

Four Issues to Consider When Producing Fulldome Content for Wide Distribution.

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Abstract:

At the request of the Denver Museum of Nature & Science, and with grant support from the National Science Foundation, Spitz Inc. performed a set of production tests to help ensure wide distribution and cross-compatibility of future fulldome shows with many different fulldome projection systems. The goals of the tests were to:

1. establish action and text safe areas for fulldome production
2. investigate how to deal with differently tilted domes
3. investigate how to deal with gamma issues
4. address what happens to stars when transferring content to systems with different resolution requirements.

This paper details the issues that were investigated, explains the tests that were performed and presents our findings.

Paper:

At the time that this paper is being written, some of the tests are still ongoing and no definitive conclusions have been reached, so it should be considered a work in process. Also, it is the opinion of this author, that some of the issues that we will address are production aesthetics issues and are not objectively testable. In these cases, the best we can do is to raise awareness of the issue, demonstrate various approaches, and if a general consensus happens to emerge amongst aesthetically trained viewers, we may be so bold as to present the consensus as a “recommended approach” or “best practice.” You will notice that we have consciously chosen to address only theaters with unidirectional seating designs in our research. While omni-directional theaters do offer certain advantages, they do not represent a significant percentage of fulldome video theaters, and the special production requirements that they impose place them outside the scope of our research. Our test theaters are:

1. Fels Planetarium at the Franklin Institute – 6 channels of 1280x1024 Mpeg-2 compressed video, CRT video projectors, 0 degree tilt
2. Denver Museum of Nature and Science – 11 Channels 1280x1024 Wavelet compressed video, DLP projectors, 25 degree tilt
3. ElectricSkyII at Spitz, Inc. – 1535x1536 Uncompressed, single lens fisheye, 12 degree tilt
4. SciDome at Spitz, Inc. – 1024x1024 Mpeg-2 compressed video, single lens fisheye, 10 degree tilt.

1. Nominal Camera Tilt

There is no standard dome tilt or sweep for fulldome video theaters, but content producers often wish to present viewers with a “gravity level horizon”. This is done by subtracting the degree of dome tilt from the tilt of the rendering camera within a 3D package. Because the viewer is immersed in the frame, a non-gravity level horizon can make the viewer feel off-balance.

In my experience, the mind quickly adapts to this contradiction between the inner ear and ocular system, but there is most likely an outer limit and an optimal range. This test seeks to, first, determine those ranges, second, to use that information to determine a tilt that is in the optimal range for the largest number of existing theaters, and third, to relate the effect of an ideal horizon to various types of content, such as those with a visible horizon, a non-visible horizon, or an implied horizon.

We created four different test sequences (culled from Spitz’s current work). Each test sequence represents a different type of content. The three types are:

1. Visible horizon – a sequence where there is a clearly visible horizon, such as a landscape.
2. Non-visible Horizon – A sequence where there is no visible horizon line and no camera motion that might imply a vector-based horizon. An example might be a scene in outer space where the camera is not moving.
3. Implied Horizon – A sequence where there is no clearly visible horizon but a horizon is implied, either through a camera motion vector (camera dolly) or perspective vectors (vanishing points). This could be a space-based scene where the camera is moving forward past objects such as planets or asteroids. The more objects that we are moving past, the more clearly defined the implied horizon will be.
4. Rolling Text plane – This is a simple credit roll, rendered out on a billboard plane. The reason for this test is to see how the tilt effects the readability of text.

Each of the three test sequences were then rendered out with camera tilts of 0, 10, 20, and 30 degrees. This means a total of 16 test sequences were rendered. It would have been interesting to expand our testing to see the effect of even greater tilts, but since our test seeks a gravity level horizon, and the majority of dome theaters are tilted from 30 to 0 degrees, we limited our tilts to this range. These sequences were then looked at and evaluated in domes of various tilts.

One approach that was suggested for ensuring a gravity level horizon in the most number of theaters but never explored beyond the conceptual level was over-rendering the field of view and then post processing to the proper dome tilt. In other words, if you change from rendering a 180 degree polar master to a 210 degree polar master, you could then do a post process to crop out 180 degrees from the 210 degree master and simultaneously apply an additional tilt factor. The disadvantage of this method is that

higher resolution masters would be required in order to maintain image quality, production would be complicated by the fact that artists would have to apply more detail to areas of the scene that wouldn't otherwise be seen, test viewing of the entire dome master at once would be impossible on anything less than a 210 degree hypo-spheric dome, and perhaps most importantly, artistic control over what is in view and what isn't would be lost. This method is something to think about, but due to all of the disadvantages, I can't personally recommend it as a standard production practice at this time.

Currently, not all of the members of the testing team have had the opportunity to see all of the tests in all of the domes, but based on what we have seen so far, a consensus seems to be emerging. If you look at the range of tilts that we tested, it should come as no surprise when I say that the consensus is that a 15 degree tilt looks the most correct in the greatest number of theaters.

2. Action and Text Safe Areas:

The idea of an action and text safe area was originally created for flat screen production to ensure that critical information survived the various processes that television broadcast or film transfer and projection forced upon the content. As fulldome video producers, we too can benefit from a defined action and text safe area guideline, but for different reasons. Our problem is not that the edges may get cropped in projection, but that since the field-of-view that we have available is so wide, it's possible to place important information beyond of the field-of-view of the viewer. It's possible to make text so large that it's illegible or to frame action over such a large area that it becomes difficult to follow. The goal of this test was to create a "Dome Master" format reference frame that shows recommended title and action safe areas.

The test that we created for this consists simply of two lines of text (a title and a subtitle) that is rendered at varying sizes. The text reads "This is a Title" and "This is a longer Subtitle". The bounding area of the text for each iteration was shown in the frame, as well as some numeric indicator of size. We observed these test frames in a dome and choose the largest comfortably readable version. Add a 15% border and you've got a rough action safe area.

There was no clearly defined conclusion that resulted from this test, but the participants all commented that viewing the test gave them a higher level of understanding of the issue at hand. It seems that there is no objectively measurable "best text size" or "safe area," but the test made it clear that it's possible to make text too small or too large to be readable. The safe area is content dependent. The most important thing is for the art director to understand the effect of his or her choices.

3. Gamma:

Gamma is a paper topic in itself and I will only give a broad overview of the issues here. In my discussions with various content producers, projector manufacturers,

and theater operators, I've come to realize that when people refer to gamma, they are often referring to far more than just gamma. They are actually talking about gamma, color temperature, white point, black point, and basically everything to do with accurate representation of the source material on the dome. This is the most challenging of all the tests because ensuring accurate color representation requires proper calibration of every system in the imaging pipeline, from creation to projection. No one can say that a projector's color doesn't look correct if we never define what "correct" is to start with. Fortunately for us, a standard already exists in the world of digital imaging that can apply directly to us.

First, let's define gamma. The values produced by a display device from black to white are intentionally nonlinear because the human eye perceives such shifts in a logarithmic curve. Gamma defines the slope of that curve at the halfway point between black and white. The standard gamma curve used on CRT displays for digital imaging is 2.2. This curve closely matches the inherent nature of the CRT device, as well as natural human vision. This is also a common target for video projectors used in theater environments. Therefore, this curve seems like an ideal target for digital dome display systems as well. Digital imaging standards also direct us to set our projectors "white point" at 6500 Kelvin.

If standards already exist that apply to us, why don't we follow them? Well, it may be that there are no really "good" reasons, but conforming to the standard does present some challenges. The first issue is most likely one of education. It seems that very few people understand objective color calibration. Theater technicians working with multi-projector edge blended displays probably feel that simply color-matching all of the projectors to each other is a big enough challenge without also having to match them all to an objective standard. Second, a spectro-radiometer is required to objectively calibrate the display. So far, few theaters have been willing to invest the \$3000 or more required for one of these devices. Spitz has been investigating some of the more common visual techniques for gamma correction of displays without the need for expensive hardware, but there is some difficulty in applying these methods to dome projection systems. Research into this technique is ongoing.

Finally, projector manufacturers aren't making it easy for us because many of the types of projectors that we use to create fulldome video displays were originally meant to be "graphics projectors," and have a different built-in gamma curve that makes text and graphics look better and brighter at the expense of dynamic range. These projectors are typically set with color temperatures closer to 9000 to 10000 Kelvin. Sometimes the controls for adjusting the color calibration are buried deep in non-user-friendly menus or even require an external computer with special software to be connected to the projector. When a projection system is "properly" calibrated, the image often looks less bright than before, when it may have been set to sacrifice dynamic range in exchange for more brightness.

Assuming that we can somehow convince artists to calibrate their monitors, projector manufacturers to set up their projectors with the needed controls, and theater

technicians to properly calibrate their display systems, have we then eliminated the need for individual color correction of the dome masters for different theaters? While it would be a huge improvement, unfortunately, the answer is that special color correction would still be required in many cases. Otherwise, all theaters would have to use the same projection technologies, the same dome reflectivity, and be the same size. It simply isn't practical to expect that this will ever happen. Content producers will still have to do some gamma testing to make sure that their imagery is represented to their satisfaction on each different type of system.

Since the slicing/splitting process is unique to each theater, that is the best time to perform gamma adjustments. Spitz's dome-master slicing software has the ability to slice and correct gamma at the same time. It is the author's opinion that this should be a standard feature of all slicing software. If there were a list of the gamma correction amounts made for each theater to which everyone has access, some trends might emerge. We might be able to look at the list and make judgments like "most X sized domes with X reflectivity and X type projection system require a gamma adjustment of 1.3" and eventually reduce the amount of testing required. If all of these issues are addressed, we will be very close to a color-managed workflow.

4. Star decimation:

Different types of theaters have different resolution limits. Most high-resolution imagery can be scaled down and played back on lower resolution systems with only the expected penalty of a corresponding loss of fine detail. Unfortunately, stars fall into the realm of "fine detail." The conundrum is that, if a production is rendered at high resolution with very fine stars, those stars might be supersampled out of existence during the scaling-down process for theaters with lower resolution limits. If the stars are rendered large enough to survive the scaling down process, then they may look too large and fuzzy when projected on systems with higher resolution capabilities. The purpose of this test is to investigate what happens to very fine stars during the scale-down process and how to best deal with that issue.

The first part of this test was simply to determine if any of the different image resampling algorithms were any better than the others at decimating a static starfield image. The static starfield also had some larger objects in it that contains both hard linear edges and softly gradated areas of color. This was to ensure that we aren't selecting a sampling method that preserves stars at the expense of image quality for non-star objects. We experimented with Hermite, triangle, Mitchell, Bell, B-spline, Lanczos, and EWA sampling methods. In the end, none of these different filters were objectively any better or worse at decimating stars. They all yielded nearly identical results.

The second part of the test was to determine if a star size compromise could be found that both looks good in high resolution theaters and scales down acceptably on lower resolution systems like SciDome. To get an idea of what star sizes look good in a theater with high resolution capabilities, we called the Denver Museum of Nature and

Science. DMNS has done their own research and typically renders stars at a size of 2.5 pixels for a 3600x3600 polar dome master. They report that sizes up to 4 pixels are acceptable on their dome, but anything over that begins to look unacceptable. This is the size range that we should look at most closely. If we can make 2.5-4 pixel stars acceptable when scaled down to 1024x1024, we will be in good shape. If no compromise can be found, then we should consider the possibility of rendering all show material in two layers: a star layer and a foreground layer, which can be composited together in post-production. Thus, the stars can be replaced with more ideal versions for lower resolution systems.

This test assumes a two dimensional starfield. The third dimension adds a layer of complexity that is not addressed directly in this test. As we approach a star in 3D space, its diameter will change from an infinitely small point to a larger sphere. The only way that I can think of to effectively deal with this issue is by having the star renderer consider stars as either “background” or “foreground.” If stars are far enough away to be “background,” then the renderer will treat them as points whose diameter is specified in base pixels (which may be larger or smaller than the base pixel number, depending on the effect of brightness on the rendered diameter.) As we get closer to stars and they pass into the “foreground” range, the renderer will treat them as 3D objects which will increase in size as we get closer. The test outlined above should be helpful in determining what base pixel size to use.

At the time of this writing, our tests are still ongoing in this area. Preliminary results suggest that a star size of 4.0 pixels is capable of holding up well at both 3600x3600 and when rescaling to 1024x1024 for sequences where the stars serve as a backdrop for other imagery (planets, nebulae, etc.) Many of the higher magnitude (dimmer) stars disappear in the scaled down image, which can make constellations difficult to distinguish. If the stars are the “stars” of the show, as in a “sky tonight” type show, more attention should be paid to star size.