events and nightclubs where color quality matters less than impressive visuals.

LED lighting of that type is at best suitable for bold color effects in film and TV work, and essentially all video wall panels have very similar color problems. Sometimes this situation can be controlled with careful configuration, although no amount of adjustment in production or post can fill in the gaps in the spectrum of light created by a simple emitter array. The panel does not emit (for instance) turquoise light; a turquoise object may simply look blue.

One solution coming to market in 2023 is video-compatible panels which include a white emitter alongside the red, green and blue. Whenever a single pixel is required to output a color which isn't entirely saturated, the white emitter will be used to create as large a proportion of the total output as possible, with the red, green and blue emitter used to trim and balance the desired color. It's not a perfect solution, much as no modern LED production light is a perfect solution, but it's likely to improve things significantly.

Video Color Standards

Despite the colorimetry issues with LED video wall panels, some cinematographers choose to rely on them as much as possible, even using individual panels as lights to add extra light where it's required. The motivation for doing that is that while the light is not ideal, it will at least match the wall. Matching production lighting may be more difficult. A video imaging standard such as Rec. 709 defines (among other things) which shade of red, green and blue is used to describe the image. Video walls tend to implement those standards. Lights often don't.

This complicates techniques such as pixel mapping, where data from the video image is used to control lighting. Send the same numeric values to the video wall and to production lights, and unless those lights implement the same color standard as the wall, the color will not match.

Solutions to this problem must come from the people who manufacture production lighting. Only the manufacturer has the requisite information about the exact configuration of emitters and the behavior of the light's firmware.

Gamuts

Finally, virtual production walls might soon develop the ability to show a wider range of colors. In principle, many of them already can, although broad adoption of the long-established Rec. 709 standard designed for television means that many video walls operate at less than their full potential. Generally this isn't hugely noticeable as many subjects just don't include many colors outside the Rec. 709 range, but there are some exceptions. Tropical water should look deep turquoise, but often just looks blueish.

This is an issue of compatibility more than capability. Many video wall panels, the receivers which drive them and the processors which send data to those receivers can implement reasonable coverage of much more capable standards. Software such as Unreal Engine, through its implementation of OpenColorIO, can produce compatible image data. Switching those capabilities on requires the entire signal chain to handle wider color gamut data. Wide color gamut is perhaps overlooked because the shortfalls are often not very obvious without a side-by-side comparison.

Speed

LED video walls control their individual emitters using pulse width modulation, flashing the light on and off very rapidly so it appears to be illuminated at less than full brightness. PWM can create complicated problems when the flicker of the light interacts with the shutter timing of the camera, especially at high frame rates or when the camera has a rolling shutter (as almost all do, even at the high end). As such, the rate at which a panel performs PWM is a key metric as to its suitability for various productions.

The speed of that pulse width modulation has other implications, too. Faster PWM rates provide more levels of dimming. If the light can only be turned on or off ten times per camera frame, it can only appear at ten discrete levels of brightness. High-end, modern cinema cameras are often capable of at least 12 or 14 bits of dynamic range, meaning (in the most straightforward sense) 4096 or 16384 levels of brightness. Many video walls used for virtual production are fast enough to achieve 10-bit, or 1024 levels, at common frame rates. That's already less than most cameras, even at normal frame rates. At higher frame rates, things become more difficult.

Since the human eye is not fast enough to perceive most of these problems, there is little incentive for LED panel manufacturers (or at leas the manufacturers of the underlying LED driver chips) to build faster devices. As with the white emitter added to panels specifically intended for film and television work, the demand for speed applies almost exclusively to virtual production, which might make solutions rare and expensive.

High Frame Rate

High speed shooting for slow motion is another concern, since the faster the camera, the faster the video wall must be. For live broadcast work, it's possible for several cameras to observe the same video wall if the cameras are configured with appropriate shutter settings and genlocked such that they shoot their frames sequentially, rather than simultaneously. The tiny timing error will not be noticeable to the audience, and it allows the video wall to switch images in time for every camera to view an image individually perspective-corrected for that camera's position and orientation.

Current setups can handle perhaps four cameras; many studios prefer more, and faster displays might make that possible, at least to the point where very short exposures on each camera might start to create odd-looking blur artifacts. Similar techniques are used to display camera-tracking data on a virtual production wall such that the taking camera does not detect it, but a witness camera does.

Resolution

Video wall panels for virtual production are often chosen to maximize resolution. That's partly because finer-pitched LED emitters require less defocusing of the background and create a lower risk of moire patterning. The problem being addressed is fill factor, the proportion of the display which emits light as opposed to simply being black. While LED panels have traditionally had rather poor fill factor, that's also been part of the advantage: the panel is largely a black object. As such, it's less obvious when normal production lighting illuminates the wall than it would have been with a white projection screen.

So, panels with denser LEDs are a double-edged sword, though that hasn't halted the drive for resolution. The finest resolution available at the time of writing was under one millimeter, approaching 0.6mm. The resolution of LED wall panels and the OLED and LCD technologies used for TVs and monitors might soon begin to coincide, perhaps in a technology sometimes called microLED, which seems likely to provide far more resolution than any virtual production stage could reasonably demand.

The push for pixel count sometimes leads to the video wall having a very high overall resolution in the tens of thousands of pixels, which presents a high processing load to the rendering servers. It might be more information than is realistically required for good results. The question of how much resolution is useful or necessary depends on the specifics, but even in current practice, a wall might be driven with an upscaled version of an image which has fewer pixels than the wall. Doing so lightens the workload while still using a wall with closely-spaced emitters for moire avoidance.

Obsolescence?

A key is the effect that future improvements to LED video wall panels might have on the popularity of the existing installed base of facilities. The wall panels are often the largest capital expenditure required to set up a virtual production stage. Whether these potential technologies might become mainstream, and the effect that might have on previous-generation facilities, is hard to predict. At best it will create choice: existing facilities might become more affordable, while more recent installations might become more capable, a status quo which is hard to dislike.

Finishing

By Phil Rhodes. *The Broadcast Bridge.*

The goal with in-camera LED wall based virtual production is to capture the final image on set, to eliminate the need for compositing in Post. How much is left to finishing and grading?

Whether or not virtual production counts as a special effect or a visual effect is an interesting question, since it involves techniques traditional to both fields. Effects which happen in camera, on set, are generally special effects, and in that context virtual production is a special effect which should, in an ideal world, be ready for cutting directly into a finished production. There should be nothing to do in post production beyond the same sort of grading that any camera original material might need.

In anything other than an ideal world, the post production team might need to take at least some care to ensure virtual production scenes look as real as they should. The most involved post production work will usually be reserved for fixing problems which perhaps should have been detected and worked-around on set. As with so much of film and TV production, there's a fine line between things which can be, or must be, addressed in post, and more complicated issues which are worth correcting on the day.

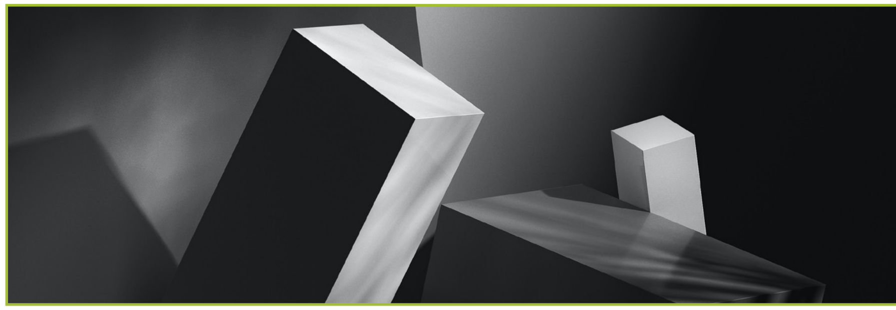
Matching Real-World Brightness

A perfect LED video wall would have enough brightness such that its brightest white highlights would cause the camera to create its own brightest possible white. Given that, highlights in the LED wall appear clean and properly-rendered. However, modern cameras often have very high dynamic range, so that may not be possible. Many background images displayed on the LED wall will still contain at least some small highlights, however, and these must match the highlights in the real-world scene. Otherwise, the background image risks looking dull, with clipped greyish highlights, and identifiably not a real scene.

Often, this problem will disappear when a fairly normal grade is applied to the image. Grading for a standard dynamic range finish involves managing the dynamic range of the camera, which is often at least fourteen f-stops, to fit into the dynamic range of a standard dynamic range display, which is often less than ten. This inevitably means extremes of brightness and shadow are reduced, often making the peak whites of both the real and virtual scenes similar enough that the problem vanishes without too much special attention.

Sometimes, especially when grading for a high dynamic range delivery, it might be necessary to adjust the brightness of the virtual scene, and particularly its highlights, to match the real world scene. The best approach will depend heavily on what's in frame, although it may still be handled in grading, perhaps using shape isolation to control just that part of the frame which represents the relevant area of the video wall. In particularly difficult cases, more advanced visual effects techniques might be required where LED wall highlights interact with the foreground scene in complex ways. With proper technique, problems that severe, and that complex, ought to be rare in practice.

In marginal situations, virtual background images, whether rendered or photographed, can avoid clipped highlights and therefore avoid or minimize the problem, though the LED wall must still be bright enough for reasonable exposure. In general, an appropriate monitoring LUT which compresses highlights in a manner closely approximating the final grade can give some confidence that the results will be as intended.



...And Real-World Shadow

Maintaining realistic black levels is a problem which has existed since the popularity of back projection. White projection screens were inevitably prone to pick up ambient light from the scene, raising the black level of the projection to levels which could affect the success of the shot. Virtual production is much less prone to the same problem because the video wall is mostly black. Even so, at least some part of the wall surface is made of reflective plastic LED emitters, and so it's still possible to suffer black level problems if light is allowed to spill onto the screen.

The best mitigation is therefore to avoid light spilling onto the screen, which is why gaffers working with virtual production will ensure there are lots of black flags on hand. Some setups make this more practical than others. A heavily-backlit sunset might make it easy to avoid light falling on the screen; a day exterior under directionless overcast, perhaps created by an array of overhead soft lighting, might be more difficult to control.

Beyond just flagging light off the screen as much as possible, anticipating and avoiding black level concerns might involve similar techniques to those used to preview white level issues. It shouldn't be necessary to deliberately crush shadow detail in order to fix a black level problem, but an appropriate monitoring LUT which applies a look reasonably close to the intended final grade will make issues easier to spot, and then to avoid. Normal grading or (in rare, complex cases) visual effects techniques might be used to deepen shadows in the same way they can be used to brighten highlights.

Extending The Backdrop

Many kinds of virtual production will involve tracking the camera, and recording that data may make it easier to add conventional effects in post production, a hybrid of in-camera and post-production effects work. This works well where, for instance, a wide-angle lens, adventurous camera move or extreme angle might reveal the edge of the LED wall. Where a fully three-dimensional virtual environment is in use, it might even be possible for the virtual production facility to render and record a full-frame image, accurately aligned to the camera perspective, at the same time as the live action material is recorded. That image is then available for straightforward compositing later.

There are downsides. The composited parts of the frame were not present in reality, as the LED wall is, so they don't add to interactive lighting of the scene. Similarly, they haven't been re-photographed by the taking camera, so that any real-world lens effects will be missing. Where foreground elements obscure the background, a solution (often manual rotoscoping) must be found to composite them against the newly added background. The flawless compositing of difficult transparent or reflective subjects common to virtual production is therefore missing in those areas.

Still, this approach can make it much easier to show larger scenes than the LED wall itself can accommodate, potentially making significant savings on scenes which would otherwise demand a much larger facility for just a few shots. The need to do some visual effects work to create a really convincing result can often be well worthwhile.

Avoiding Problems

As with any special effect, the best ways to avoid the need for post production fixes is in camera. Virtual production can, if not properly handled, create some classes of problem which might require a more complicated visual effects intervention in post. One trivial example might involve a less-than-ideal setup which places a subject too close to the LED wall, which might end up too sharply focussed, revealing the pixelated nature of the backdrop.

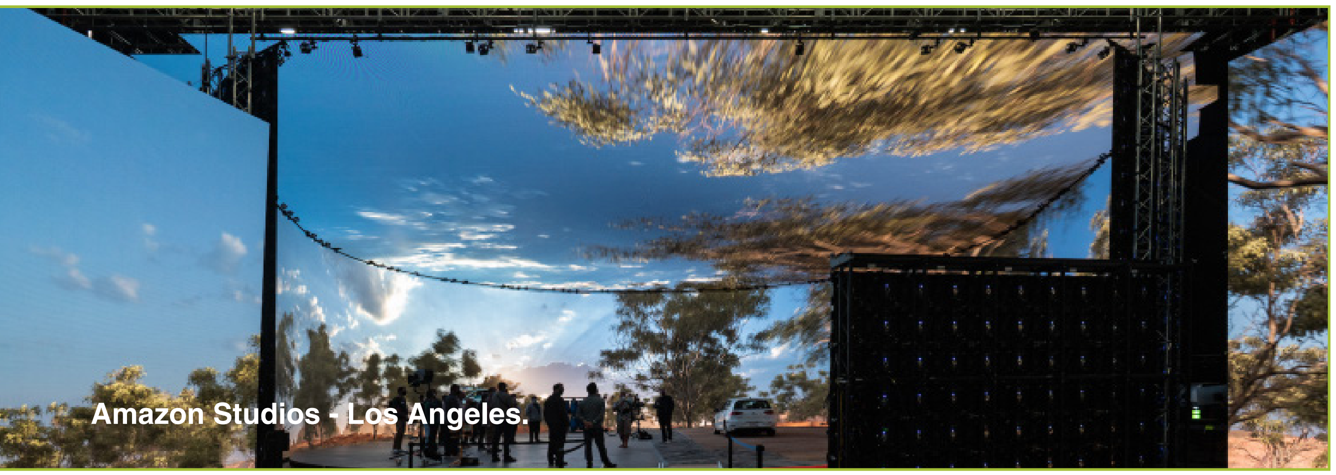
Fixing that might demand the addition of more blur in post. More serious problems might involve poor camera or lens tracking, improper characterization of lens distortion, or geometry errors in the screen setup. Some of these are fundamental to the physical arrangement of the virtual production facility itself. Others will involve collaboration of the facility with the camera team, but all of them are detectable given careful observation on a large, high-quality monitor.

That's particularly true when a cinematographer is evaluating the match between the LED wall and any other lighting involved. Here, the color quality considerations of most LED walls can conspire to create a situation where the match as viewed on a monitor looks very different to the match which exists in reality. Some cinematographers have preferred to isolate themselves from viewing the stage by eye, using black flags or retreating to the DIT's tent to concentrate solely on how the scene looks to the camera. Mismatched lighting, tracking or geometry issues may be difficult to fix later.

The Big Idea

Well-shot virtual productions should demand little or no more post work than any other conventionally-shot scene. That is, in the end, the whole purpose of using an in-camera effect. It requires moving much of the creative and technical effort from post production to pre production, which inevitably affects workloads and scheduling. Even so, the potential to walk away from a shooting day with finished shots featuring advanced effects is enormously valuable to a production team concerned over the potential for conventional visual effects budgets and timescales to slip.

At the time of writing, virtual production had been in widespread use for two to three years, meaning it should have moved out of the earliest, least-reliable phases of deployment. Even now, though, virtual production setups represent a stack of technologies which will always demand a collaboration between different disciplines. Get that right, and post production demands drop to near-zero, and the director has an unprecedented freedom to shoot complex shots which might challenge a conventional visual effects pipeline. In the end, that's the promise of virtual production – and as techniques and technologies mature, it should become easier to fulfil.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