Projection Screens

Foreword

This module, ***Projection Screens***, is part of the ***Image*** chapter of the document, ***A Best Practices Guide*** published by the ***European Digital Cinema Forum***. It should be read in conjunction with other modules and chapters of the complete guide and in particular the modules on ***Architecture*** that help the reader to make the right choice in screen size and orientation for a given auditorium. The aim of this module is, however, to offer standalone guidance to help the reader gain a practical understanding of the range of projection screens available, how best to install them, and how to evaluate their suitability towards a particular cinema, preview theatre, colour-grading suite, or sound re-recording theatre application.

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Why is this important?

Upon the screen falls the duty of delivering the director’s vision. If ever there were proof that engineering is the art of compromise, it is here where all eyes rest. The accommodation of many viewing angles, the need to transmit sound, and the many vagaries of physics and the human visual system all come to rest on this screen. The more optimum the screen-choice is for each auditorium, the closer the resulting image is to the director’s vision, and the more powerful the immersive experience is for the cinemagoer. Similarly, the right choice of screen in a post-production facility offers a more optimum level of performance and a dependable reference for film-makers. Ultimately, the right choice makes for a more efficient and safer investment.

General considerations

There are several projection screen types, each with advantages and disadvantages. Screens can be made from white- or silver-coated plastic (PVC), rigid engineered substrate, or woven. Non-woven screens are primarily perforated but non-perforated PVC options are often available. Perforated screens permit sound to transmit through the screen and a range of perforation patterns, sizes, and densities offer varying trade-offs between sound performance versus picture performance. The woven screen is the least common type, but it has the advantage of offering the best transmission of sound from the screen channels: Left, Centre, Right and the Low Frequency Effects (L, C, R, LFE). Unfortunately, it is more expensive and hasn't yet been refined for large sizes. It also doesn't handle gain very well.

White screens are the most commonly used screens. The silver alternative, actually an aluminium material applied to the screen, became popular as it has the characteristic of being able to hold the polarization pattern of the most used type of stereoscopic equipment and achieve much higher levels of gain. Silver screens can sometimes introduce a textured or grainy look to the image, but modern advances have reduced this effect and some excellent examples are now available.

Gain describes a screen's reflectivity where a gain of 1.0 (or rather no gain / matte) describes a screen that reflects light in all directions equally. Plotting the relative light level of a gain 1.0 (matte) screen against a range of both horizontal and vertical viewing angles would show a hemispherical polar pattern. Such a pattern reflects stray light on to side walls, the floor and ceiling, which is distracting to the audience and reduces perceived contrast. It also reduces actual on-screen contrast because there is more stray light in the room that reflects back on to the screen indiscriminately.

Higher gain screens reduce stray light by reflecting more on-axis light at the expense of off-axis light and thus also at the expense of uniformity of light across the screen, which—when pronounced—is observed as a hotspot. Too much gain causes other problems than just hot spotting; apparent shifts in hue can be perceived by the human visual system when luminance—white light—is subtracted from colours. Without going into detail, Abney, Bezold–Brücke and Purkinje describe how changes in light level cause some colours to shift towards blue and others towards yellow, and some vary on the red-green axis: oranges might turn toward red, for example. Higher gain screens also tend to interfere more with laser projectors and the system can suffer more from speckle.

A benefit of gain is that a smaller projector bulb, and even a smaller projector, can meet the standard luminance goal than might otherwise been achievable with a matte 1.0 screen. White screens can be given gain for this benefit and silver screens inherently have gain. Careful optimisation is essential to match the gain of the screen to the room as will be discussed in the section, ***Gain and screen hotspot***.

Material

Consider the previous section, ***General considerations***, of this module and the following summary table to become familiar with the pros and cons of different projection screen materials for the particular application. For example, a sound studio that only needs a guide-image might choose a woven screen; a sound re-recording theatre might prefer a perforated white PVC screen in order to be closer in sound to the cinema norm; a colour grading suite might prefer a non-perforated white PVC screen; and a large 3D cinema might prefer a higher-gain screen.

	Sound transmission		3D compatibility		Gain
	Perforated	Non-perforated	Polarised	Non-polarised	
Woven	▲▲▲			▲▲▲	
White PVC	▲▲			▲▲▲	▲▲
Silver PVC	▲▲		▲▲▲	▲▲▲	▲▲▲
Engineered	▲▲		▲▲▲	▲▲▲	▲▲▲

The following sections provide further detail around the key parameters that must be balanced and will assist in the evaluation and optimisation of the desired specifications before the final choice is made. It may be necessary to revisit the choice of material during the evaluation process.

▶ Target image specifications

Luminance level, white point chromaticity, luminance uniformity, and masking requirements for theatrical projection in review rooms and commercial cinemas are specified in:

- ISO 2910 for 70 mm, 35 mm, and 16 mm film projectors; and
- ISO 26431-1, SMPTE ST431-1, and SMPTE RP431-2 for projectors with digital light engines.

The respectful application of these standards in both post-production and exhibition result in the cinemagoers' experiences being a very close match to the director's intent. Noting that ***sides*** and ***corners*** here are considered to be 5 % in from the image's edge, the common summary from these standards is as follows:

▶ Peak luminance (centre)	for review rooms:	14.0 ± 1.0 fL = 48.0 ± 3.5 cd/m^2
	for cinemas:	14.0 ± 3.0 fL = 48.0 ± 10.2 cd/m^2
▶ Peak luminance (sides)	for review rooms:	80 % - 90 % of centre
	for cinemas:	75 % - 90 % of centre
▶ Peak luminance (corners)	for review rooms:	80 % - 90 % of centre
	for cinemas:	not specified
▶ Chrominance (film)	5800 ± 400 K (black body colour temperature)	

▶ Chrominance (digital)	for review rooms:	x = 0.314 ± 0.002 and y = 0.351 ± 0.002
	for cinemas:	x = 0.314 ± 0.006 and y = 0.351 ± 0.006
▶ On-screen stray light	for review rooms:	≤ 0.4 % of centre
	for cinemas:	≤ 1.0 % of centre

To convert from cd/m² (candelas per square meter) to fL (foot-Lamberts), just divide by 3.43; of course, to get cd/m² from fL, just multiply by 3.43. (Please note that terms ***nits*** and ***candelas per square meter*** are the same and completely interchangeable.)

3D

The standards referenced in the previous section, ***Target image specifications***, are not exclusive to 2D presentations and, at the time of writing, there are no separate and differing standards for 3D presentation. Especially with the advent of high-output 6P laser projection with high-efficiency spectral-filtered 3D glasses on a lower-gain screen, it is quite possible to reach these standardised image specifications—and without visible ghosting. 3D has evolved, however, from a less-than-ideal scenario where a vast number of systems have been previously deployed with low light performance and poor ghosting. Because of this, many film distributors make multiple 3D DCPs mastered at a range of lower peek luminance levels (typically 3 fL, 4.5 fL, and/or 7 fL) in order to compensate for the de facto situation of the majority of 3D screens, which is typically between 3.5 fL and 4.5 fL. When considering 3D, it is important that cinemas match the light level performance with the content expected to be received. A dialogue with key film distributors to check for availability is an important element of research—especially considering the trend towards higher brightness. Talking to screen, projector, and 3D systems manufacturers is also advisable. Poor results can be experienced when projecting at a higher-than-expected luminance level and, less so, at a lower-than-expected luminance level.

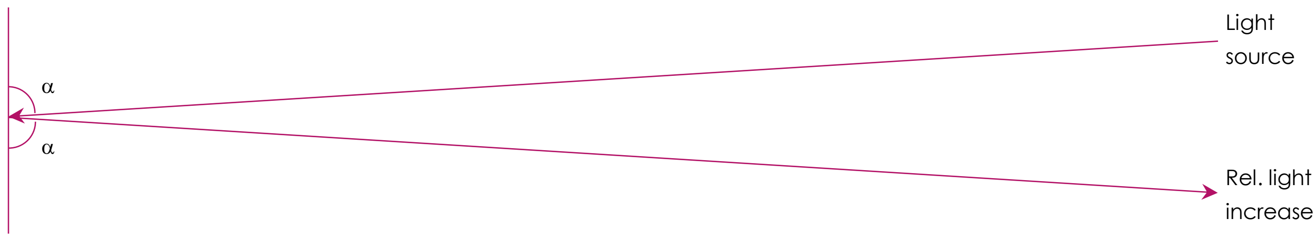
As per the table at the end of the section, ***Material***, the type of 3D system chosen may limit the choice of screen material. Non-polarising 3D systems, such as active shuttering or spectral filtering systems, can be used with any screen material but polarising 3D systems depend upon a high-gain silver or engineered screen to preserve as much of the original light polarity as possible to minimise ghosting. Polarised light will partly be depolarised by the screen, adding to the extinction ratio. Screen manufacturers typically aim for good extinction ratio values above 100:1 and higher values are achievable with higher gain screens. Lower values will contribute to 3D ghosting and may or may not be perceivable depending on the total ghosting of the entire 3D chain.

Different 3D systems—in combination with the choice of projection illumination and screen type—will introduce significant light losses into the system and typically enough loss that makes it impossible to vary the lamp current sufficiently to completely compensate between 2D and 3D.

Laser illumination helps considerably in this area. It is important to ascertain exact system efficiencies (that describe the losses) from each 3D vendor and incorporate that into the light level calculations that also include the projector output (including headroom), colour correction losses, lens speed, porthole glass losses, screen area, and screen gain.

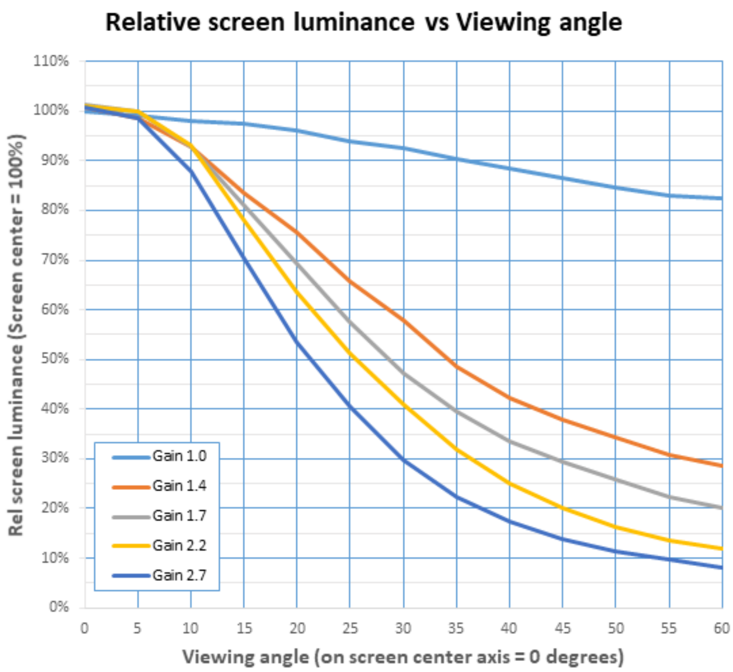
Gain and screen hotspot

Projection screen manufacturers typically specify the reflectivity characteristics of their screens with a ***gain*** value and a ***half-gain-angle (HGA)*** value. The gain value (given as a single decimal and typically between 0.9 and 3.5) is the amount of on-incident light reflected from the screen relative to the amount of on-incident light reflecting from a matte (1.0 gain) reference screen. For example, if 2.4 times the light is reflected compared to the reference matte screen under these strict conditions (normally in a laboratory), then the gain is determined to be 2.4.



Please note that ***on-incident*** means that the light path's angle of reflection is the mirrored match of its angle of approach, as illustrated above with angle α. The half-gain-angle is the angle away from α (in any direction) where the same central point on the screen now reflects only half of the amount compared to the on-incident amount. For example, if:

- the light measured on-incident (α) with the reference matte screen is 10 fL,
- the light measured on-incident (α) with the screen under measurement is 27 fL, and
- the light measured at an angle 22° away from α is 13.5 fL (= 0.5 × 27 fL),

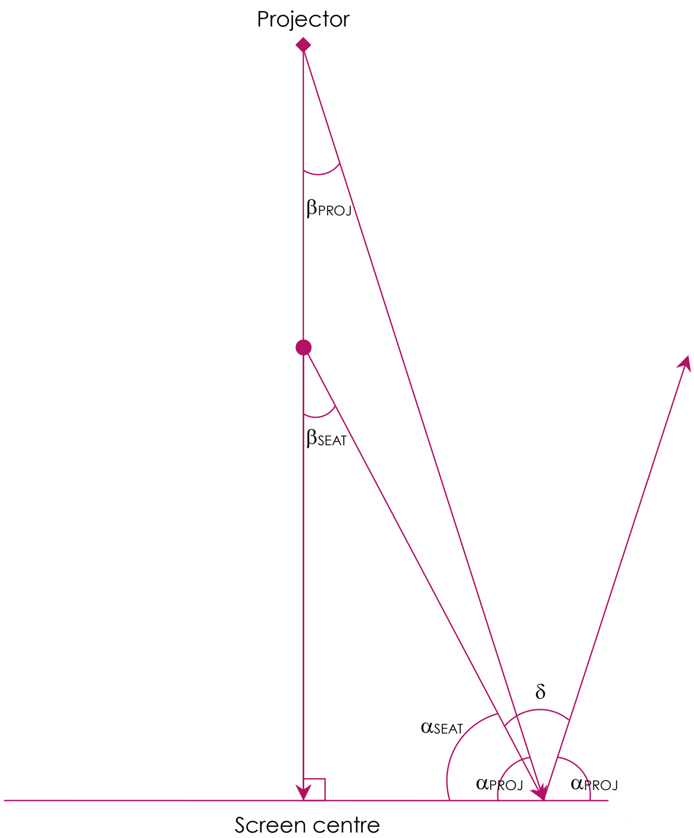


then the screen under measurement can be described as ***gain 2.7 : 22° HGA***. On-incident reflectivity is increased by reducing off-incident reflectivity. Screen gain, therefore, has a natural relationship to how quickly light falls off with increasing angle as the chart here shows. Note that different types of screen may deviate from these curves even if they have the same screen gain, so always check with the manufacturer. Also note that this chart assumes that the on-incident 100 % value is located at the centre of the screen—which is only true at one observed angle in 3D space (the angle has both horizontal and vertical components).

Interpreting the gain figure of a screen is straightforward but interpreting the effect of its HGA figure and gain curve on the resulting image requires greater imagination especially when considering projection and viewing angles in the 3D geometric space—and the potential for tilting and curving the screen. More on tilt and curvature later in this module.

Firstly, imagine sitting at a seat that is perfectly on-incident with the projector and a point at the very centre of the screen. It will be observed that the very centre of the screen is the brightest part of the image and the other points on the screen will all be darker. This is a hotspot caused by the gain of the screen, which is a sperate and additional effect to the static hotspot that is caused primarily by poor projector lamp alignment. (Please refer to the module, ***Projector Alignment***, also in this ***Image*** chapter of the guide, for more information on lamp alignment and minimising the static hotspot.) The diagram here illustrates the cause of the screen hotspot and how to interpret a screen's gain curve on the resulting image quality. In this example, the projector is perfectly centred at a distance of 10 m from an 8 m wide screen, the on-incident seat is at a 6 m distance, and the viewer is looking at a point 3 m away from the centre of the screen. This point is at angles β_{SEAT} and β_{PROJ} away from the seat and the projector, where:

- β_{SEAT} = tan(3/8) = 23°, and
- β_{PROJ} = tan(3/10) = 18°.



These projection and seating lines meet the screen at respective screen angles α_{SEAT} and α_{PROJ}, where:

- α_{SEAT} = 90° - β_{SEAT} = 67°, and
- α_{PROJ} = 90° - β_{PROJ} = 72°.

Working logically through the illustration, the angle from the on-incident reflection back to the seat (δ) is easily calculated, where:

- δ = 180° - α_{PROJ} - α_{SEAT} = 180° - 72° - 67° = 41°.

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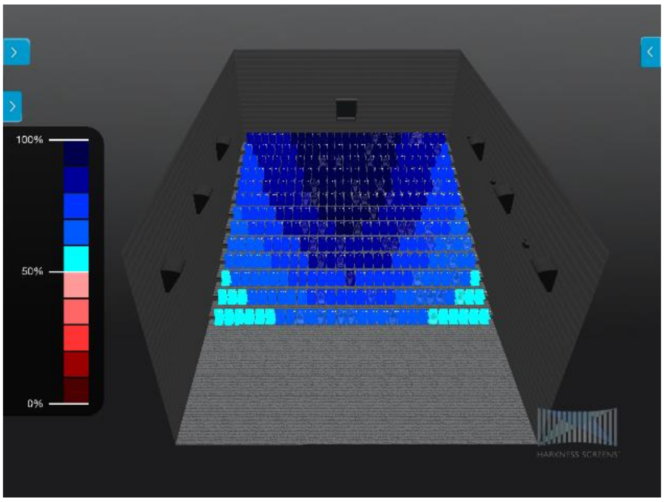
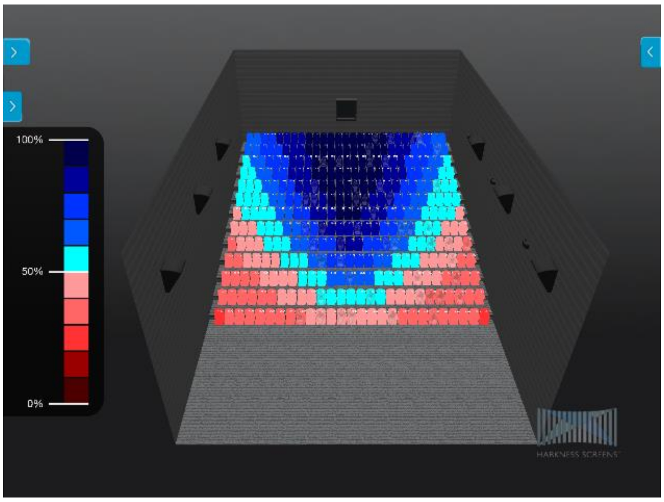
Looking this angle up on the gain curve published by the screen manufacturer will ascertain how much light loss there will be for the screen under consideration. According to the chart on page 5 of this module, a difference angle (δ) of 41° will reflect light at only 40 % for a 1.4 gain screen and even less for higher gain screens. With a high proportion of the audience receiving an inadequate level of light and uniformity, and where such performance does not meet the industry standards referenced earlier in this module, ***Target image specifications***, this is clearly an example where a gain screen is not the correct solution for such a geometry.

Secondly, imagine moving to a new seat away from that original on-incident seat. It will be observed that the very centre of the screen is no longer the brightest part. The following images are taken from Harkness Screen's popular digital screen modeller application and show how the centre screen peak brightness typically changes when viewed from individual seats on a lower gain screen (left) compared to a higher gain screen (right). (Please note that the perspective is down, through the screen, towards the projector, and looking at the seats.)





Finally, not only does the light level of the centre of the screen change, but the screen hotspot moves relative to the new seat position resulting in an unsymmetrical non-uniformity of the light on screen. In extreme angles, the far side of the screen can be so dark as to not show much image at all and what is seen is of low contrast and colour saturation. Moreover, for 3D presentations, the reflectivity of the screen is required to preserve polarity and therefore, as the screen gets darker, the potential for a 3D image to become ghosted increases. The following three mock-ups illustrate the same image projected onto:

- a matte (1.0) screen (left image);
- a high gain screen when viewed on-incident (centre image); and
- the same high gain screen when viewed from the left of the auditorium (right image).

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- The left-most image is the filmmaker's intent.
- Whilst the central image suffers from the addition of an unwanted vignette, it is at least symmetrical.
- The right-most image is very poor with most of the road in darkness—which is arguably supposed to be the main focus of attention for the audience as crafted by the filmmaker.

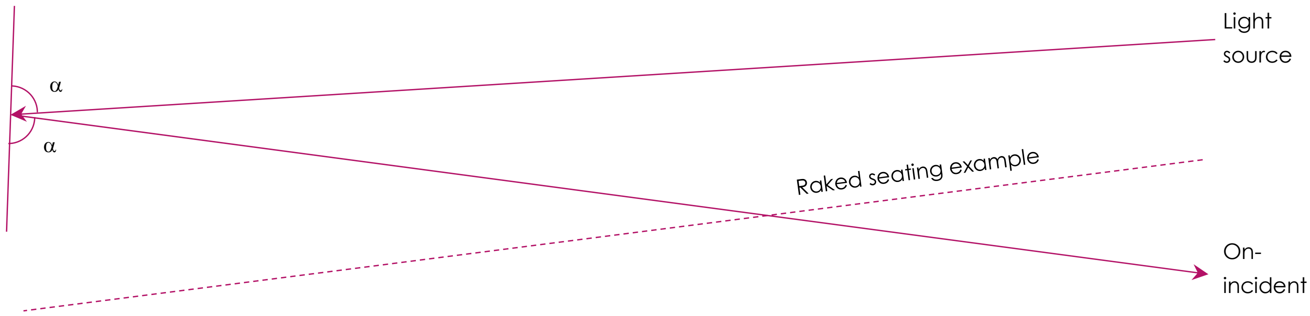
When the screen plays tricks like this example comparison shows, some of the audience are steered to the trees, some to the sky, and only some will see who is to drive towards us from the distance.

In summary, although gain is very useful, it is a balance where theatre geometry ***must*** be the prime consideration when choosing the right gain and ***not*** the needs of 3D, otherwise the image quality for both 3D and 2D will suffer. As gain essentially focuses reflected light into a narrower cone as the gain increases, this means that a higher gain screen may generally work well in a longer throw (narrow) auditorium but might be unsuitable for a shorter throw (wide) auditorium.

These images above illustrate how on-centre-incident uniformity changes between a moderate gain screen (left) and a high gain screen (right). Note that being on-incident means that this is the best case scenario and achieving the specification of the standards referenced early in this module, ***Target image specifications***, when positioned on-incident does not mean that these standards will be met at other parts of the seating area. Care must therefore be taken to balance performance across a suitably wide viewing area and not just at one spot. Also note that neither of these example images meet the standards for uniformity and only the right one meets the standard for cinema peak luminance but not for review rooms, which has a tighter tolerance.

Tilt and curve

It might be necessary in some circumstances to tilt the screen to ensure the on-incident line meets the central seating area, which ensures the hotspot is not too high or too low on screen. Compare the illustration below to the one in the previous section, ***Gain and screen hotspot***. Here the screen is tilted 2° forwards and has the result of rotating the on-incident line from the screen by twice that amount. This moves the on-incident viewing position lower and further towards the screen, which raises the hotspot from the bottom of the screen to the centre for those central seats.



Ideally if one were to look at a side elevation CAD drawing of an auditorium and drew an incident light path line from the projector lens to the screen centre and then a reflected light path line at the same but opposite angle into the seating area—respecting the screen tilt—this line would ideally hit the centre row seat at eye height. In this condition, with a gain screen, the brightness at the top would approximately equal the brightness at the bottom when measured from the geometric centre of the seating area. However, if the incident light line struck the seats above or below the centre row due to theatre geometry then the top to bottom uniformity would be uneven. Whilst tilting the screen either backwards or forwards as appropriate can reduce or eliminate this issue by redirecting the light path, one must consider image deformity and how the screen looks to the audience; tilting is best kept as minimal as possible.

The previous section, ***Gain and screen hotspot***, describes in detail how gain increases peak brightness by focusing the reflected light to the detriment of uniformity: the edges appear dimmer when looking from the centre and they may not be equal if the projector or viewer is not on the centre line. A curved screen frame may help with these issues. Curving the screen frame allows reflected light to be redirected back into the seating area (by essentially reducing the δ angle described in the previous section, ***Gain and screen hotspot***), making the screen sides visibly brighter and reducing any visible hotspot. Screen curves are usually referred to in percentages and typically a 5 % screen curve offers advantages in most gain screen situations. For example, a 10 m screen with a 5 % curve would have a curve depth of 0.5 m; i.e. (0.5 m / 10 m) × 100 = 5 %.

Caution has to be taken with curves above 5 % due to the increased risk of image deformities and / or cropping in the centre area, which must be considered. In the illustration below, a

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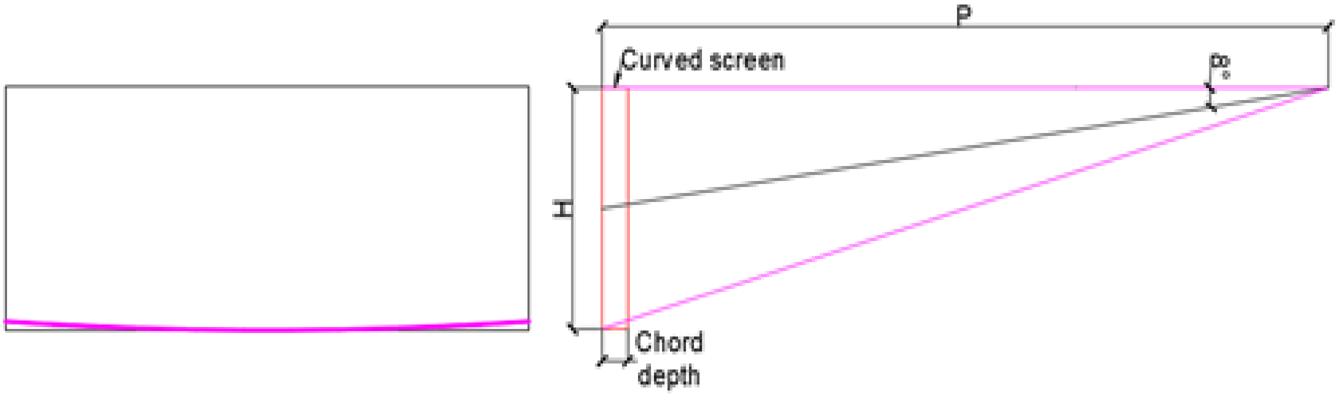
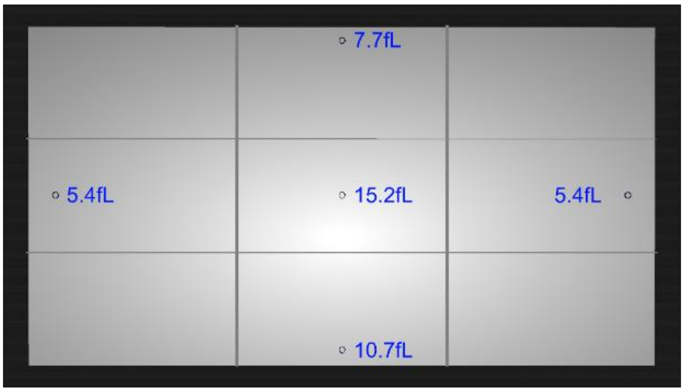
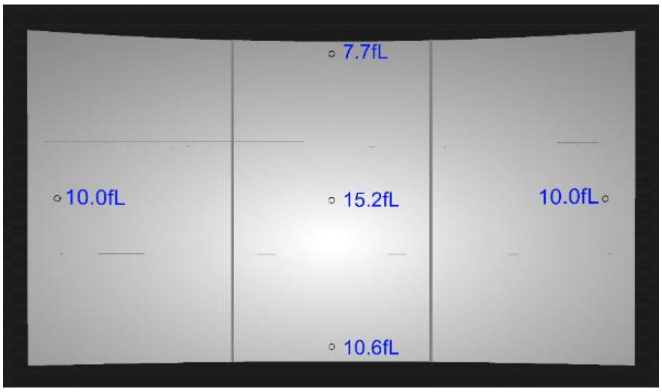
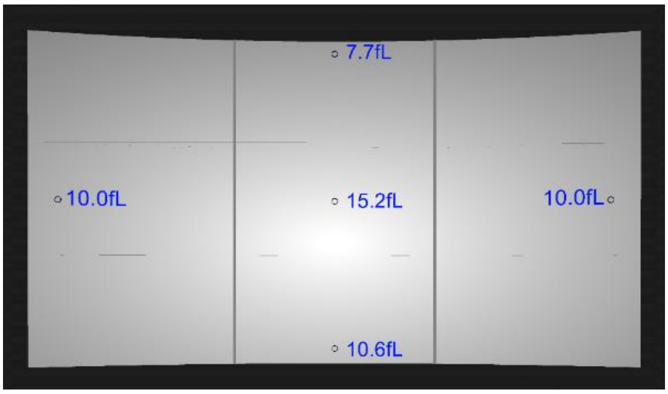
straight magenta line is projected on to the bottom of a 5 % curved, un-tilted cinema screen with an 8° vertical projection angle and where P / H = 3.4. Note that the magenta line appears curved on the screen and yet a similar line at the top of the screen will appear straight. That means subtitles and credits and other image elements that should be straight will seem deformed depending on where they are located on-screen.

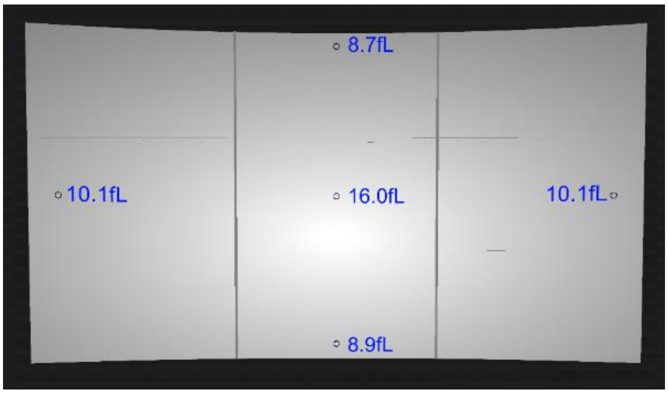


Using the digital screen modeller application helps provide equipment calculations and can typically show the effects of tilting and curving in a 3D space.









The images above show a non-curved frame (top left) and a curved frame (top right) and the positive effect the curve has on light uniformity at the expense of image deformity and cropping.

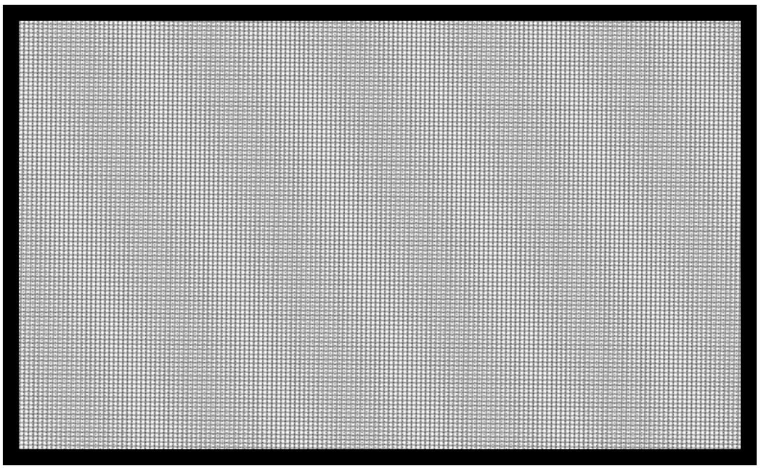
The images also show a non-tilted frame (bottom left) and, in the case of this example, a forward-tilted frame (bottom right) and the corrections it produces in evening out the top-bottom uniformity and, thus, centralising the hotspot.

Here are some further aspects to consider when comparing non-curved and curved screens:

- Projection lenses give best geometry on non-curved screens.
- The picture on non-curved screens looks less deformed when viewed from oblique angles.
- Consider curving a screen when using a gain screen surface to improve brightness uniformity and to minimize the hotspot effect.
- Subjectively, curved screens may, consciously or subconsciously, enhance or amplify the audience's sense of immersion, like in the days of 70 mm, Cinerama, etc.
- Do not use deep curved screens. 5 % curve is a good compromise. This means that the chord depth (sagitta) is 5 % of the chord length.
- On a curved screen, a straight horizontal line projected on the screen will be slightly curved. A larger angle, larger screen, and deeper curved screen increase the deformity.

Perforations and sound transmission

The PVC sheet can be manufactured with perforation patterns for sound transmission from the speakers mounted behind the screen. Most cinemas and review rooms have the front loudspeakers placed behind the screen in order to give the most convincing unification with the on-screen action. Such setups require the sound to transmit through the screen and this is achieved with either a woven screen or—more commonly—a perforated screen. The total opening should be around 5 % to give acceptable sound transmission without losing too much reflected surface and, thus, light level.



Standard perforations have a diameter of approximately 1.1 mm, which will be invisible at distances greater than about 5 m from the screen. Smaller *mini perf* patterns are possible for closer viewing situations to avoid perforations becoming visible to the audience. Standard perforations may also interfere with the size of the pixels from a digital projector, especially 4K projectors.

Different perforation patterns are typically available to minimise Moiré fringing, which is an effect caused when projected pixels align with screen perforations in some cases. See the Moiré fringing example on the previous page to see the interference patterns that can seem to exist. The size of the projected pixels can be calculated by dividing the full-chip-projected width in 2.39:1:

- by 2048 for 2K projection, or
- by 4096 for 4K projection.

Full-chip-projected means that no electronic scaling is employed. Alternatively, the same pixel-size should be derived by divide the full-chip-projected height in 1.85:1:

- by 1080 for 2K projection, or
- by 2160 for 4K projection.

It should also be noted that all potential issues with perforations are completely avoided by selecting a non-perforated screen. Whilst this is obvious, for applications where sound is of low value, such as in a colour grading suite in post-production, selecting a non-perforated screen should certainly be considered.

Installation, aspect ratios, physical masking, and electronic masking

It is important to set out clearly at the outset of this section that there are effectively two different levels of 'black' on screen:

- the grey from the room's stray light that shines on ***all*** of the visible screen regardless as to whether or not there is also an image; plus
- the lighter grey from the ***entire*** 1.9:1 chip of the projector where there's either no image or where electronically masked (cropped)—both of which are identical and are the lowest light level projectable. (Please refer to the projector's contrast ratio specifications for more insight.)

Cinema screens are mounted using two types of screen frame:

- The first is a ***lace-in*** type where the screen is laced inside a frame. This is similar to how a trampoline is fixed into its frame with fixed masking used to cover the fitments and to frame at least the largest image size—and ideally to move to frame all aspect ratios.
- The second method is known as a ***wrap-around*** because the screen surface wraps around the frame and is fixed at the rear. This method is sometimes referred to as a ***floating screen*** because the frame and fixtures cannot be seen, only the mounted screen

surface. Floating screens are often used where a wall-to-wall screen experience is required and typically do not employ masking—which is against DCI specifications (§ 8.3.3) and results in areas of the reflective screen being consistently projected with the darkest grey the projector can manage plus the reflected stray light from the room.

The aspect ratio is simply the ratio ***width:height*** of the image. It is the norm in cinema to reference the width as a decimal relative to a normalised height of 1. The broadcast industry, the content of which is ever more being replayed at the cinema, prefers to represent aspect ratios as fractions in their simplest form, such as 4:3 or 16:9. Of these, dividing the width (numerator) by the height (denominator) will give the equivalent aspect ratio for cinema (e.g. HD16:9 = 1.78:1). In most cases, for-cinema-films are made and projected using two common aspect ratios:

- 2.39:1 (scope)—which is adopted by ~70 % of the top-grossing films (a 20-year increase from ~40 %)—and
- 1.85:1 (flat, also called widescreen)—which is adopted by ~30 % of the top-grossing films (a 20-year decrease from ~60 %).

Whilst these two are the common norms by a significant margin—especially scope—there is no rule that precludes the use of any other aspect ratio, only that the image container on the DCP must extend to either the entire width of the chip or its entire height. Historically, 1.66:1 was prevalent; now a few filmmakers have started to experiment with new fixed aspect ratios, or even to vary the aspect ratio scene-by-scene, or to adopt a floating window technique, which often helps in the illusion of 3D depth. These departures from the two norms are quite rare and this is fortunate because such departure presents practical issues for cinemas who wish to ensure all non-image areas of the image are masked off—which is important to give the illusion of full immersion and high contrast—or, otherwise, who wish not to have both a letter-boxed and pillar-boxed presentation—which is likely to be the result if the projector does not have the matching macros set up.

It must also be recognised that, depending on territory, cinemas are presenting an increasing amount of non-cinema content that is mostly produced in the broadcast standard aspect ratio of 16:9 (1.78:1).

All this complexity means that the actual screen surface aspect ratio must be very carefully considered before the ultimate decision is made and this section aims to help in that decision. It should also be noted that, independently, the digital cinema light-engine chip aspect ratio is 1.90:1 (Full-chip: 2048:1080 for 2K and 4096:1160 for 4K). The size and shape of the auditorium will play a significant role in the choice of screen aspect ratio. Aside from that, the first two choices are as follows:

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- **Scope screen (2.39:1)**
  Most feature films will be presented wider than the pre-show.
  It looks impressive when widening for scope content.
  Side masking moves out for scope content.
  Side masking moves in for flat content.
  Top and bottom masking is fixed.
  This requires a zoom lens.
  This requires lamp current adjustment between flat and scope.
  It looks bad if no masking is used (pillar- and/or letter-boxing).

- **Flat screen (1.85:1)**
  Most feature films will be presented smaller than the pre-show.
  Scope looks underwhelming when smaller than flat.
  Side masking is fixed.
  Top and/or bottom masking moves in for scope content.
  Top and/or bottom masking moves out for flat content.
  This requires a zoom lens.
  This does not require lamp current adjustment (too minor).
  It looks less bad if no masking is used (letter-boxing only).

A hybrid approach that completely eradicates the need for a zoom lens (which is an advantage for dual-projection systems and format-accuracy) is:

- **Full-chip screen (1.90:1)**
  Most feature films will be presented smaller than the pre-show.
  Scope looks underwhelming when smaller than flat.
  Side masking moves out for scope content.
  Side masking moves in for flat content.
  Top and/or bottom masking moves in for scope content.
  Top and/or bottom masking moves out for flat content.
  This does not require lamp current adjustment at all.
  It looks bad if no masking is used (pillar- and/or letter-boxing).

It should also be noted that Premium Large Formats (PLF) may indeed differ from the above and the specific advice or requirement from each PLF vendor should be heeded. Outside of PLF, which option is selected is highly subjective and depends on the personal vision of each facility.

A lace-in screen will always have some static black material to frame the largest aspect ratio image and cover its fixtures, and then further masking is required when changing to a smaller format to ensure this is also framed correctly. This further masking must be moveable and is typically motorised in order to be fully automated. This moveable masking is black material that must also be transparent to sound if used on a scope screen because the masking is likely to be positioned in front of the left and right screen loudspeakers when the masking is set to flat (1.85:1).

Projection Screens

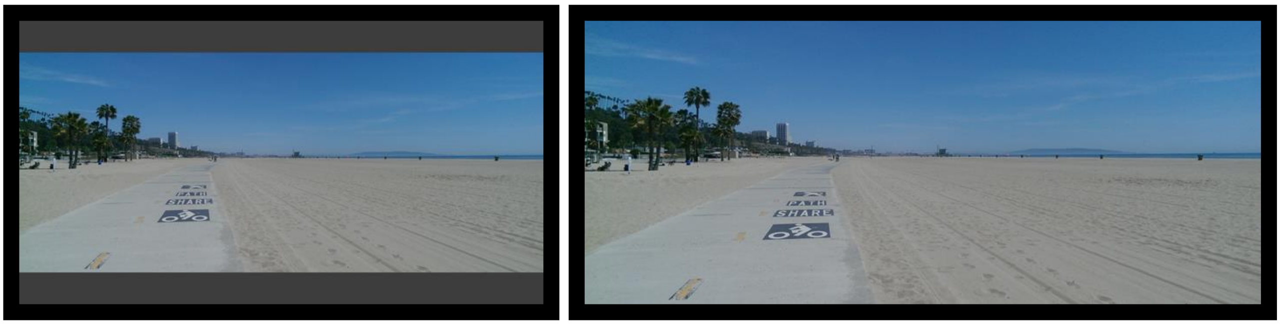
It is also possible to have moveable top and bottom masking instead of, or in addition to, moveable side masking.

DCI specifies (directly in V1.2 and via normative reference to SMPTE RP431-2 since) that the screen is required to have variable black masking, adjustable to tightly frame the projected image. This is essential in order to create the illusion that blacks are black. Parts of the screen that are consistently pseudo-black (such as a letterbox, pillar-box, or both) will never look black because the highly reflective white or silver screen will be reflecting back stray light from the room plus any projection of empty or electronically masked areas of the chip. This makes for a presentation that breaks, or at least challenges, the cinematic illusion and makes for a subjectively lower-contrast experience for the cinemagoer.

Electronic masking is not masking and must not be confused with—nor substituted for—physical masking. It is impossible for the projector to project black let alone negative light. Any 'black' area of a screen will always look grey. Electronic masking is actually a final set of cropping instructions in the projector that are used—if necessary—to crop the projected image very slightly. This is done as a final stage in projector alignment to precisely match the projector output to the physical masking so that there is no image projected onto that physical masking, only the darkest grey the projector is able to achieve. This is at least a final fine tune, but—and especially for curved screens—electronic masking is a particularly important and necessary final alignment step. (Please refer to the module, ***Projector Alignment***, also in this ***Image*** chapter of the guide, for more information.)

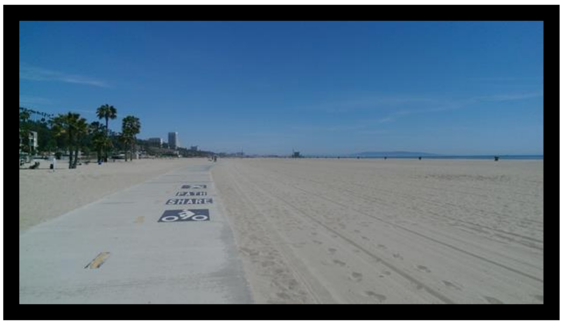
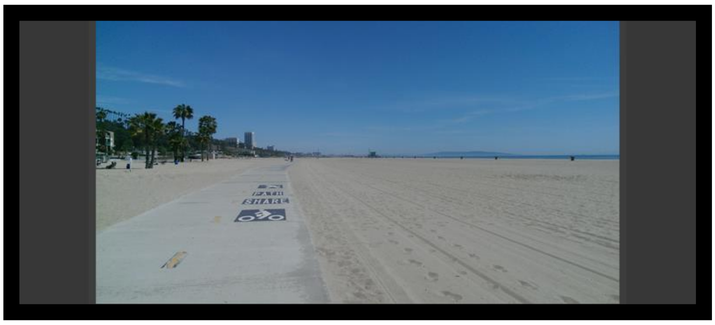
It is indeed recognised that there are many cinemas that have chosen not to use physical masking. Such a practice is not recommended, as discussed above, and the following scenarios for flat screens (left) and scope screens (right) aim to further illustrate why. Note the two levels of 'black' (as described at the outset of this section) in some of these examples.

- A ***DCP player*** outputting ***scope content*** to the projector's ***scope projection*** results in either a ***letterbox*** (left) or ***perfection*** (right).

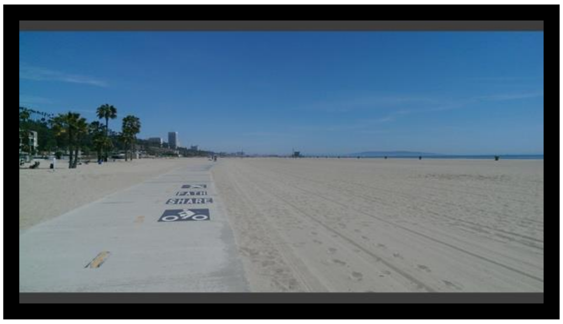
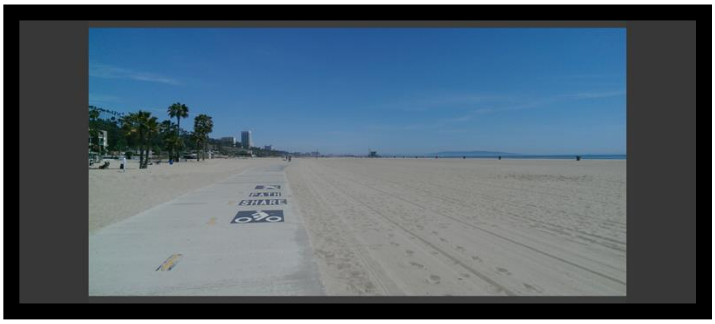


Projection Screens

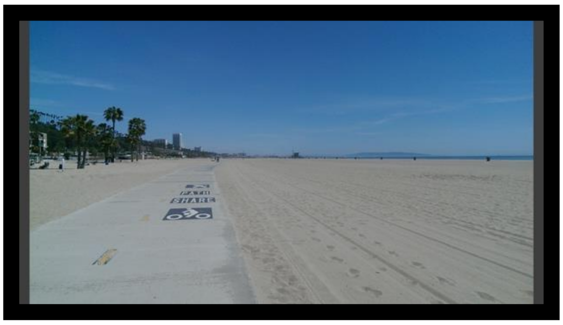
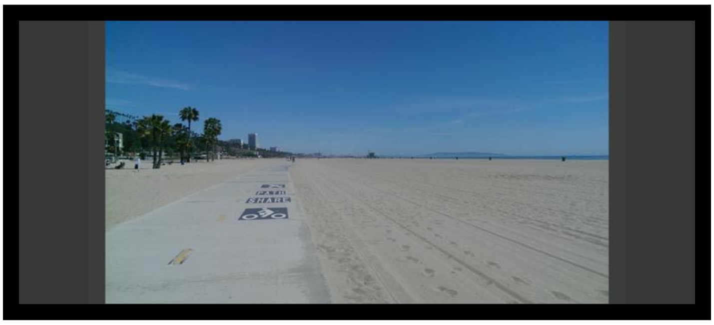
- A ***DCP player*** outputting ***flat content*** to the projector's ***flat projection*** results in either ***perfection*** (left) or a ***double pillar-box*** (right).

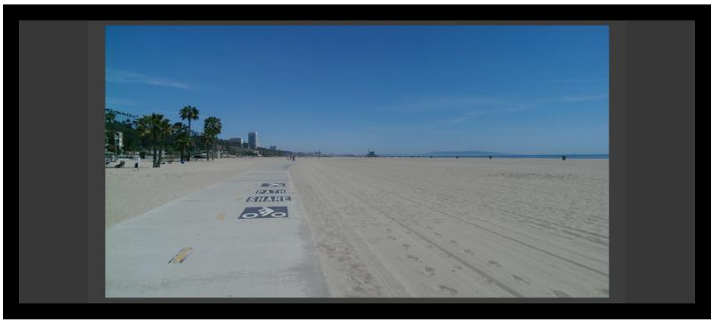
- A ***DCP player*** outputting ***2.00:1 content*** to the projector's ***scope*** (left) or ***flat*** (right) ***projection*** results in either a ***letterbox*** (left) or a ***pillar-boxed letterbox*** (right).

- An ***HD/UHD player*** outputting ***16:9 content*** within a ***16:9 container*** to the projector's ***flat projection*** results in either a ***single*** (left) or ***double pillar-box*** (right).

- An ***HD/UHD player*** outputting ***letterboxed flat content*** within a ***16:9 container*** to the projector's ***flat*** projection results in either a ***single-*** or ***double-pillar-boxed letterbox.***

- An ***HD/UHD player*** outputting ***letterboxed scope content*** within a ***16:9 container*** to the projector's ***flat*** projection results in either a ***single-*** or ***double-pillar-boxed letterbox***.

Note that it is always advisable to analyse the text string of the ***ContentTitleText*** of the CPL which indicates the ***Projected Aspect Ratio*** and the ***Content Type Modifiers***, which include the mastered luminance if there are multiple versions distributed. For the entire description of the Digital Cinema Naming Convention (DCNC), please refer to the Inter-Society Digital Cinema Forum's on-line resource: ***https://isdcf.com/dcnc/***.

De-speckling

Projector light sources need to be considered. Lamp-based technology and laser phosphor technology typically work well with all screen types; however, RGB laser technology can suffer from an interference pattern known as laser speckle. RGB laser projection onto certain screen surfaces, often higher gain and standard silver screens, will unfortunately result in noticeable speckle on screen. That said, there are white screen and certain newer generation silver screen technologies that mitigate laser speckle better than others; projector and screen manufacturers can provide the most current product advice.

Another less common but successful method for mitigating laser speckle is by installing an array of actuators on to the screen frame. These vibrate the screen, thereby continuously changing the angle of illuminance, which disrupts the visible speckle that otherwise seems static to the eye. The type of screen surface has great influence on how well actuators are working. An engineered substrate screen works very well with actuators reducing the number of actuators needed and thus reducing the noise these produce. The noise does have to be taken into account as it can be quite intrusive.

Tools and headroom

There are several useful calculation tools available that reference peak brightness and take into account all elements in the projection chain. All major cinema projector manufacturers (e.g. Barco, Christie, NEC and Sony) provide calculation tools as well as Harkness Screens, which provides its Digital Screen Calculator, which comes as an app for the web, iOS, and Android. The Digital Screen Modeller shows more information such as light uniformity and performance across the specific auditorium being modelled.

Also refer to other modules of this wider document, ***A Best Practices Guide***, in particular the modules of ***Lens Selection***, ***Projector Light Sources***, and ***Light Output Calculation***.

Ultimately, there are clearly many different choices that must be made when considering screens but regardless of what projector, light source, or 3D system is initially desired, one must consider initial target light levels (fL or cd/m^2) for both flat and scope, and for 2D and 3D, that include an appropriate amount of system headroom. For example, calculating and meeting a target light level with a new projector and a zero-hour lamp operating at maximum power will lead to problems during most of the lifetime of the light-source and optical components of the projector as they age. Light levels will only drop and there will be no additional light source power to compensate for the aging process. Check with manufacturers and with industry peers as to the expected performance-over-time characteristics of the equipment under consideration.

Your notes