

# **The Black Hole Project**

Denver Museum of Nature & Science  
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## **Spitz, Inc. Sub-Award Project Summary**

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# Black Hole Project Spitz, Inc. Sub-Award

## Final Report

The Black Hole Project includes a feature-length planetarium program for the new digital dome planetarium theater projection format (herein referred to as “fulldome” video). There are now over 125 fulldome theaters and portable systems worldwide, with approximately 60 of these being large-format digital domes (greater than 1000x1000 pixel display). While quality shows are being produced and distributed in the fulldome medium, there are few published industry standards or guidelines for the production, distribution or exhibition of fulldome programs. The distributor of the Black Hole Project planetarium program, Spitz, Inc., was therefore contracted via sub-award to research and help develop production guidelines and distribution/exhibition standards for the program.

The effort was divided into two tasks. **Fulldome Production Guideline Development** utilized in-theater tests to determine production and rendering parameters required for widespread distribution of the Black Hole Project including image resolution, camera tilt, text safe area, etc. The second task focused on establishing fulldome distribution and exhibition standards and guidelines. To be relevant, it was decided that standards development should be an industry-wide effort. The standards development task therefore involved the formation of an industry-wide **Fulldome Standards Summit** with subsequent dissemination of the resulting technical papers. In addition to helping guide the Black Hole Project planetarium show distribution, the summit was the first ever technical conference on fulldome planetarium technologies.

## Fulldome Production Guideline Development

Spitz Inc. performed a set of production tests to help ensure wide distribution and cross-compatibility of future shows with many different display systems. While there are many issues that need to be considered when attempting to ensure wide distribution, Spitz chose to deal specifically with issues that are fundamental to the production pipeline and must be understood before show production can begin. The goals of the tests were to:

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

Most of the issues investigated involve production aesthetics and are not empirically testable. In these cases, the testing methodology employed a series of graphical tests screened by a small team of aesthetically trained viewers who utilized a collaborative consensus approach to converge on a recommended “best practice.” Only theaters with unidirectional seating designs are addressed in our research. While omni-directional

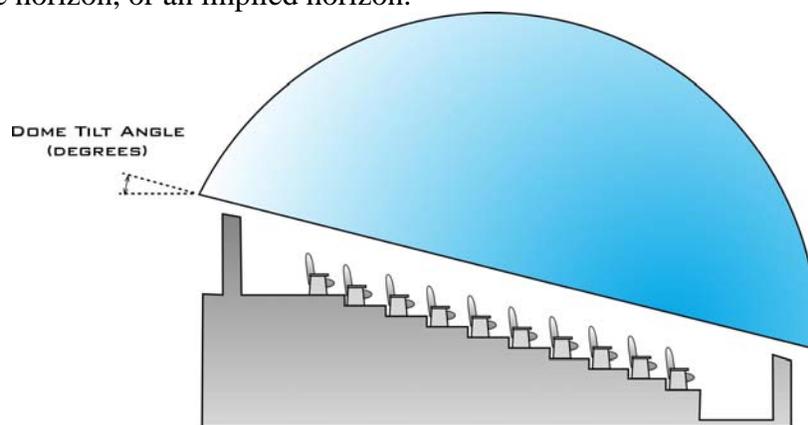
theaters do offer certain advantages, their penetration into the fulldome video planetarium market is not significant, and the special production requirements that they impose place them outside the scope of our research.

Tests were performed on a range of theater types. Test theaters included:

1. Fels Planetarium at the Franklin Institute – 6 channels of 1280x1024 mpeg-2 compressed fulldome 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 video, single lens fisheye, DILA projector, 12 degree tilt
4. SciDome at Spitz, Inc. – 1024x1024 Mpeg-2 compressed video, single lens fisheye, 10 degree tilt.

**Nominal Camera Tilt.** Unidirectional planetariums often utilize a tilted configuration whereby the hemispheric dome screen is tilted forward, lowering the screen into the field-of-view of a comfortably seated viewer. There is no standard dome tilt for fulldome video theaters – tilt angles range from zero degrees (horizontal dome) to 30 degrees. Content producers often wish to present viewers with a virtual “gravity level horizon,” requiring a virtual camera tilt that is commensurate with the dome tilt. This is done by subtracting the degree of dome tilt from the tilt of the rendering camera (degrees from vertical) within a 3D package. Because the viewer is immersed in the frame, a non-gravity level horizon can make the viewer feel off-balance.

The mind quickly adapts to this contradiction between the inner ear and ocular system, however, there may be an outer limit and an optimal range for adaptation. 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.



**Dome tilt in unidirectional theater**

Four different test sequences were created. Each test sequence represents a different type of content. The three types are:

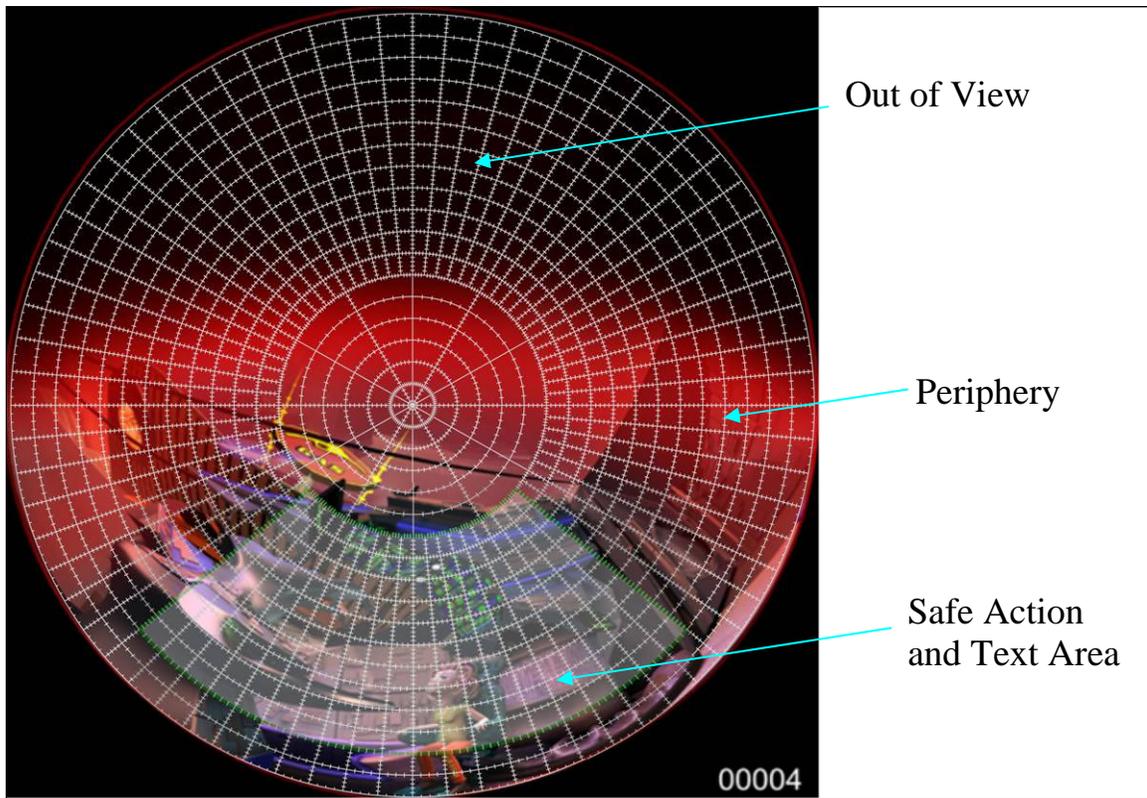
1. Visible horizon – a sequence where there is a clearly visible horizon, such as a landscape.
2. Non-visible Horizon – A sequence where there is no visible horizon line and no camera motion that might imply a vector-based horizon. An example might be a scene in outer space where the camera is not moving.
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 would be a simple credit roll, rendered out on a billboard plane. The reason for this test is to see how the tilt affects the readability of text.

Each of the three test sequences were then rendered out with camera tilts of 0, 10, 20, and 30 degrees, resulting in a total of 16 test sequences. These sequences were then looked at and evaluated in domes of various tilts, ranging from DMNS theater (25 degree tilt) to the Fels Planetarium in Philadelphia (zero degree tilt). Consensus is that a 15 degree tilt looks the most correct in the greatest number of theaters.

An alternate approach was suggested for ensuring a gravity level horizon in the most number of theaters that involves 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 hypospheric 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, it is not recommend as a standard production practice at this time.

**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.



**Dome master frame showing typical action area**

It was difficult to reach consensus on “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 most important thing is for the art director to understand the effect of his or her choices. However, all agreed that text and action contained within +/- 50 degrees from dome longitudinal center, and at an elevation of 10-60 degrees would be easily visible to all viewers. Placing important text or imagery on the very bottom of the dome should be avoided since, in some theaters, audience members’ view of the “spring line” could be occluded in the case of a short person sitting behind a tall person.

**Gamma.** Gamma is a paper topic in itself and only a broad overview of the issues are given here. In our discussions with various content producers, projector manufacturers, and theater operators, we realized 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, 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 ( $\alpha$ ) defines the slope of that power function curve at the halfway point between black and white used to match the projector power response to the eye, and is simplistically defined as

$$F(x) = x^\alpha$$

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.

Conforming to this standard in dome displays 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 spectroradiometer 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.

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 previously set to sacrifice dynamic range in exchange for more brightness. Additionally, the limited brightness and contrast of many fulldome systems can be compensated to a degree by "boosting" gamma such that the blacks are raised to make dim images appear brighter.

Assuming that we could 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, we conclude that this is the best point in the production chain to perform gamma adjustments. Spitz's Polydome dome-master slicing software has the ability to slice and correct gamma at the same time. Our group agrees 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.

**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 and starfields – the staple of planetarium programming – 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 super-sampled 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 was 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 contain 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 & 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 pixels 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. In this case, the star shader must 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 shader 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.

Our 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 a major feature of the show, as in a “sky tonight” type show, more attention should be paid to star size.

At the MAPS (Middle Atlantic Planetarium Society) conference in Philadelphia, held at the Fels Planetarium (level dome, or zero degree tilt) at the Franklin Institute during May of 2005, we had the opportunity to evaluate all of the fulldome tests on two different playback systems. The Fels’ 6-channel CRT Mpeg-2 based fulldome playback system (6-channels of 1280x1024 edge-blended video) was compared with a single-lens fisheye projection system supplied by Spitz (one channel of 1536x1536 uncompressed video). Since the fisheye system was temporarily installed at the Fels for the conference, we took advantage of the opportunity to do some in-dome A/B comparisons of imagery.

As noted previously, the results of our camera tilt (optimal tilt was determined to be 15 degrees) and action and text safe area tests (+/- 50 degrees from dome center, and at an elevation of 10-60 degrees) were confirmed to be valid for a variety of dome tilts, including the Fels level dome.

The more interesting of the tests involved projecting a short scene from the Black Hole show prepared by the NCSA and DMNS that depicted a flight to the core of the Milky Way galaxy. This particular scene has a variety of difficult to reproduce imagery – fine star detail, gaseous clouds and filamentary structures, that we wished to evaluate. The scene was prepared for display on both systems, and then watched several times on each system. Because both systems were installed with identical content, we had the opportunity to play the test sequence on both up to a certain spot, freeze it, then evaluate images one system, then the other, by turning on or off the display to do an A/B evaluation.

Though the results are somewhat subjective, both observers (Mike Bruno of Spitz and Dan Neafus of DMNS) were in agreement that the scene held up quite well on both systems. While differences were noted between the higher resolution 6-channel system and the lower resolution fisheye system (some fainter background stars were sampled out of existence on the fisheye system), the loss of some of the fainter stars was expected and did not affect the overall quality of the scene.

Interestingly, there was not a noticeable difference between the two systems in the visual quality of the gaseous clouds and filamentary structures, when viewed in motion or as static fulldome frames. The fisheye system also exhibited superior brightness and color reproduction over the entire visual field, as well as a more uniform, seamless appearance (the latter due to the fact that the fisheye system does not require mosaicking individual projectors to create a single fulldome image) . Additional testing will be performed for the lower resolution (1024x1024) fisheye systems currently offered by several manufacturers.

## Fulldome Standards Summit

A Fulldome Standards Summit was organized and held as a special session at the International Planetarium Society (IPS) 2004 conference in Valencia, Spain. The Summit was held on July 7 & 8 at Valencia's Ciudad de las Artes y las Ciencias, concurrent with other IPS conference sessions. Summit co-chairs were Ed Lantz of Visual Bandwidth, Inc. ([www.visualbandwidth.com](http://www.visualbandwidth.com)) and Ryan Wyatt of the American Museum of Natural History's Rose Center for Earth and Space ([www.amnh.org](http://www.amnh.org)).<sup>1</sup> Wyatt and Lantz secured permission from IPS 2004 to hold the Summit, and published a Call for Papers (linked to the IPS website) that resulted in 13 excellent quality technical and informational papers related to fulldome standards. Paper sessions were held over a 2-day period, and included a lecture session, an in-dome session, and a roundtable forum. The in-dome session utilized a temporary laser-based fulldome display (called ADLIP) provided by Zeiss, driven by a real-time playback system provided by Sky-Skan, Inc., and projected on Valencia's 23 meter dome screen to supplement presentations with actual fulldome imagery. Graphics were prepared for presentation by Spitz, Inc.



**Ciudad de las Artes y las Ciencias**

There were nearly 100 pre-registered delegates for the Summit, and over 50 in attendance at each lecture session. This attendance represents about 20% of the IPS delegation present at the conference. Complementary hors d'oeuvres were provided prior to the in-dome session to attract attendees who were otherwise on a conference "dinner on your own" period. Papers ranged from a keynote talk by Visual Acuity's Blair Parkin and Jim Costigan on the need for fulldome standards based on experiences in allied industries such as visual simulation, to an actual proposal for display system specifications by Ed Lantz. Benjy Bernhardt of the American Museum of Natural History discussed the need for audio standards, while Benjamin Cabut of France's RSA Cosmos discussed the state of fulldome standards in Europe. Brad Thompson of Spitz presented a paper summarizing preliminary tests made for the Black Hole Project's Fulldome Production

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<sup>1</sup> Ed Lantz & Ryan Wyatt, Co-Chairs, Fulldome Standards Summit, IPS 2004, Valencia, Spain, July 2004  
[http://research.amnh.org/~wyatt/Community/summit2004\\_description.html](http://research.amnh.org/~wyatt/Community/summit2004_description.html)

Guideline development, including in-dome demonstrations of results. Other topics included standards for specifying color space, hemicube rendering techniques, institutional imperatives for standards, and experiences with organizing a fulldome video festival. The Summit paper abstracts are included in Appendix 1. Web links to full paper and Powerpoint presentations are also provided.



**Ryan Wyatt addressing the Fulldome Standards Summit**

**Roundtable Discussions.** The final 2-hour roundtable discussion resulted in a lively exchange focused on how to create “official” standards through the IPS organization. The discussion moved into the initial development of a standard for fulldome mastering, and ended with a list of names for an ongoing standards committee. It was also decided that an industry survey should be performed to assist with show distribution and to serve as an industry-wide resource to better justify and target new fulldome productions.

**Summit Proceedings.** Summit Proceedings with full text and/or PowerPoint slides for all presentations were published on several websites.<sup>2</sup> Notice that the Summit Proceedings are available for public use was made on several list-serves and websites that service the planetarium and museum professional community, including Dome-L, MAPS-L, RMPA, fulldome.org and ASTC.

**Fulldome Theater Survey.** In addition, an ongoing, on-line survey and registry of fulldome theaters was commissioned that identifies all fulldome theaters and their distinguishing features.<sup>3</sup> This registry will guide the Black Hole Project during the next several years, and will also stand as an industry resource to guide similar future projects.

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<sup>2</sup> Fulldome Standards Summit Papers are available at the following websites:  
<http://fulldome.org/index.php?option=content&task=view&id=27&Itemid=33>  
<http://extranet.spitzinc.com/reference/IPS2004/default.aspx>

<sup>3</sup> Fulldome Theater Compendium ONLINE! is available at  
<http://www.lochness.com/lfco/lfco.html>

The Fulldome Standards Summit was well received by the industry, and it clearly sparked the long-term process of standards development in the planetarium community. Continued funding for this effort beyond the Black Hole Project would have far-reaching effects in the planetarium market, resulting in a stable, long-term platform for the dissemination of immersive content to tens of millions of informal science education visitors annually.

### **Recommendations for Black Hole Project**

Program distribution will require repurposing the dome masters and audio files into a variety of different file formats and compression schemes for transfer to the individual playback system or systems. It is recommended that the distributor, in this case Spitz, Inc., accept the finished master files and work with each individual theater or vendor to format the program to meet their particular requirements.

The process will include initial in-theater tests for gamma correction, audio balance, etc. By following the below production and mastering recommendations, the master content is assured of conforming to the greatest number of fulldome theaters. Based on the Fulldome Production Guideline Development, Fulldome Standards Summit, and general industry practices, the following recommendations are suggested for fulldome production and mastering.

**Dome Master Format and Size.** Dome master frames should be rendered at a minimum of 3600x3600 pixels in an equidistant polar format. Rendered stars should have a half-intensity width of 4 pixels. Frame number and copyright should be placed in the lower RH (NCSA uses the Low. Left) corner of the frame. Recommended file types include TIFF and TARGA with RLE compression, or other lossless compression format compatible with distributor's system. Image should be oriented such that the bottom of the frame represents the front-bottom of the dome screen, and the right and left hand sides of the master correspond with the respective right and left sides of the dome to a viewer sitting at dome center within the theater.

**Camera Tilt.** Nominal fisheye camera tilt should be 15 degrees from vertical.

**Safe Action Area.** Recommended safe action and text area is the region approximately defined by +/- 50 degrees longitude (measured from dome front/center), and ranging from 10-60 degrees latitude (altitude).

**Audio Format.** To accommodate for variations in sound systems in different venues, the original digital "stem" tracks and project files must be available for re-mixing or encoding for individual venues. A "generic" 5.1 mix is derived from these files as well as a number of odd formats such as 16.1. It is preferable to re-mix the sound in each venue when possible utilizing a portable editing system.

It is recommended that program soundtracks should be made available in (minimally) stereo and/or 5.1 surround formats. Audio shall be formatted as 16-bit, 48kHz .wav files.

Two versions of each soundtrack should be prepared: one that is timed for synchronization with 29.97 video and another that is timed for systems that use 30fps for video playback. Audio shall be provided as discrete mono channels, so that the show distributor may properly format/encode the soundtrack for the requirements of the specific playback system. The following naming convention shall be used:

### 5.1 Format Soundtrack

USE	FILENAME	CHANNEL
required	filename_FL.wav	Front Left
required	filename_FR.wav	Front Right
required	filename_LR.wav	Rear Left
required	filename_RR.wav	Rear Right
required	filename_Center.wav	Center
required	filename_LFE.wav	Low frequency signal (Sub-bass)

### Stereo Soundtrack

USE	FILENAME	CHANNEL
required	filename_FL.wav	Front Left
required	filename_FR.wav	Front Right

**Show Distribution Medium.** Dome master video frames and audio content should be delivered to Spitz on external PC-formatted (NTFS file system) 6-pin, Firewire drives. Video should be organized into folders according to frame numbers, typically with a maximum of 10,000 frames per folder. Audio should be organized into a 29.97fps folder and a 30fps folder, with sub-folders for stereo and 5.1 surround mixes.

### **Future Considerations**

During the development of the Black Hole Project, the producers realized that there remains a vast amount of work to be done regarding "production" guidelines as well as technical guidelines. Fulldome production guidelines include:

- Work-flow issues; such as nomenclature, archiving and sharing digital content.
- Scenic design for the dome environment,
- Designing for the greatest content comprehension in a VR environment.
- Preview and verification processes for visuals and scripts.
- Formative testing during show development and creation.
- International / Universal show design and language.
- Design for greatest audience experience and satisfaction.
- Legal standards and templates for contracts and copyright issues.
- Acquisition and manipulation of live action footage for the dome.
- Vocabulary used by a distributed production team.
- Scientific accuracy, crediting and verification.
- Transitions, motion, editing, & "framing" for fulldome,.
- Designing in the "viewer oriented" VR environment, the personal experience.

## Appendix 1 - Fulldome Standards Summit Abstracts

### Introduction

This Fulldome Standards Summit was conceived to be the first in a series of Fulldome Summits designed to bring together industry leaders - from institutional to corporate, technical to artistic - to advance the state-of-the art in fulldome video through technical exchange and the formation of industry standards and recommended “best practices”.

This first Summit was a special session of the IPS 2004 Conference in Valencia, and was sponsored by a sub-award to Spitz, Inc., under the National Science Foundation grant awarded to the Denver Museum of Nature & Science for its proposal No. ESI-0337286, a suite of projects collectively titled "The Black Hole Project."

With more than a dozen talks and 100 registrants, the Summit provided an opportunity to begin discussions and formulate a roadmap for future endeavors. The Summit focused on the following general topics pertaining to fulldome video-based theaters and related professions:

- Potential or proposed fulldome industry standards
- Industry guidelines or “best practices”
- Standard nomenclature or terminology
- Standardized test frames or sequences
- New technologies that will affect standards efforts
- Methods to facilitate cross-platform show distribution
- Areas benefiting from greater vendor cooperation
- IPS support for standards and technological exchange
- Philosophical discussion of standards issues

We would like to thank all those who took part, especially those who presented papers; broad participation made the event very much worthwhile. Special thanks to the National Science Foundation, Denver Museum of Nature & Science, Spitz, Inc., Thomas Lucas Productions and the International Planetarium Society for supporting this event.

Ed Lantz, Visual Bandwidth, Co-chair

Ryan Wyatt, American Museum of Natural History, Co-chair

Mike Bruno, Spitz, Inc., Editor

Dan Neafus, DMNS, Event Organizer

**Ed Lantz, Visual Bandwidth, Inc.**

**“Fulldome Unity: The Need for Technical Exchange and Fulldome Standards”**

Nearly all successful technology-based business areas thrive on technical exchange, recognition of excellence, and the establishment of industry standards. The fulldome industry has yet to institute such practices under a formal banner. The case is made for unity within the fulldome industry, including an annual summit that can act as a focal point for fulldome vendors, users and artisans.

**Ryan Wyatt, American Museum of Natural History**

**“Institutional Imperatives”**

Standards are the sort of dotted-i's-and-crossed-t's topic that cause planetarians to slumber, but our institutions have a vested interest in addressing standards issues explicitly and promptly. With media remaining costly to produce, distribution and collaboration must occur as painlessly and efficiently as possible: the definition of standards or “best practices” can significantly aid in this process. Furthermore, astronomical imagery taxes the display capabilities of many systems, which underscores the need more objective means of describing the quality of reproduction between systems. In the midst of these challenges, we lack even a basic vocabulary for describing many of the issues we need to address. In short, planetarians find themselves at the head of an emerging technology that combines significant advances in various arenas; we must navigate the headwaters cautiously but bravely, mapping out a route that enables increased institutional cooperation without curtailing future development.

**Keynote Address**

**Blair Parkin and Jim Costigan, Visual Acuity**

**“Developing a Fulldome Standard: A Historical Perspective for Success”**

The recent surge in the development of digital domes is presenting an opportunity to establish a technical understanding, nomenclature, cooperation and maybe even a standard for the technologies used to drive these venues. The development of a standard or set of standards could provide the opportunity to decrease the cost in developing and sharing content, an increasing the opportunities for hardware and software to support digital domes, and an increase in the number and popularity of digital domes as a public venue.

This presentation will look at the effects of standards in other fields, from a technical stand point, the industry effects and the market effects. We will specifically deal with the electronic medium standards such as Television (NTSC, PAL/SECAM, HDTV,) Computer (VGA, MPEG) and those proposed by the MPAA for digital theatres.

In the technical section we will see what areas were defined and standardized and which areas were left open to allow for the development of new technologies, to support market development of standards and to support advancements within the standard.

We will also review the role of market forces in the success and failure of standards. Finally, we will look at the standards organizing committees, how they were formed, when they were formed, who was on them and what were the results. We will examine where these committees were effective, where they were a hindrance, and how the markets adopted the standards. Through all of this we will highlight the successes and pit falls and draw some conclusion and comparisons that may be applicable to the development of a Full Dome Standard.

**Tom Casey, Home Run Pictures**

**“Off-the-shelf software limitations when stitching camera views for fulldome: An over-rendering the camera-view technique to avoid seam edge issues”**

Since all the available software applications are primarily designed to create “framed” views and the application developers treat “what’s beyond the view” as a throw-away, problems can arise when stitching the multiple camera views used to create fulldome imagery. This paper will detail an approach that employs rendering an area beyond the needed camera view to “trick” the rendering software into creating camera-views that will stitch together without seam edge issues. An explanation as to what elements in a scene can potentially cause problems, why these elements cause problems and how the over-rendering technique can eliminate the problem will be discussed. Although the solution will be implemented with the scripting tools available in Alias Maya software, similar techniques can be employed in any of the software tools being used to create fulldome imagery.

**David Beining, LodeStar Astronomy Center**

**“Lessons in Collaborative Fulldome Training and Production”**

LodeStar has opened its dome to university students, visiting artists, researchers, and independent producers for more than three and a half years — including the world's only fulldome video festival, DomeFest. The collaborations have been both taxing and enthralling as a culture of fulldome production has developed in New Mexico. LodeStar will share some of the program designs, documents and tricks it has learned through the community-based efforts which have resulted in more than 150 fulldome producers and hours of content development. The presentation will describe practices such as dome orientations, production manuals, selection of supported producers and artists, file management, production reviews and public presentation of finished works. These practices have defined something of a standard — though not curbing — technique for LodeStar-based productions.

**Benjamin Cabut, RSA Cosmos**

**“Sound and Video Production Solutions”**

AllSky video shows currently represent a growth market and it is urgent to propose a format meeting all requirements. R.S.A. Cosmos, as a European player in the AllSky video shows market and manufacturer of a complete AllSky digital planetarium solution, wishes to participate actively in this elaboration by defending some European specifications, such as frame rates. What are the specifications of the projection system to

consider to create a standard exchange of AllSky video shows?

Fish-eye images have been adopted as standard by the community, so it is important to define how to obtain them, their resolution as well as a working chain allowing to the planetariums to use them. The fish-eye image rendering method will also have to meet the requirements of planetariums that produce videos according to their technical, temporal and financial means. What method should be used to produce fish-eyes? What resolution should be adopted for these images? What method should be used to adapt them to a particular planetarium theatre?

In addition, most of the shows currently produced take advantage of a spatial sound system. But each theatre is different, either in its architecture (titled or not) or in its sound installation (5+1, 6+1, 7+1, others) Which files are supplied to the planetariums and how do they have to treat them to optimize their installation?

**Benjy Bernhardt, American Museum of Natural History**  
**“Audio Standards That Aren’t”**

In the film industry THX sound describes a quality assurance program for audio systems rather than an audio format. This simple set of standards and practice allows for reasonably faithful audio mix reproduction in theatres around the world. Digital Planetaria have largely adopted 5.1 as an audio track format, but generally have no meaningful standard as to the placement, power balance, and equalization of the speakers. A short description of the difficulties this situation has created in porting content will be presented, along with some possible approaches toward achieving more consistency in sound system design. Some strategies for spatialized mixing and mix portability will also be discussed.

**Staffan Klashed & Anders Ynnerman, Linköping University**  
**Carter Emmart, American Museum of Natural History**  
**“UniView: Scaling the Universe”**

UniView is a software framework for real time astronomical visualization. One of the main features of the framework is seamless transition between an arbitrary range of scales, from satellites or space stations to the edge of the observable universe. The scale transitions are implemented using multiple layers of scenegraphs, denoted scalegraphs. In the context of the UniView framework the paper addresses standardization of the use of different coordinate systems for data representation and navigation.

UniView supports real time broadcasting of shows and remote lectures, with a network-based event kernel broadcasting actions taken by a host to connected clients. Databases needed for the UniView software are stored locally with updates distributed automatically in advance, and show scripts can be distributed through the same mechanisms. Broadcasted events include among other things camera movement and object manipulation.

UniView runs on laptop to full dome systems and is a joint effort between Sciss AB, Linköping University and the American Museum of Natural History.

**Martin Howe, SEOS Ltd.**  
**“The Flight of the Pixel”**  
**“Proposal for Dome Standards”**

By their very nature, Digital Domes are Pixel centric environments. Their performance and capability dictated by the hardware and software used to generate, distribute and ultimately display each and every pixel in the system. “The Flight of the Pixel” follows the journey of a Pixel from content to eye to describe the core principles that apply across the range of solutions in an attempt identify the key considerations for standards relating to large screen spherical displays.

**Philip Groce, Konica Minolta Planetariums**  
**“The Past, Present, and Future of Fulldome Single Projector Digital Planetariums”**

Single projector systems have become the dominant format for fulldome digital planetariums, surpassing the number of multiple projector systems in 2004. This presentation outlines the benefits of these single projector systems, the challenges they face and the future they hold for planetariums.

**Andreas Deter, Jenoptik Laserdisplay Technology**  
**“Color Reproduction Complex”**

Currently, different types of projection equipment are used for video image representation in planetarium applications. They include data sources that are exclusively based on a normalized RGB color space (IEC 61966-2-1). This color space has been adapted to the capabilities of classical tube monitors and traditional projector types for representation of colors. Latest developments such as laser display technology are aimed at perceivably extending the visible color space, in order to create new possibilities for visualization.

The source material for working in an extended color space can be computer-generated data, pictures which have been shot with a special camera using an extended color space, specifically scanned color films or scientific false-color pictures (e.g. astronomical image data). In addition, color space spreading can be introduced to display existing picture material in an extended color space. For users, it is also essential to visualize these color representation possibilities on a control display. The paper discusses methods to put this into practice.

**Brad Thompson, Spitz, Inc.**  
**“Four Issues to Consider When Producing Fulldome Content for Wide Distribution”**

At the request of the Denver Museum of Nature & Science, and with support from the National Science Foundation, Spitz Creative Media performed a set of production tests to help ensure wide distribution of future shows. The goals of the tests were to establish

action and text safe areas for full-dome production, investigate how to deal with differently tilted domes, investigate how to deal with gamma issues, and to 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.

**Ed Lantz, Visual Bandwidth, Inc.**  
**“Fulldome Display Specifications: A Proposal”**

General standards are proposed for specifying fulldome displays. Proposed specifications include brightness, brightness uniformity, color uniformity, contrast, resolution and update rate. A methodology for measuring edge-blend uniformity is proposed, and suggestions are made for approaching more difficult parameters such as color gamut.

## **Web Links**

**Fulldome Summit Paper and Powerpoint Presentations**  
<http://fulldome.org/index.php?option=content&task=view&id=27&Itemid=33>  
<http://extranet.spitzinc.com/reference/IPS2004/default.aspx>

**Web Link to Fulldome Theater Survey**  
<http://www.lochness.com/lfco/lfco.html>