CINEMASSIVE

VISUAL INTELLIGENCE FOR CRITICAL DECISIONS

A CineMassive Technical White Paper

A COMPARISON OF VIDEO WALL TECHNOLOGIES

A Guide to Key Features and Benefits

Issued April 2015
Release 1.0

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ABSTRACT

CURVE, Georgia State University Library

Selecting the ideal video wall solution can be bewildering. A complete video wall system requires a number of components, and a wide range of options are available for each of them. Of all of the decisions that must be made when planning for a video wall system, perhaps the most deceptively simple is selecting the display type. An enormous range of video wall display technologies are available on the market today, each with their own unique characteristics, advantages, and disadvantages. Many potential buyers, architects, and engineers become quickly overwhelmed by the sheer variety of display types. Worse, manufacturers provide a plethora of promotional materials that often make conflicting claims and use widely inconsistent terminology and systems of measurement to describe their products. It is unsurprising that organizations often struggle to compare competing technologies or even to define which characteristics are most valuable and relevant for them.

This white paper aims to demystify the video wall display selection process by providing an unbiased guide to the most popular display technologies available today. It introduces four of the currently most popular display types and three emerging display technologies that may also merit consideration. Each display discussion provides a basic explanation of the technology behind the display type and describes some of the common advantages and disadvantages of that technology with regards to physical performance, aesthetics, maintenance, and cost of ownership.

The information presented in this document has been collected from internal subject matter experts along with external sources, including industry research papers, dissertations, journals, and more. While the writers have made every effort to provide current, accurate, and useful information, it should be noted that individual products and user experiences will vary. In addition, video wall technology is advancing rapidly and the characteristics of a particular display type may shift over time. Ultimately, only the customer can determine the ideal video wall system for his or her own application and environment. The information that follows is simply intended as a framework to introduce available technologies and present considerations that may be useful in refining the selection process.

INTRODUCTION

A video wall is a large-scale visual display consisting of multiple monitors, projectors, or other display technologies that are tiled or overlapped to form a single, expansive display surface. Today, video walls are transforming the way people communicate, learn, and solve problems around the world. At their best, these large-scale visual displays are engaging and powerful tools that enhance users' ability to see, understand, and share information with others.

Why A Video Wall?

In many cases, video walls offer significant advantages over the use of a single, large display. Perhaps most importantly, video walls can provide much larger, higher-resolution images than single displays. A large, high-resolution central display enables all of the users in a space to clearly view, interact with, and share information. Teams can unite their resources on a centralized platform and engage in collaborative monitoring, exploration, and problem-solving. Video walls can also offer far more flexibility of shape and dimension than single displays. Video walls can be curved, non-rectangular, or even three-dimensional. Far more versatile than a single display, a video wall can function as an immersive research environment, a 3D simulation system, or even an element of architectural design.

When integrated with effective processors and software, video walls can provide benefits for virtually any application and environment. Video wall systems can provide enormous advantages in control room environments, from military command centers to utility control rooms and security operations centers. Functioning as large-scale, high-resolution dashboards, they can increase situational awareness, enhance collaboration, and facilitate agile incident response. In universities and research facilities, video walls enable the interactive exploration of big data and research content and can display high-resolution material at extraordinary scale and detail. In corporate boardrooms and conference rooms, video walls can provide engaging, interactive presentation platforms and enhance unified communications. In public spaces, video walls can create visually stunning platforms for promotional media or public information boards for critical messages.

Choosing a Video Wall Display

The exploding popularity of video walls in recent years has generated an intensely competitive market and a large selection of video wall options. For many organizations, it is an excellent, and even necessary, time to invest in a video wall system. However, selecting the ideal video wall can be a confusing and overwhelming task due to the enormous variety of display technologies available in today's market. An internet search for "video wall" yields a range of terms, including "LCD," "LED," "LPD," "cubes," and "projectors," to name only a few. Each of these terms represents a distinct type of display technology and even within each of these categories, there are a number of nuances and options.

The materials provided by video wall manufacturers often claim that the display technology of their specialty is the ideal solution for any application. In reality, however, every application is unique and each type of display offers a distinct set of advantages and disadvantages. A particular display type may be excellently suited to some activities and environments, but poorly suited to others. In order to select the ideal video wall for a particular application and environment, it is critical to first develop an understanding of the technology behind each display type, its inherent strengths and weaknesses, and the options available.

U.S. Army

LCD VIDEO WALLS

LCD Video Wall (CURVE, Georgia State University Library)

How It Works

LCD is one of the most popular video wall technologies available today. LCD technology will already be familiar to most due to its widespread use in personal computer monitors and televisions. An LCD, or liquid-crystal display, is a flat panel display that uses the light modulating properties of liquid crystals to display an image. Each pixel of an LCD is composed of a layer of liquid crystal molecules aligned between two transparent electrodes and two polarizing filters. When an electric field is applied, the liquid crystals twist or reorient, allowing light to pass through and produce images in color or monochrome (Matuszczyk, 2000).

Because liquid crystals do not emit their own light, LCD panels must utilize a backlight located at the back of the LCD glass. CCFL (cold cathode fluorescent), an older backlighting technology, may still be used in laptop computer monitors. However, most of the large-scale LCDs used in video walls are LED-backlit. In this system, LEDs (light emitting diodes) shine through the liquid crystals to produce an image. An LCD video wall is built from an array of commercial-grade, narrow-bezel LCD panels that create a large-scale visual display. The individual panels used in LCD video walls typically measure from 42” to 60” diagonally.

Most LCD displays on the market today utilize TFT (thin-film-transistor) LCD technology, an active-matrix scheme in which each pixel is controlled by one to four transistors. The two major varieties of TFT LCD panels that are typically used in LCD video walls are TN (Twisted Nematic) and IPS (In-Plane Switching). These two technologies differ in the way that their liquid crystal molecules move in relationship to the panel plane. In TN panels, crystal molecules move parallel to the plane, while in IPS, they move perpendicular to it (Matuszczyk, 2000). This distinction creates a number of differences in the way that TN and IPS LCD displays perform and may be an important factor in selecting the ideal LCD video wall. The nuances of TN and IPS LCD performance will be further explored below.

In full-array backlighting, common in early LED-LCDs, rows of LEDs were spread across the entire back panel of the display and divided into a number of zones that were controlled individually by a local dimming feature, enabling portions of the backlight to be dimmed while others remained illuminated. This feature helped to improve contrast and black ratios in early LED-LCDs, but resulted in the displays being relatively thick and quite expensive (Wilcox, 2012).

Direct-lit (sometimes simply “backlit”) LED-LCDs were developed as a more affordable alternative to expensive full-array displays. They feature fewer total LEDs across the back of the display and some lack the local dimming function. Direct-lit displays are frequently even thicker than their full-array predecessors because since fewer LEDs are used, they must be moved farther back from the screen to provide the necessary light coverage. However, they are advantageous in terms of brightness uniformity, and models that feature local dimming offer excellent contrast ratios.

Edge-lit LED-LCDs light the display from the edges of the panel instead of the back. Light signals then transfer across the panel to display an image. Edge-lit LED-LCDs can be extremely thin compared to direct-lit models. However, they may lack the excellent brightness uniformity and contrast levels of direct-lit displays since the LEDs are not arranged evenly across the back of the display (Wilcox, 2012).

Characteristics and Performance

Visual Performance

Resolution

LCD video walls offer a number of advantages in terms of visual performance. One major advantage is resolution. LCD panels can provide some of the highest total resolutions of any technology available today, with most displays between 47 and 55 inches offering at least 1920x1080 (full HD) and some displays providing resolutions as high as 3840x2160 (4K) or even 7680x4320 (8K). These ultra-high resolutions are made possible by the high pixel density, or PPI (pixels per inch) that LCD technology can provide.

Due to its high pixel density, of LCD can produce a sharply detailed image that allows viewers to discern text and images with minimal eye fatigue. This high PPI also enables LCD video walls to be approached and viewed at extremely close proximity with no perceived loss of image quality. On display types with lower PPI, text and images can be difficult to discern at close range.

LCD video walls may be said to have a "stacked" resolution as each additional panel increases the total resolution of the video wall. This represents a significant advantage over projection-based systems, in which the projected image is simply stretched across a larger surface, diminishing the pixel density.

Brightness

Many LCD panels can provide high brightness, and brightness levels can be adjusted quickly and easily. For this reason, LCD is a popular display choice for environments with significant ambient light that would wash out a projection-based display. Maximum LCD brightness decreases gradually over time, but higher brightness settings may be used to compensate for this if the displays were not initially running at their full brightness potential.

Contrast Ratios and Black Levels

Early LCD displays were not able to provide the excellent contrast ratios and black levels available in technologies like Direct View LED and plasma. This was because some of the light produced by the backlight was still visible behind pixels that were fully off, making black regions appear greyish. However, this issue has been improved significantly over the years. Current high-quality LCD displays, particularly IPS, can provide high contrast levels and deep blacks.

Viewing Angle

LCD technology can also offer extremely wide viewing angles. IPS LCD panels provide a particularly excellent viewing angle with minimal color and light drop-off, making images easier to see from a distance or from off-axis. TN LCD displays provide a more limited viewing angle, causing pixel colors to invert at extreme angles. This makes IPS LCD a superior choice for large control room environments in which many operators will need a clear view of the video wall.

Appearance on Camera

When viewed on camera, older display technologies like CRTs (cathode ray tubes) often appeared to flicker or show scan lines. This issue was caused by disparities between the refresh rates of the cameras and the refresh rates of the displayed images that the cameras were recapturing. Because many older displays had fixed refresh rates, they could not be adjusted to match the cameras filming them. However, most modern display technologies, including LCD, do not suffer from this issue because the refresh rate of the displays can be synched to the refresh rate of the camera. Therefore, LCDs appear solid and steady and do not show scan lines or other artifacts when viewed on camera.

Color Reproduction and Uniformity

Regarding color reproduction, or how well colors can be accurately displayed, LCD video walls vary depending upon whether TN or IPS panels are used. Most TN panels only display 6-bits per RGB color, and as such can only represent 70% (18 bits total) of the 24-bit color available from graphics cards. To compensate, TN panels display interpolated 24-bit color by using dithering or Frame Rate Control (FRC) adjacent pixels to create the missing desired shade (Artamonov, 2004). Due to using 8 bit or even 10 bit panels, professional IPS LCD displays have a much wider color gamut, enabling them to provide highly accurate color reproduction without dithering (although dithering may still be found on certain models). For this reason, video walls that use IPS LCD panels may be the preferred choice for marketing groups or any users that require excellent color reproduction.

Color uniformity is typically excellent within individual LCD panels, although color may initially need to be calibrated when a video wall is built to ensure precise uniformity across multiple panels. While the brightness of LCD panels will decline over time, color generally remains consistent. This represents an advantage over projection-based systems, which may experience heavy color changes over time.

Visual Artifacts

LCD displays may experience some minor issues with image retention, although they are not nearly as susceptible as plasma displays. In applications where a static image is displayed for an extended period of time, pixels may lose their ability to return to a relaxed state. This image persistence is generally minor and temporary.

Dead and stuck pixels may also occur in LCD displays, typically due to transistor error. Stuck pixels may cause a single sub-pixel to appear "stuck" on a certain color, while dead pixels may appear permanently white or black. Stuck pixels can sometimes be corrected by software or physical methods, or may eventually correct themselves. Dead pixels are more difficult to correct. However, most LCD manufacturers will replace a display with a certain number of sub-pixel defects and some manufacturers have zero-tolerance policy for these defects. Dead or stuck pixels are generally a minor concern unless the video wall will be viewed at close proximity and such defects will be easily noticed. In larger environments, individual pixel defects are rarely noticeable during regular use.

Response Time

Response time, measured in milliseconds, is a measurement of the amount of time a pixel in a display takes to change. Displays with lower response times can perform faster transitions and show fewer image artifacts.

While response time for LCD has been improved significantly over the years, it is still somewhat slower than many competing technologies. The minimum response time for the latest LCD displays is around 1 millisecond, while some DLP projectors offer response times in the low microseconds. However, this distinction may be imperceptible to the human eye, so the response time of today's LCD displays is rarely considered a disadvantage for most video wall applications. TN and IPS technology once varied significantly in response time, with TN LCDs having far faster response times than IPS LCDs. However, this disparity has been reduced in recent years and there is now little practical difference in most use cases.

Touch Interactivity

LCD displays can be configured to provide multi-touch control, enabling users to interact directly with display content. While most display technologies can be modified for touch, LCD is unique in that touch can typically be provided by the manufacturer, eliminating the additional installation time and expense of a third-party integration. Touch provides increased interactivity and can be a valuable asset for presentation, research, and education applications.

Bezels

One frequently-cited disadvantage of LCD video walls is bezel width. Compared to projection cubes or blended projection systems, LCD panels have thicker bezels, or seams, appearing around each panel in the array. For applications in which detailed charts or graphs are displayed, bezels may be seen as disruptive. They may also diminish the effect of 3D content in virtual reality and simulation applications. In some cases, customers may simply find them unattractive.

However, LCD manufacturers are well aware of this complaint and have made significant progress in reducing bezel width with each new generation of display. Some current LCD displays offer bezel widths as low as 3.5mm, a dramatic reduction from previous 5mm and 7mm models.

Spatial, Environmental, and Aesthetic Concerns

Footprint

Bezels aside, LCD video walls can offer a number of aesthetic and spatial advantages. Perhaps the most evident of these is their minimal footprint. LCD video walls have an extremely shallow depth, which can be as narrow as 4" deep when wall-mounted. LCD video walls are extremely space-efficient when compared to projection cube systems, which require a minimum of 24” and cannot be wall-mounted, or blended rear projection systems, which may take up 14’ or more and require their own rooms or enclosed spaces.

Size and Shape

LCD video walls offer a wide range of options in terms of size and shape. They are extremely scalable and can be easily expanded by simply adding additional LCD panels to the array. In addition, because of the narrow profile of LCD panels, a wide range of mounting options are available. LCD video walls can be freestanding, wall-mounted, recessed into a wall, or even mobile. They can also be built on a curved radius to accommodate unusual architecture, save space, or create an immersive environment.

Ease of Deployment

Weight

LCD panels are easy to mount and align, and because little maintenance is necessary after installation, re-alignments are rare. However, while individual LCD displays are lightweight, total weight can become substantial depending on the size of the video wall. A structural wall may be required to safely hold the weight of a large wall-mounted LCD video wall. Similarly, the supports of large freestanding systems may need to be mounted to the building structure for extra stability.

Location of Power Supplies

One variable affecting the installation of LCD video walls is the location of the power supplies. Displays using local power supplies may require electrical additions or modifications to be made to the wall. Displays with remote power supplies will require electrical circuits to be available at the equipment location. However, these circuits are frequently available in a nearby data center or IT closet, making them less expensive to connect. Remote power supplies are also advantageous in that they reduce the depth of the video wall, lower the thermal footprint of the system, and enable easier serviceability than local power supplies.

Scalability

LCD video walls are easily extensible over time, making them an excellent solution for organizations with budget constraints that may want to expand their systems in the future. However, it is always recommended to plan for such expansions in advance, taking into account the increased spatial and electrical requirements of an expanded system so as to minimize construction later. In addition, because LCD displays are constantly being developed and improved by manufacturers, it is advisable to undertake expansions as soon as possible in order to guarantee the availability of the original displays and minimize brightness discrepancies between the older displays and the new additions.

Reliability and Resilience

Reliability

LCD video walls can provide extreme reliability and are capable of 24/7 performance with no down-time needed. This gives LCD a tremendous advantage over lamp-based projection systems, which require regular system downtime to replace and cool lamps.

The reliability of LCD technology is due in part to the long lifespan of the LED light source and the absence of consumable parts that would need regular maintenance. Some premium LCD displays even offer redundant power supplies for each individual display, ensuring continuous operation even if a power supply is compromised. In addition, modern LED-LCD panels generate relatively little heat, particularly in contrast to early CCFL-LCD and plasma panels. LCD displays that use remote power are superior in this regard because the power supplies are located away from the display panels, reducing heat levels.

Resilience, Serviceability, and Lifespan

LCD video walls enjoy an extremely long lifespan, with some systems having an MTBF (mean time between failures) of over 100,000 hours when used 24/7 (CineMassive, 2014). Because LCDs are composed of solid-state electronics with no moving parts, they are very resilient to environmental stressors such as vibration, humidity, UV light, and rugged landscapes, and can be easily transported with minimal risk.

If they are mounted properly, LCD panels are quick and easy to service. Some models even include replaceable modular electronics, enabling certain components to be replaced without replacing the entire panel. The resilience and easy serviceability of LCD video walls makes LCD an excellent solution for mobile displays and rugged, sub-optimal environments.

Cost of Ownership

Initial Cost
The initial cost of LCD video walls is moderate. They are generally much less expensive than projection cubes and rear blended projection systems, while initially more expensive than traditional front projection systems. The main economic advantage of LCD video walls is in their low total cost of ownership (TCO).

Total Cost of Ownership
As previously discussed, LCD systems include no consumable parts and do not require regular maintenance, both factors that make traditional front projection and blended projection systems costly to maintain over time. LED-LCD displays have a much lower power consumption than many competing technologies, particularly when compared to projection, plasma, and legacy CCFL-LCD systems. With minimal maintenance requirements, low power consumption, and a typical lifespan of around 6.8 years to half-brightness, LCD video walls offer an extremely low total cost of ownership and are one of the most affordable video wall options in the long term.

PLASMA DISPLAY PANEL VIDEO WALLS

How It Works

Plasma display panels (PDP) are a flat panel display technology that uses small cells containing electrically charged ionized gases, or plasmas, to produce an image. A plasma display consists of millions of tiny gas-filled compartments, or cells, between two panels of glass.

PDPs produce an image by applying high voltage to trigger a series of reactions in the gas-filled cells. When voltage is applied to a cell, the gas inside forms a plasma, causing a reaction that increases the energy level of the atoms until that excess energy is shed as ultraviolet photons. The UV photons then strike phosphor molecules that are painted on the inside of the cell, resulting in a second reaction that causes the phosphor molecules to shed a photon at a lower energy level than the UV light. This energy is shed mainly as infrared heat, but also produces some visible light. Different phosphors are employed to produce various colors of light and each pixel is comprised of three cells to provide the primary colors of visible light. Varying the voltage of the signals applied to these cells results in different visible colors. Like LCD video walls, plasma video walls are built from an array of multiple plasma panels (Harris, 2000).

A Technology in Decline

When plasma technology entered the mainstream display market in the mid-1990s, it offered a number of advantages over the CCFL-LCD and CRT (cathode ray tube) displays of the time. Plasma provided larger screen sizes than traditional tube TVs and ushered in an era of wide format, high-definition displays. Although plasma displays were still somewhat heavy, they were lighter and thinner than comparable CRTs at the time. Plasma also provided superior contrast ratios, viewing angles, and response times when compared to many early CCFL-LCD displays. This excellent image quality along with the availability of displays up to and over 100” enabled plasma to enjoy broad popularity, particularly in the television and home cinema markets, for some time.

Throughout the years, however, plasma has continued to suffer from some significant disadvantages. Perhaps the most widely-recognized of these issues is image retention. When a static image is displayed for some time, phosphors in the cells overheat, losing their luminosity and producing permanent “shadows” that persist even with the power off. In addition, when very bright images are displayed, pixels may build up a charge, producing “ghost images” that linger temporarily on the display. Plasma also consumes far more power and gives off much more heat than LCD, particularly when displaying bright content.

In the mid-2000s, as the thinner and lighter LCD technology began to see significant improvements in contrast ratio, viewing angles, and response times, plasma gradually lost market share. Eventually, plasma’s advantages over LCD were minimized and could no longer outweigh the issues of screen retention and power usage. In addition, the price of plasma displays failed to decrease as rapidly as LCD prices throughout the 2000s. At the time of this writing, most major manufacturers no longer produce plasma displays, and while some existing inventory may still be available, the technology is rapidly becoming obsolete. Because plasma technology is vanishing quickly and may not be supported much longer, it is not recommended as a video wall solution.

PROJECTION CUBE VIDEO WALLS

Projection Cube Video Wall

How It Works

Like LCD, projection cubes are a popular variety of video wall technology. Projection cubes consist of a rear projection system that is housed in a sealed cube to increase contrast levels and limit ambient light from washing out the projected image. In a projection cube system, images are produced by projecting light onto a mirror that then reflects the image onto a screen for viewing. While legacy projection systems used lamps as a light source, most contemporary projection cubes employ LED backlighting. The adoption of LED backlighting has reduced maintenance requirements, eliminated expensive consumable parts, and lowered operating temperatures, making projection cubes a much more competitive and versatile option than they were previously.

Projection cube video walls are constructed from a series of projection cubes that are stacked on top of each other. Individual cube sizes vary widely. While most cubes currently measure between 50” and 80” diagonally, some cubes may be as small as 20”.

While not altogether seamless, projection cubes feature extremely narrow bezels, enabling cube-based video walls to appear virtually seamless from a typical viewing distances. For this reason, projection cube video walls may be chosen for applications that require a near-seamless display, but demand more reliable performance than traditional projection-based systems can offer.

Characteristics and Performance

Visual performance

Near-Seamlessness
From a visual perspective, the key distinguishing characteristic of projection cube video walls is their near-seamless appearance. With bezels as narrow as 0.2 mm or less between screen surfaces as large as 80” (2032 mm) diagonally, a projection cube video wall can appear to be virtually seamless. Projection cube technology is therefore an excellent solution for applications in which more perceptible bezels could compromise display content and distract viewers.

Resolution
The resolution of projection cube technology varies, but can be relatively high. Like LCD video walls, projection cube video walls have a “stackable” resolution, meaning that the total resolution of the video wall is increased with each additional cube. A number of different aspect ratios are available, including 4:3, 16:9, and 16:10. Typical resolutions include 1024x768 (XGA), 1400x1050 (SXGA+), 1920x1080 (Full HD), and 1920x1200 (WUXGA).

Projection cubes can provide higher total resolutions than some other technologies, such as direct view LED and LPD. Compared to LCD or plasma systems however, projection cube systems have a lower pixel density, so larger displays must be used to create a video wall canvas of a certain resolution. For example, an 80” 1080P projection cube is comparable in height to two stacked 47” 1080P LCD panels, but provides only half the vertical resolution of the LCD panels. This reduced resolution and increased pixel spacing may not be an issue if the video wall will be viewed from some distance. However, if viewers will be seated in close proximity or will be able to walk up to the wall, this factor may be of more concern during the system design.

Brightness
The sealed casing of projection cubes limits the effects of ambient light and increases contrast levels, enabling cubes to produce images that are easier to discern and cause less eye fatigue than most standard front projection systems. However, projection cubes cannot provide as much brightness as LCD or Direct View LED technologies. Therefore, some ambient light control is generally required to ensure that display content is clearly visible. While projection cube video walls appear steady and solid on camera, the need for lower ambient light levels may affect photography and filming. Much like LCDs, projection cubes gradually lose brightness over time as the LED light engine ages.

Viewing Angle
The viewing angle of projection cubes is lower than that of competing technologies like LCD, LED, and LPD. This is because projection screens focus light toward the on-axis viewer, so viewers located at wider angles experience drastic light fall-off and color uniformity issues. Due to this limitation, projection cube technology may not be ideal for environments where viewers will be distributed across a wide viewing area.

Color Uniformity
Like LCD displays, individual projection cubes have excellent color uniformity but a projection cube video wall will need to be calibrated during assembly to ensure uniformity across all of the cubes. Some cube technologies feature auto calibration which reduces the ongoing need to calibrate displays. DLP-LED projection cubes experience no image retention issues and are preferable to emissive technologies for displaying static images over extended periods of time.

Refresh Rates
Refresh rates for rear projection cubes are typically comparable to those of LCD displays of similar resolutions (Mitsubishi, 2014). Expressed with a frequency rating of Hertz (Hz), refresh rates indicate the number of times the screen redraws or refreshes to form a fluid video image. Refresh rates may also be expressed as scanning frequency per the given resolution, i.e. 60Hz at 1920x1080, or simply listed alone as a maximum rate, i.e. 120Hz Refresh.

In cases when only the maximum refresh rate is listed, additional research may be necessary to determine whether the display will accept the intended input resolution and frequency. Typically, displays are also capable of displaying lower resolution and refresh rate standard combinations than the specified maximum. If only the full pixel clock rate is listed, it will be necessary to calculate the pixel clock or bandwidth for the intended input. A basic formula may be used to determine this information: (Horizontal Pixels + Horizontal Blanking) x (Vertical Pixels + Vertical Blanking) x Desired Refresh Rate = Total Pixel Clock. For example, if the desired input was a PC with a 1600x1200 image at 60Hz, the formula would appear as (1600+560) x (1200+50) x 60 = 162MHz. The result, 162MHz, represents the total pixel clock capability that the display would need to show the image. Online calculators are also available to perform this calculation.

If refresh rate information is not presented clearly, it is always advised to contact the display manufacturer for further clarification.

Touch Interactivity

Unlike LCD displays, projection cubes do not typically offer touch interactivity as a factory option. A projection cube video wall can be configured for touch after assembly, but this typically requires the use of rear-serviceable cubes, which demand more floor-space for serviceability. In this case, a glass substrate can be permanently installed in front of the cube wall. For video walls composed of front-serviceable cubes, the sheet of glass required for touch must be removable so as to not inhibit serviceability. In either arrangement, the addition of a touch system to a cube video wall adds significant complexity and cost. For projects in which touch interactivity is a major focus, LCD displays may be a more practical and cost-effective option.

Spatial, Environmental, and Aesthetic Concerns

Size and Shape

Projection cubes offer an excellent range of options in terms of shape and size. Cube video walls can be flat, curved, and even non-rectangular in shape, and the broad range of aspect ratios and cube sizes that are available increase these options further.

Like LCD panels, projection cubes are tileable, and if large cubes are used, they can be a more cost-effective solution than LCD for very large video walls. The large dimensions of each cube allow a large video wall to be built using fewer individual cubes, although the weight of the cubes places certain limitations on the number of cubes that can be stacked on top of each other.

Footprint

Compared to flat panel technologies like LCD, cube video walls have a large footprint. Most cubes are at least 24” deep, and because of their weight must be mounted on the floor or on a solid platform. In addition, most basic cube models are rear-serviceable, necessitating additional floor space to provide technicians with rear access to the cubes. Upgraded models may offer front-serviceability, which reduces floor space requirements but adds to the initial price of the cubes.

Ease of Deployment

Weight

Cube-based video walls require a significant amount of assembly during implementation as compared to LCD or other emissive technologies. Because fully assembled cubes are both heavy and fragile, the projectors, screens, cabinets, and light engines for each cube are typically shipped separately to the building site and cubes are assembled on-site during the construction of the video wall. While quite heavy, projection cubes provide the advantage of an in-built mounting system, since cubes can simply be stacked on top of one another. This represents an advantage over LCD panels, which require an external mounting frame or wall.

Scalability

Like LCD video walls, LED-based projection cubes are scalable over time, enabling customers to expand their systems after initial implementation. As with all scalable systems however, it is advised to consider any plans for future expansion when designing the video wall environment so that an expanded system can be accommodated in the space. It is also recommended to implement desired expansions as soon as possible in order to guarantee parts availability and consistency in brightness.

Reliability and Resilience

Reliability

Today's LED-based rear projection cubes offer very high reliability, particularly in contrast to lamp-based cubes or projection systems. Like LED-LCD video walls, LED-based cube walls can provide 24/7 performance and are suitable for use in critical control room environments. Because LED-backlit cubes do not rely upon consumable parts like lamps, they require no regular maintenance or downtime. In addition, internal fans or water pump cooling systems help ensure that operational temperatures are kept within optimal thresholds, increasing the lifespan of the system.

Resilience, Serviceability, and Lifespan

LED-based cube video walls can have a very long lifespan, typically ranging from 60,000 to 100,000 MTBF (Mitsubishi, 2014). After implementation, LED-based cubes require minimal maintenance. However, the presence of moving parts within each cube places this technology at a slight disadvantage against technology like LED-LCD, which is composed entirely from solid-state electronics, and thus includes fewer potential points of failure. In LED projection cubes, screens are the most common component to require maintenance as they can be damaged easily if impacted and may be prone to peeling over time. More rarely, a light engine or fan may need to be replaced. If maintenance is required for a cube, most components can be replaced with minimal downtime and without requiring the entire cube to be removed. As discussed above, the method of serviceability varies depending upon whether the cubes are rear-serviceable or front-serviceable.

While extremely reliable within most climate-controlled, indoor environments, projection cube video walls lack the environmental resilience of LCD video walls. Although LED-backlit cubes are less fragile than lamp-based projection systems, they still contain a number of moving parts and cannot withstand a great deal of vibration or instability. They are also sensitive to high levels of humidity and heat, which may cause screen damage and peeling over time. The need for a stable, controlled environment along with the sheer size and weight of each cube make a cube-based video wall an unlikely candidate for use in rugged, temporary, or sub-optimal environments.

Cost of Ownership

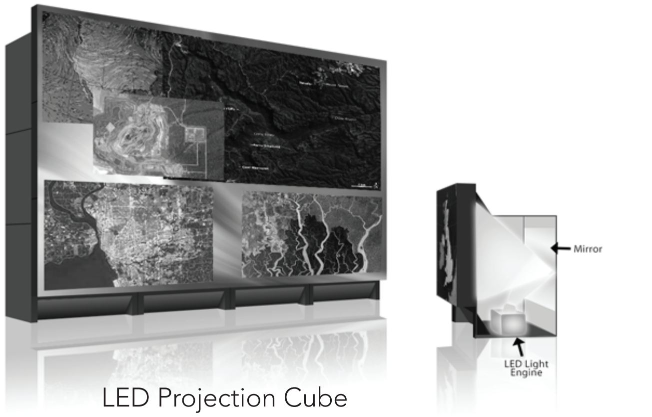
Initial Cost

In most cases, the initial cost of a projection cube video wall is significantly higher than some competing technologies. A small to medium LED-based cube wall may be around three times the price of an LED-LCD video wall of similar dimensions. However, for very large-scale video walls, projection cubes may be a less-expensive option than LCD, particularly if large individual cubes are used.

Total Cost of Ownership

Long-term cost of maintenance for LED-based cubes is minimal, although, as discussed previously, screens may occasionally need to be replaced. The power consumption of LED-based projection cubes is similar to that of LED-LCD systems. While LED-based cubes require more power than lamp-based projection systems to produce an image of the same size, lamp-based systems generate far lower resolutions. In order to produce an image at the same resolutions as an LED-based projection system, a lamp-based system would require multiple blended projectors, and would ultimately draw more power. Therefore, if high-resolution output is required, LED-based projection cubes are a more energy-efficient solution than lamp-based projection systems.

Overall, while the initial price of LED-based cubes is quite high, their minimal maintenance, low power consumption, and long lifespans lower the total cost of ownership, making them a far more economical solution than lamp-based projection systems in the long term. Total cost of ownership is still higher than LED-LCD systems, but the near-seamlessness of cube video walls may justify this additional expense for some customers.



LED Projection Cube

BLENDED PROJECTION VIDEO WALLS

Blended Projection Video Wall

How It Works

Similar to projection cubes, but on a larger scale, blended projection video walls combine two or more projectors in order to produce an image that is larger or higher-resolution than could be generated by a single projector. Blended projection systems are able to display high-resolution images on a completely seamless surface of virtually any size and shape. This unique capability makes blended projection a popular choice for simulation and training, virtual environments, and other applications requiring hyper-realistic or immersive effects.

In a blended projection system, multiple projected images are overlapped and their edges are gradually cross-faded or dithered to produce a single, seamless image. Most blended projection systems require some amount of external processing to blend and warp the image, but some premium projectors have most of these functions built-in. Blended projection systems may be designed with either rear or front projection.

In a rear blended projection system, the projectors are located behind the screen, typically in an enclosed rear projection room. The projectors may either project light directly onto the screen, or may project light onto mirrors that then reflect it onto the screen. This latter arrangement "folds" the image, doubling the throw ratio of the projectors so that the desired image size can be produced from half the distance, and the projection room can be smaller. The projection room functions much like a projection cube in controlling light levels on the screen. By minimizing ambient light, rear projection systems can produce high contrast ratios and bright images, so they generally do not require projectors as bright or as costly as those needed for front projection systems. Another advantage of rear projection is that the projection room prevents much of the heat and noise generated by the system from entering the viewing environment.

In front blended projection, projectors are mounted from the ceiling or wall in front of a screen surface and light is reflected off of the screen. This method requires much less space than rear projection and is typically selected when there is insufficient room available to house a rear projection system. Brighter, more expensive projectors may be required for front projection because of the presence of ambient light in the space. However, front projection arrangements are typically still less expensive overall than rear projection systems due to the less costly screens and mounting systems that can be used.

Projectors used for blended projection video walls typically employ one of three types of light sources: lamps, LEDs, or laser. Each light source has unique advantages. Traditional lamp-lit projectors can be extremely bright, making them well-suited for front projection systems. However, lamps will need to be replaced about twice a year and are expensive, leading to high operating costs. LED-backlit projectors eliminate the maintenance issues caused by lamps, but cannot provide the same levels of brightness. Thus, LED-based projectors may be a preferable choice for rear-projection systems, but current models are not yet bright enough to be ideal for front-projection. Laser projectors, a relatively new technology, can provide brightness levels comparable to many lamp-based systems. Although not as bright as the brightest lamp-based projectors, their high contrast levels may make them appear nearly as bright. With no consumable parts, laser projectors also provide far lower operating costs and maintenance requirements than lamp-lit projectors (Digital Projection, 2012).

Projectors also vary in their imaging technology. DLP and LCD are the most common types of image production technology currently available for commercial projects (Morrison, 2013). LCoS (liquid crystal on silicon) projectors, while popular in the consumer market, are typically too small to be used for commercial video wall projects. DLP and LCD each offer unique advantages and disadvantages. However, it is worth noting that these technologies are in constant development, so the characteristic strengths and weaknesses of each may shift over time.

DLP (digital light processing) projectors use tiny mirrors to reflect light toward or away from the screen. To create color, most models use spinning color wheels with color filters. Some premium DLP projectors use three DLP color chips instead of a color wheel. DLP projectors can provide extremely low response times, in some cases in the low microseconds. This enables them to provide greater sharpness and detail for fast motion images than LCD projectors. DLP also often provides superior contrast ratios and black levels compared to those produced by LCD projection. In addition, models with color wheels may produce an artifact called a "rainbow effect" in which bright objects appear to have a trail of rainbow light when moving rapidly across a dark surface (Morrison, 2013). This artifact is not perceptible at all to some viewers, but others may find it distracting. LCD projectors use three liquid crystal panels which each create an image using just one primary color (red, green, or blue). The three images are projected simultaneously to produce a full-color image. Due to their use of LCD panels, these projectors frequently cannot provide the excellent contrast ratios and black levels available from DLP projectors and may suffer from dead pixels. In addition, LCD projectors are susceptible to motion blur when displaying fast motion content (Morrison, 2013). This may not be noticeable to some viewers, but may bother others. Because they use emissive, rather than reflective, technology, LCD projectors may also produce a more visible pixel structure than DLP, creating a "screen door" effect. ("DLP vs. LCD vs. LCOS," 2014).

Another variable in blended projection systems is screen technology. Depending upon whether front or rear projection is used, different materials and arrangements may be used for the projection screen. The most common screen solution for front projection systems is a lightweight, flexible fabric stretched over a fixed supporting frame and permanently mounted to the wall. The framing device applies uniform tension to the screen surface to keep the surface taut. Front projection systems occasionally use rigid glass or acrylic screens, but this is generally not necessary unless the system is located in a busy public space and must be particularly robust. The most common screen solution for rear projection systems is a rigid, frame-mounted glass or acrylic screen with a layer of projection film bonded to the surface. These rigid screens provide uniform flatness and minimize image distortion. Fabric screens are also available for rear-projection, but are rarely used outside of mobile applications like production staging.

Both front and rear projection screens use a rating system called screen gain, or focus, that provides specifications about the screen's visual performance. Gain is the measurement of the amount of light reflected off of the screen (in front projection) or passed through the screen (in rear projection) to the viewers in the space. In this system, a screen gain of 1.0 is a "flat reflection," or the amount of light reflected by a standard white board.

Screens with a gain higher than 1.0 reflect more than this standard amount of light, increasing brightness by focusing the light directly at the viewer. High-gain screens can help enhance the perceived brightness of smaller, less-costly projectors. However, this brightness comes at the cost of the viewing angle, which must be reduced to focus the light. Thus, higher-gain screens are best-suited to narrower spaces where the reduced viewing angle is not noticeable. High-gain screens may also suffer from hot-spots, or regions near the center of the screen that are brighter than others. Hot-spots are especially a concern in blended projection systems.

Screens with a gain of 1.0 or lower provide little to no focusing or redirecting of light back to the viewer. Often produced in darker colors, these low-gain screens can produce superior contrast ratios and black levels than those produced by high-gain screens. In addition, their even distribution of light enables wider viewing angles and produces a more uniform brightness, reducing the risk of hot spots. For these reasons, lower-gain screens are often recommended above high-gain screens for blended projection systems.

Characteristics and Performance

Visual Performance

Absolute Seamlessness

The most striking visual characteristic of blended projection video walls is their absolute seamlessness. Competing technologies like LCD panels and cubes require multiple displays to be tiled together to create a video wall, which inevitably produces a seamed display surface (however narrow the seams may be). In a blended projection system however, the size and resolution of the display surface depends only upon the type and number of projectors used, so a single video wall may, in theory, be as large as desired.

Resolution

The combination of multiple projectors enables blended projection systems to produce far higher resolutions than single-projector systems. However, when compared to LCD or projection cube video walls of similar dimensions, blended projection video walls typically have lower-resolutions. One reason for this is that when multiple projected images are blended, 10 to 20% of the image is lost in the overlapping blend area, lowering the overall resolution to less than the total combined resolution of the independent projectors.

In addition, the resolution of blended projection systems may be limited due to the sheer number of projectors that would be required to yield the same resolutions produced by tiled display systems. Traditionally, in order to produce resolutions similar to a 4x4 array of 1080P LCD panels, a blended projection system would have to use sixteen 1080P projectors. Such a system would be prohibitively expensive for most customers, both initially and over time due to the ongoing costs of the consumable parts. In recent years, the availability of 4K projectors has increased the practicality of large, high-resolution blended projection systems. If 4K projectors were used in the scenario described above, only four projectors would be needed to produce resolutions similar to the 4x4 LCD array. However, the projector mounting system and ongoing maintenance for multiple 4K projectors may still be too costly for many customers. As 4K and 8K LCD displays are now being released, LCD will likely remain a better value than blended projection in terms of resolution.

Image Sharpness

There are a number of variables that affect perceived image sharpness in a blended projection system. Because sharpness is largely determined by resolution, the number and resolution of the individual projectors in the system has a large effect. The make and model of the projectors, lens type, and precision of lens focusing during the installation process will also have a significant effect. In addition, as previously discussed, projectors using DLP imaging technology generally provide superior sharpness and detail for fast motion video than LCD projectors. Finally, the amount of processing required to optimize the image may also have an effect on image sharpness. Systems with flat projection surfaces produce the sharpest projected image because minimal correction and processing is needed to produce the image. If a curved projection surface is used, or if the projectors are simply poorly placed, the pixels must be manipulated to compensate, altering the image from its raw format and reducing the perceived sharpness. While this may be acceptable for general viewing, it is not ideal for applications like marketing or branding, where sharpness, image shape, and uniformity are a primary concern.

Image Brightness

As with sharpness, the perceived brightness of blended projection systems depends upon a number of factors. The size, light source, and screen type of the projectors may all have an effect on brightness. The distance between the projectors and the screen is also an important factor; brightness will decrease as the projectors are moved farther from the screen. Ambient light in the environment will affect brightness as well. While all blended projection systems require some amount of ambient light control, front projection systems are particularly vulnerable to being washed out by ambient light and may require particularly bright projectors to produce sufficient contrast ratios.

Viewing Angle

Viewing angles for blended projection systems will vary depending on the material and shape of the projection surface. Please refer back to the discussion of screen materials for a more in-depth discussion of how screen technology affects viewing angles. In general, however, the viewing angles produced by blended projection are quite narrow and brightness levels drop off sharply as the viewer moves off-axis.

Color Reproduction and Uniformity

Blended projection video walls can provide fairly high-quality color reproduction, but are typically unable to produce the extended color gamut provided by LCD displays and LED-based cubes. Both LCD and DLP projector types may eventually lose color and brightness uniformity over time. LCD projectors may suffer from gradual degradation of the LCD panels, manifesting in dead pixels and unevenness. In DLP projectors with color wheels, the color wheel may collect dust or degrade over time and bearings may wear and affect the rotation of the wheel, impacting color uniformity and occasionally producing screen artifacts. Finally, if lamp-lit projectors are used, the lamps will dim at differing rates, resulting in gradual loss of uniformity until all of the lamps are replaced at once. Due to these issues, blended projection systems may not be ideal for applications that require exact color reproduction and uniformity.

Response Time

Depending on the projectors used, some blended projection systems can provide extremely fast response times and refresh rates. As mentioned previously, some DLP projectors offer response times in the low microseconds and combined refresh rates as fast as 120Hz or more, making them faster than LCD displays. The speed, advanced internal processing, and the seamlessness of blended projection systems makes them an excellent option for displaying 3D content.

Touch Interactivity

Like cube-based systems, rear blended projection video walls can be modified for smooth and seamless touch interaction. This can be achieved by integrating special glass screens with an in-built touch sensor. However, this modification is not recommended for front projection systems, since in this arrangement, the user would need to step between the projector and the screen to contact the wall, casting shadows and partially blocking the projected image.

Spatial, Environmental, and Aesthetic Concerns

Size and Shape

One of the major advantages of blended projection systems is their ability to project images onto a surface of virtually any shape and size. With additional image mapping software and processing, projectors can produce images on curved, angular, or spherical surfaces. The additional processing required to blend multiple images and warp content for display on a non-standard surface may be provided externally or by the projectors themselves. Blended projection systems can also produce extremely large images, although very bright projectors must be employed to accomplish this, resulting in a higher up-front cost.

Footprint

The space consumed by a blended projection system varies dramatically depending upon whether the system uses rear or front projection. Rear blended projection systems have a very large footprint, typically requiring up to 14 feet or more of enclosed floor space to house the projectors. In many cases, mirrors are used to “fold” the image, doubling the throw ratio of the projectors so that the desired image size can be produced from half the distance.

Front blended projection is one of the most space-efficient display technologies available. Projectors are mounted to the ceiling or wall, and the display screen is usually quite thin and can be wall mounted. Thus, the only floor space required is the space between the projectors and the screen, which must be kept clear to prevent shadows from being cast on the screen.

Heat and Noise

One environmental disadvantage of blended projection systems is the heat and noise that they produce. Most large projectors give off a significant amount of heat and their internal fan systems can be quite loud. Naturally, heat and noise levels are multiplied when several projectors are used together in the same space.

This issue is more noticeable with front projection systems because the projectors are located in the same room as the users. Projector cases with cooling systems and air silencers may be integrated to reduce the heat and noise in front projection systems.

Heat and sound issues are minimized in rear projection arrangements as the projectors are generally housed in a separate, enclosed space. However, care should still be taken to ensure that sufficient cooling systems are in place in the rear projection room because an excessively hot environment can reduce system lifespan.

Ease of Deployment

Weight and Complexity

The ease of implementation for blended projection systems depends largely upon whether front or rear projection is used. The glass or acrylic screens used in rear projection systems are heavier than front projection screens, and rear blended projection systems may involve a more complex implementation process if mirrors are used. However, when maintenance is required, rear projection systems are relatively easy to service because their components are closer to the ground and more accessible.

Front blended projection systems may be easier to install initially because screen materials are much lighter. However, if projectors are mounted on high ceilings, installers may need to use ladders or a lift to install them, increasing the difficulty and expense of the installation. High ceiling-mounted projectors will also require a more complicated maintenance process, and the space may be unusable while maintenance is being performed.

Scalability

When compared to tiled systems like LCD and projection cube video walls, blended projection systems are not easily scalable over time. To enlarge a blended projection system, significant changes must be made to projector placement and lens alignment. In some cases, additional projectors may be integrated into the existing system, but in many scenarios, the projectors will need to be replaced completely. This is especially likely if the current projectors are several years old. A new, larger screen will also need to be implemented to achieve an expanded image. Overall, the expansion of a blended projection system is likely to be costly and labor-intensive.

Reliability and Resilience

Reliability

The overall reliability of blended projection systems is typically lower than LCD or projection cube solutions. In general, this technology requires more monitoring, maintenance, and part replacement than competing technologies to maintain optimal performance. One issue is that blended projection systems rely upon light sources that require either regular service or replacement. In lamp-backlit projectors, lamps burn out and typically must be replaced about twice a year with moderate to heavy usage. In LED-backlit projectors, LED light engines usually require replacement within three to five years. The laser light source in laser-backlit projectors will need to be replaced after about two years. Color and brightness uniformity will also decrease as projectors age, causing image quality to suffer if key components are not replaced regularly. As previously discussed, large projectors may also produce a great deal of heat, which can accelerate system wear over time.

Resilience, Serviceability, and Lifespan

In terms of environmental resilience, blended projection systems are often more fragile than competing technologies, even within normal, climate-controlled environments. Image stability is very sensitive to vibration, a vulnerability that is particularly severe in systems in which the projectors are located far from the screen. Over time, environmental vibrations can also cause projector lenses to drift out of alignment, impacting image sharpness. Vibrations can also cause moving parts to rub together, producing heat and accelerating wear and tear. Because of these vulnerabilities, it is critical to be aware of any vibration-producing equipment nearby and plan projector placement accordingly.

Most blended projection systems are not well-suited for transport. However, some manufacturers offer road-ready projectors for use in event production and trade shows. These travel-friendly projectors can be packed into cases and projection screens can be simply rolled up for transport. However, this mobile concept is more practical for single projection than for blended projection systems. If multiple projectors are to be used, painstaking mounting and lens positioning will always be required to achieve the correct blending effect.

Due to this complex assembly process and the high price-point of travel-friendly projectors, mobile blended projection systems are rarely used outside of large-scale, production-level event staging.

While system lifespans vary depending on the individual components used, blended projection systems typically have significantly shorter lifespans than LCD and cube video walls. The need for regular maintenance downtime and part replacement may bar blended projection from environments where reliable 24/7 performance is critical. In other environments however, these issues may be less of a deterrent.

Cost of Ownership

Initial Cost
The initial price of blended projection systems is typically lower than the price of LCD or LED-based cube systems of similar dimensions except when complex mirror systems are used. After six to twelve months however, the price of regular system maintenance and replacement parts causes the total cost of ownership to increase significantly.

Total Cost of Ownership
Light source replacement is a major expense contributing to total cost of ownership. Lamps may cost thousands of dollars and must be replaced about twice a year. Lasers and LED light engines are also very expensive and typically require replacement within two years and three to five years, respectively. Other system components like filters, fans, and color wheels may require service or replacement around twice a year. Thus, when replacement parts and maintenance labor are considered, the long-term cost of blended projection systems may be significantly higher than that of LCD and cube-based video walls.

Blended projection systems can also draw a larger amount of power than some competing technologies. While they may require less power than LCD or cube systems to display an image of comparable size, blended projection systems require far more power to produce an image of comparable resolution. Therefore, blended projection may not be an energy-efficient solution for applications that require high resolutions.

EMERGING TECHNOLOGIES

New video wall technologies are being developed and refined every day. While these new technologies may spend years in development, once on the market, they may quickly become popular or even disruptive. At the time of this writing, three of the most exciting emerging video wall technologies are direct view LED, OLED, and Laser Phosphor Display.

Because these technologies are relatively new, some aspects of their performance have not yet been thoroughly tested in the video wall industry. However, it is possible to make some preliminary assessments of the strengths, weaknesses, and long-term potential of these emerging solutions.

Indoor Direct View LED

Generally speaking, direct view LED is not a new technology. It has long been the standard display technology used in large outdoor billboards and scoreboards as well as simple indoor signage like “open” and “exit” signs. In a direct view LED display, an array of LEDs is mounted on a flat panel and the LEDs themselves produce the visual display. This represents an important distinction from LED-backlit technologies like LCDs and rear projection cubes, since in those systems, the LEDs serve as a light source only and do not produce images on their own.

In direct view LED displays, a particular voltage is applied to the leads of the LEDs, causing electrons to recombine with electron holes within the device and release energy, producing colored light. The color of the light produced is determined by the energy band gap of the semiconductor in the LEDs. Full-color pixels are formed by clusters of red, green, and blue LEDs. In some cases, white and yellow LEDs may also be incorporated (LED, 2014).

In traditional outdoor LED displays, individual diodes are quite large, producing very large, very bright pixels. Because these displays are designed to be viewed from a distance and must compete with strong sunlight and artificial light sources, extreme brightness is critical. High resolution is unnecessary in displays that will be viewed from afar, so pixel pitch (the distance from the center of one LED cluster--or pixel--to the center of the next cluster) may range from 10mm to 34mm or wider in these systems (NanoLumens, 2011). Due to its low resolution and intense brightness, direct view LED has not traditionally been used for indoor video walls that are viewed at close proximity. However, as smaller LEDs have been developed in recent years, direct view LED technology has emerged as a more viable option for indoor displays.

The latest indoor direct view LED displays are much higher-resolution than their outdoor counterparts, featuring reduced size LEDs and pixel pitch as low as 1.5mm (SiliconCore, 2014). However, even these displays still produce far lower perceived pixel density than LCD, projection, or other technologies, so their resolutions are much lower than competing systems of similar dimensions. Continuing development of direct view LED technology will likely produce progressively smaller LED's with tighter pixel pitch, so higher-resolution displays may be available in the near future. In their current form, however, direct view LED displays are not ideal for applications in which highly detailed content must be viewed in close proximity.

One major advantage of direct view LED is its brightness. Although not as bright as outdoor versions, indoor direct view LED can still provide several times the brightness of competing technologies like LCD, cubes, and other projection systems. This makes direct view LED well-suited for environments with significant ambient light, so long as ultra-high-resolution detail is not required and the display will not be viewed in close proximity. In addition, due to the very high refresh rates that are available for the latest indoor LED displays, this technology displays well on camera (SiliconCore, 2014). Broadcast studio sets, trading floors, and shopping centers are a few environments for which direct view LED might be considered.

Direct view LED may also provide a wider viewing angle than projection technologies due to its direct emission of light. However, there are some limitations to the viewing angle produced by direct view LED because of the shape of the individual diodes. Because the diodes are rounded and emit more light toward the front, brightness and color uniformity drops off when the display is viewed off-axis. Therefore, direct view LED displays may have somewhat lower viewing angles compared to LED-backlit LCDs, in which the LEDs serve only as a light source instead of producing the image themselves.

Direct view LED displays have a very small footprint. The latest panels may be less than 4 inches deep and lighter per square inch than LCD displays (SiliconCore, 2014). This technology also offers great flexibility of shape. Individual LED panels can be flat, curved, or even formed into custom shapes like cylinders (NanoLumens, 2014). This can enable customers to create striking and unusual video walls or accommodate architectural elements like curved walls and columns.

Direct view LED is a very robust and reliable technology, as evidenced by its popularity for outdoor displays. Like their outdoor counterparts, indoor direct view LED displays can withstand a wide range of temperatures and high humidity levels. Maintenance issues typically involve the failure of individual modules, which may result in a "patch" of non-functioning LEDs. These issues may be caused by the display itself, but may also be processor-related. If maintenance is necessary on the display itself, serviceability is relatively easy. Individual panels are typically lightweight and can be easily removed, repaired, and replaced in most cases. In terms of expected lifespan, individual LEDs may offer up to 100,000 hours MTBF, while the electronics MTBF for the entire display may be somewhat less (SiliconCore, 2014) (PixelFLEX, 2014).

The price-point of the latest higher-resolution, indoor direct view LED panels is currently out of the reach of most customers. A direct view LED video wall may be many times the price of an LCD or projection-based video wall of similar dimensions. Since total resolution for direct view LED is still far lower than competing technologies, current models are not a great value in terms of resolution. However, maintenance costs are generally low, and for applications where brightness is a major focus, direct view LED may be a more energy efficient solution. Most indoor direct view LED panels can provide far more lumens (brightness) per watt than LCD or other competing technologies.

Direct View OLED

OLEDs, or organic light-emitting diodes, are another emerging video wall technology that merits discussion. OLED is a type of indoor direct view LED in which the emissive electroluminescent layer is a film of organic compound that emits light in response to an electric current. OLEDs offer a number of advantages over traditional direct view LEDs. First, OLED technology can provide much higher resolution and lower pixel pitch than standard direct view LED displays. Standard direct view LED uses diodes housed in small epoxy cases, and as discussed above, these diodes are still relatively large, placing limitations on pixel density for current LED displays. In contrast, OLED is a flat, light-emitting technology made by placing a series of thin organic films between two conductors. OLED screens can be extremely thin, and can even be "printed" on flexible surfaces. High pixel density can be achieved with OLED technology. As of 2014, the latest OLED displays offer resolutions as high as 4K (3840 x 2160) for a 65" display and a 55" 8K display (7680 x 4320) is reportedly in development (Morrison, 2014)(Cho, 2014).

In addition to resolution, OLEDs offer several other visual advantages. Because OLEDs emit their own light and do not require a backlight, pixels can be shut off individually. This allows OLED displays to produce higher contrast ratios and deeper blacks than backlit technologies like LCD and cubes. OLED displays are also brighter than many competing technologies. The inclusion of a white OLED in some displays increases brightness and contrast levels further.

The direct emission of light also allows OLED displays to provide wider viewing angles than LCDs. Pixel colors remain unshifted as the viewer moves off-axis, even at angles approaching 180°. Pixel response time and refresh rates for OLEDs are also significantly faster than LCD. OLED displays may provide a response time of less than 0.01 milliseconds, enabling a refresh rate up to 100,000 Hz.

If used to create a video wall, OLED displays would likely be comparable or even easier to install than LCD displays. With no need for a backlight, OLED panels can be extremely thin and lightweight; some OLED panels are as thin as 4mm. Like LCD and projection cube systems, an OLED video wall would likely be a tiled array of multiple panels. While the largest individual display currently available is 77", extremely large panels may be available in the future due to the light, thin nature of OLED technology (Morrison, 2014). In addition, the ability to "print" OLEDs onto a display surface opens a wide range of display possibilities, including flexible displays, roll-up screens, transparent displays, and even camouflage.

Early OLEDs had limited lifespans due to challenges of maintaining the organic material. In these early prototypes, certain colors, especially blue, tended to fade quickly, making the technology short-lived and unviable for 24/7 use. However, recent developments have reduced these issues and some of the latest OLED panels claim an MTBF of up to 100,000 hours, a lifespan comparable to LCD and LED projection cube systems.

Direct View OLED technology is still quite new and displays are currently very expensive due to high production costs. While leading manufacturers have debuted a number of OLED TVs, high prices and manufacturing limitations have prevented this technology from being adopted in the video wall industry thus far (Morrison, 2014). However, provided that development continues and prices begin to fall, OLED will become a highly competitive technology in the video wall market.

Laser Phosphor Display

Like OLED, Laser Phosphor Display (LPD) technology combines traditional technology with new components. First brought to the market by Prysm, Inc. in 2010, LPD employs a variation on cathode ray tube (CRT) technology, the system used in traditional tube televisions. LPD adapts this technology by using lasers instead of an electron gun to excite phosphors and produce an image. In an enclosed arrangement similar to a projection cube system, a set of movable mirrors reflects light from ultra-violet lasers onto a screen. The screen is made of a plastic and glass hybrid material and is coated with colored phosphor stripes. As the reflected lasers scan the screen from top to bottom, the energy from their light activates the phosphors, which emit photons, producing an image (Greene, 2010). Multiple LPD cubes, or tiles, can be stacked andarranged in various configurations to create a large-scale video wall.

Like projection cubes, LPD tiles feature narrow seams, which measure only 0.5 mm in some models. However, unlike cube displays, which may measure up to 80" diagonally, LPD tiles offer a surface area of only 25". Thus, while an LPD video wall will have narrower seams, it will also have many more seams than competing technologies. The pixel density of LPD displays is lower than many competing technologies, with a 25" display surface providing a maximum resolution of 427 x 320 (Prysm, 2013).

In terms of visual performance, LPD offers some notable advantages. LPD displays provide far better color reproduction than competing technologies. The unusually wide color gamut produced by this technology enables LPD panels to display 98% of the 24-bit color available from graphics cards. As a reflective technology, LPD displays are not as bright as LCD or emissive technologies like direct view LED and OLED. Some amount of ambient light control will be necessary to prevent images from being washed out. However, because the speed of the lasers enables pixels to be shut off individually, LPD provides excellent contrast ratios and black levels. LPD technology also offers significantly faster response times and refresh rates than LCD displays (Prysm, 2013).

Spatially, LPD tiles have a depth of around 16 inches. Depending on the type of frame that is used, the total installed depth of an LPD system will be around 24 to 30 inches, producing a footprint similar to that of an LED-based projection cube system. Because current LPD tiles are only rear-serviceable, a minimum clearance of 31.5 inches is required behind the displays to enable maintenance (Prysm, 2013). One positive aspect of this rear-serviceable design is that it enables the tiles to be more easily configured for touch interactivity. Like LED-based projection cubes, LPD video walls may be extended over time by stacking additional tiles on the array. The small surface area of LPD tiles allows them to be arranged in a wide range of patterns and shapes.

The initial price of an LPD video wall may be significantly higher than an LCD video wall of similar dimensions, but is typically less than a rear projection cube system. Typical power usage for LPD is similar to LCD and may be less than some competing technologies like blended projection and cubes (Prysm, 2013). LPD systems have no consumable parts and are mainly composed of solid-state electronics, so regular downtime should not be necessary. Provided that no maintenance issues arise, the long-term cost of ownership for an LPD video wall may be quite low. However, because the first LPD systems were installed only four years ago, there is little information available thus far on the long-term performance and maintenance requirements of this technology.

In terms of life span, LPD technology has not yet been thoroughly time-tested. While similar phosphor-based display systems like CRT have proven durable and long-lasting, the longevity of the laser component in LPD has not yet been established. The latest LPD tiles advertise an MTBF of 60,000 hours at 24/7 operation, a shorter life span than LED-LCD and LED projection cube technologies, which may offer MTBFs of up to 100,000 hours at 24/7 operation.

Because laser phosphor technology is still quite new, little is known about long-term performance and the range of options available to consumers is limited. However, as LPD continues to be tested and refined, it may emerge into the mainstream to compete more closely with LCD and cube technologies.

CONCLUSIONS

Searching for the Ideal System

This paper has chosen to focus on video wall display technologies because the selection of a display type is a common starting point in choosing a video wall system. However, there is much more to a video wall system than visual displays. Video wall controllers, which process content sources and route them to be displayed on the video wall, are another critical component of the system. The controller that is selected will determine the type and number of sources that can be displayed on the video wall, the way that content can be displayed and manipulated, and the stability and reliability of the system as a whole. Content rendering engines, or controllers with rendering capabilities, may also be desired to ensure fluid, seamless rendering for ultra-high-resolution video and big data sets. Video wall software is another essential system component. It is critical to select a software platform that enables users to perform the desired activities, is easy to learn and operate, and is compatible with user workflow.

Beyond these basic system components, additional elements such as integrated audio, video conferencing, video streaming and distribution, and external device control may also be desired. Regardless of the complexity of the video wall system, all components must be fully compatible with one another and expertly integrated to ensure consistent, reliable performance.

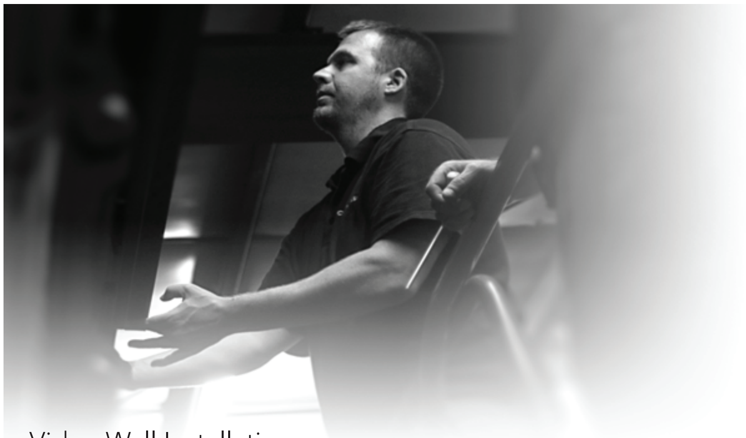
The process of selecting each component of a video wall system is further complicated by the fact that most manufacturers do not offer all necessary system components. Many offer only displays, while others can only provide processors and software. In addition, few manufacturers offer integration services for their products. As a result, customers may find themselves selecting components from multiple manufacturers and hiring an independent integrator to assemble their video wall system.

To ensure that their video wall system is built from the ideal components and is seamlessly integrated for optimal performance, customers should select a reliable and experienced partner to aid in the development of their system. Some customers hire independent contractors for this purpose. Alternatively, other customers leverage partnerships with video wall companies that provide end-to-end solutions, including all system components, integration, and support.

Concluding Thoughts

As this paper has demonstrated, an enormous variety of video wall display technologies are available today. All of these technologies have value, but their unique characteristics may make them better suited to some applications and environments than to others. In addition, because display technologies are in constant development, the characteristics and limitations of each will inevitably shift over time. This paper has attempted to provide potential buyers with a clearer understanding of some of today's most popular and emerging display technologies.

It is hoped that in learning about the characteristics of various technologies, the reader has been prompted to consider the unique demands of his or her application, workflow, and environment. Developing a clearly-defined set of goals and requirements is an excellent way to begin researching the ideal video wall display. As a next step, it is recommended to select a trusted and experienced display solutions expert to begin developing a fully-realized solution. The ideal solutions partner can offer a broad range of knowledge and experience, not only with various display types, but also with diverse applications and environments. It is also advised to seek a partner that takes a customized, solutions-oriented approach and can develop video wall systems that are optimized for the unique demands of each project.



Video Wall Installation

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