DIGSS 1.0:
DIGITAL IMMERSIVE GIANT SCREEN SPECIFICATIONS

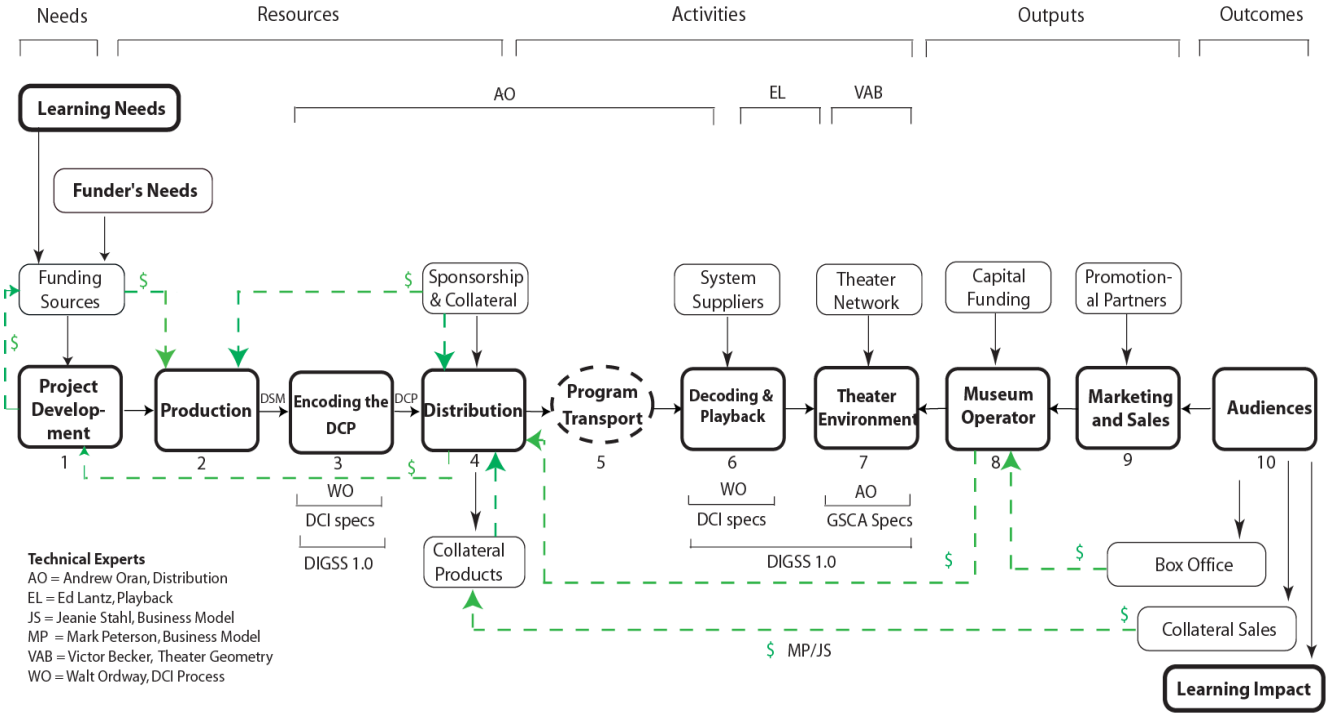
Note: These DIGSS specifications are the end results of the Digital Immersive Screen Colloquium for Unified Standards and Specifications (DISCUSS) and subsequent field-wide circulation and discussion of drafts leading to this version. The process brought together a panel of 21 advisors, technical experts and others involved in the Giant Screen industry plus 61 more through the online wiki. The goals is to create specifications for immersive digital GS theaters that create a viewer experience as good as or better than the film-based GS theaters now in place in museums and science centers. The DISCUSS Colloquium was made possible by a grant from the National Science Foundation (NSF-ISE 0946691). DIGSS 1.0 also appears as Chapter 6 in the final report, DISCUSS Proceedings (June 2011).

The views, opinions, recommendations, and findings expressed herein do not necessarily reflect those of the National Science Foundation, the United States Government, or its officers or employees. DIGSS 1.0, described in the following sections, is likely to evolve over time.

LOGIC RATIONALE

The Digital Immersive Giant Screen Specifications (DIGSS) and their rationale are organized according to the three core links (Links 3, 6 and 7) in the Logic Rationale.

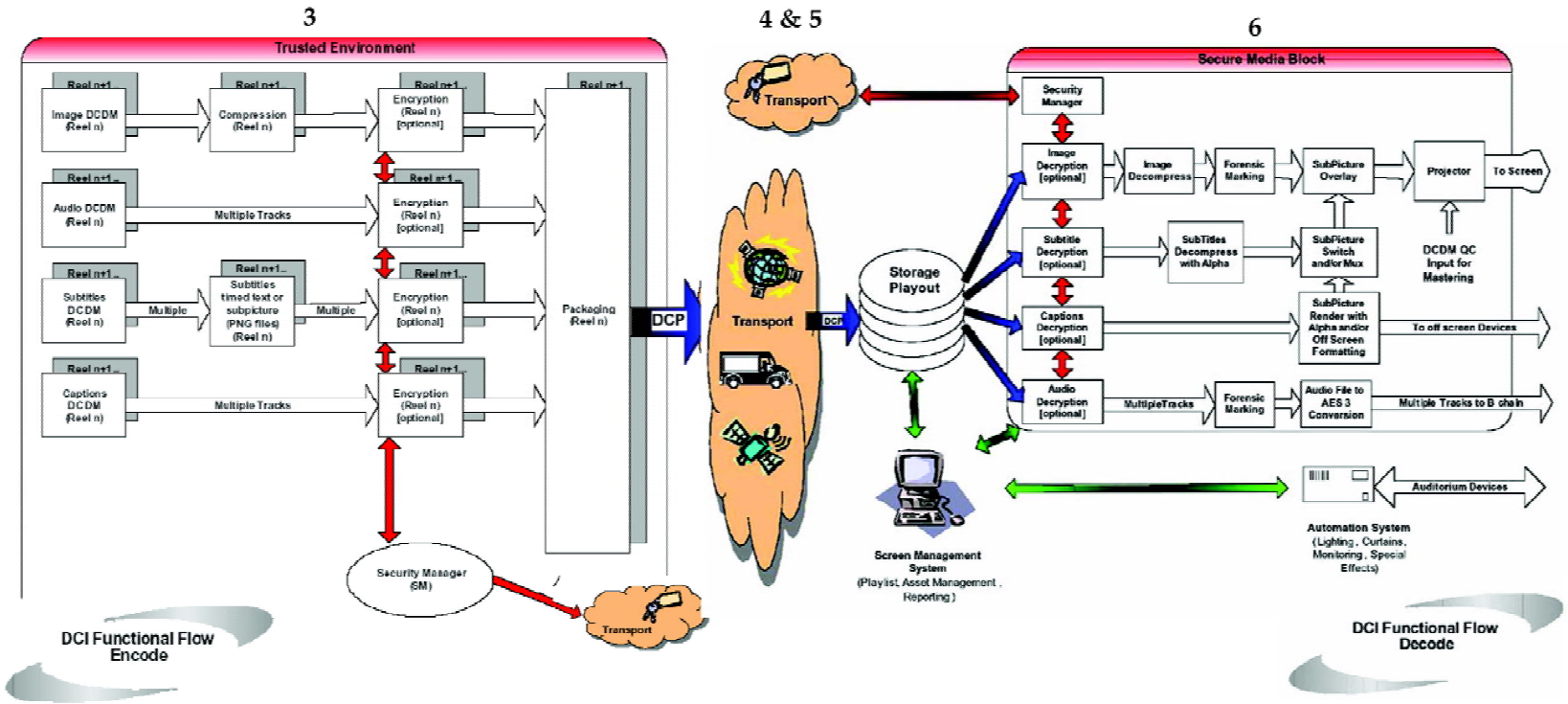
Author: John W. Jacobsen



Logic Rationale: Detail on 3-6

Institutional Giant Screen Flow Diagram

(DISCUSS – NSF# 0946691)



This diagram is copied from the DCI Specifications, version 1.2, captured off http://www.dcimovies.com/ on March 17, 2010.

PRINCIPLES AND DEFINITIONS

Author: Victor A. Becker

The first fundamental requirement of the GS theater environment is creating an effective and satisfying immersive experience by filling the eyes and ears of the viewer with images and sounds that convincingly evoke a specific time, place, and/or situation outside of the theater.

The second fundamental requirement is reducing viewers' awareness of the theater's structure and the technical systems that produce the experience.

These requirements generate several principles:

- The image shall be projected on a screen that fills the front wall of the theater, in the case of flat screens, and the entire "ceiling," in the case of domes.
- The viewers shall be physically oriented toward the center of the screen in a manner that is as intimate, comfortable, and natural as possible.
- The sound system shall be robust, dynamic, and clear; the theater shall be insulated from all external sources of sound.

Specifications: A set of metrics to which all theaters wishing to be defined as *Giant Screen Immersive Digital Theater* should adhere (see "Grandfathering," below). Specifications are intended to provide guidance to all new GS theaters and renovations and upgrades of existing theaters.

DIGSS-compliant theaters and programs meet these specifications. However, DIGSS 1.0 applies to *future* GS theaters, and during the transition time from analog to digital — a period that will likely see interim systems — DIGSS 1.0 is for practical purposes an aspiration and an upgrade path. Nevertheless, DIGSS 1.0 has many specifications that can be met now with currently available technologies. Greater compliance with these specifications will come with innovation, particularly if the museum market continues to insist on reaching the "museum quality" aspirations of a DIGSS-compliant GS theater.

Uncontested Specifications and *Provisional Specifications* *(listed in italics):* Reflect a distinction between specifications that no one questions and those that someone felt should be tested. All specifications began as the considered opinions of an independent technical expert in that link along the Logic Rationale. The resulting "DIGSS Draft 0" was reviewed and discussed by the other technical experts and museum advisors during the three-day Colloquium, resulting in DIGSS Draft A. That draft was then circulated back to the technical experts for their revisions (Draft B), and then forwarded to the advisors for their input (Draft C), which was then posted on the DISCUSS Online Forum (wiki) for wider professional comment, attracting 79 GS professionals and 48 discussion entries. The resulting Draft 1.0 contains all comments submitted by the DISCUSS team. If any technical expert or advisor along the way felt that a specification

should be screen tested, it was marked as *provisional*, shown in *italics*, and added to the list of desirable future research that the Giant Screen Cinema Association's Technical Committee will consider. In time, this should result in DIGSS 2.0 and subsequent versions, each having fewer provisional specifications. In the interim, however, the field can use the independent experts' opinions.

Recommendations: These adjuncts to some specifications are expected, over time, to become the accepted specifications as existing exceptions are corrected or eliminated and as technology progresses. Recommendations are the long-term aspirations of the field.

Grandfathered Specification: The recognition that a theater has one or more pre-existing conditions, such as a slightly shorter screen, that do not meet the specifications, but do not materially affect the experience.

Advisory Guidelines: Principles and objectives offered to aid in the design process of new and/or renovated theaters, in film production, and in theater operations. These are advisory in DIGSS Draft 1.0 and appear only in the Executive Summary, but are likely to evolve in future versions.

LINK 3: ENCODING THE DIGITAL CINEMA PACKAGE (DCP)

Author: Andrew Oran

LINK 3: ENCODING: The Digital Cinema Package (DCP)					
Note: Italics are used to designate "provisional specifications," which reflect current expert judgments, but which will benefit from on-screen and in-theater testing.					
			Specifications	**Recommendations**	**Notes**
	All Screens				
	3.1	Compression	JPG2000		DCI testing complete
	3.2	Frame Rate (unique frames)	24 frames per second for 2D; 48 FPS for 3D	*48 FPS (2D) and 96 FPS (3D); plus Video 30 (2D), 60 (2D/3D) and 120 (3D)*	
	2D Flat Screen				
	3.3.1	*Resolution*	*4K All screen*	*8K*	*To be tested* Must be even multiples — 4K, 8K, 16K to use JPG 2000
	3.4.1	Color Bit Depth	12 bit		
	3.5.1	*Bit Rate Compression (maximum; studios can use lower)*	*250 mb/s*	*500 mb/s*	*To be tested*
	3.6.1	Brightness (measured off screen)	20:22 FL for 2D silver screens 6–8 FL. for 3D silver screens		GSCA Task Force
	3D Flat Screen				
	3.3.2	*Resolution*	*4K All screen*	*8K*	*To be tested* Must be even multiples — 4K, 8K, 16K to use JPG 2000
	3.4.2	Color Bit Depth	12 bit		
	3.5.2	*Bit Rate Compression (maximum; studios can use lower)*	*250 mb/s*	*500 mb/s*	*To be tested*

			Specifications	Recommendations	Notes
	3.6.2	Brightness (measured off screen)	20:22 FL for 2D silver screens 6–8 FL. for 3D silver screens		GSCA Task Force
	2D Dome Screen				
	3.3.3 *3.4.3* *3.5.3* *3.6.3*	*Resolution* *Color Bit Depth* *Bit Rate Compression (maximum; studios can use lower)* *Brightness (measured off screen)*	*8K* *8 Bit* *250* *3-4 fL*	*16 K* *12 Bit* *500*	*To be tested* *To be tested* *To be tested* *To be tested*
	3D Dome Screen				
	3.3.4 *3.4.4* *3.5.4* *3.6.4*	*Resolution* *Color bit depth* *Bit rate compression (maximum; studios can use lower)* *Brightness*	*8K* *8 Bit* *250* *3-4 fL*	*16 K* *12 Bit* *500*	*To be tested* *To be tested* *To be tested* *To be tested*
	Audio				
	3.7	*Specs over DCI to be determined*	*16 channels*	*32 channels*	*To be developed*
	Security				
	3.8	DCI compliant security processes and encryption			

DCI Spec relative to DIGSS: DCDM, DCP and Transport, v3

INTRODUCTORY NOTES:

Sections 3 through 6 of the DCI Spec cover the topics of the DCDM, DCP and Transport of Digital Cinema content. Much of the Spec as written is transferable to DIGSS. Several key areas however require review and customization, and several key issues unique to Giant Screen exhibition are missing entirely. Some of the most important issues to grapple with as we construct DIGSS relative to these sections of the DCI Spec are:

1. Developing separate DCDM and DCP image and audio standards for dome screens.
2. Going beyond 4K to 8K (for flat screens) and even 16K (for domes).
3. Increasing the maximum allowable (if not practically achievable) bit rate from 250Mbit/sec to 500Mbit/sec and higher.
4. Adding the 4:3 (1.33:1) aspect ratio which is entirely missing from the DCI Spec.

Another big topic to tackle relative to the development of customized specifications for giant screens is the design and execution of empirical tests that will serve to support or revise the theoretical standards we lay out.

DCDM (DIGITAL CINEMA DISTRIBUTION MASTER)

The DCI's definition and basic outline of a DCDM is covered in the following passage:

3.1.1. Introduction

The Digital Cinema Distribution Master, or DCDM, is a collection of data file formats, whose function is to provide an interchange standard for Digital Cinema presentations. It is a representation of images, audio and other information, whose goal is to provide a complete and standardized way to communicate movies (compositions) between studio, postproduction and exhibition. A specific instance of a DCDM is derived from a Digital Source Master (DSM) that is created as a result of a post-production assembly of the elements of a movie (composition). A DCDM can be transformed into a Digital Cinema Package for distribution to exhibition sites (see Section 5 PACKAGING). Alternatively, it can be sent directly to a playback system for quality control tasks.

This definition is universal, applicable to all size screens. What follows are sections of the DCI Spec covering the DCDM that will require rewording or rethinking for DIGSS.

3.1.3. Major DCDM Concepts

The Digital Cinema Distribution Master (DCDM) is the fundamental interchange element in the system. Since digital mastering technology will continue to change and develop with time, the DCDM is designed to accommodate growth.

…it is the content provider's responsibility to convert the DSM into the DCDM specification, defined in this section, before it can be used in the Digital Cinema system.

So far, so good, though what's missing is an acknowledgement of the requirement to create custom DCDM's for various screen types and exhibition formats. The DCI attempted to address this point in their (brief) Sterescopic Digital Cinema Addendum, dated Jul 11, 2007, 3 months after the April 12, 2007 publication of the DCI Spec master document:

2.1. SINGLE INVENTORY OF STEREOSCOPIC DIGITAL CINEMA PACKAGES (DCP)

A single stereoscopic DCP shall be able to be used for all stereoscopic implementations (e.g., no stereoscopic exhibition system shall require a unique color or density timing). It is not required or intended that the same image track file used for stereoscopic DCPs also be used for nonstereoscopic DCPs.

Additionally, no signal pre-processing unique to any single stereoscopic exhibition technology shall be required of a stereoscopic Digital Cinema Distribution Master (DCDM) or DCP.

The intention as stated stands in stark contrast to the present day reality, as noted in this extract from a March 25, 2010 Carolyn Giardina article in The Hollywood Reporter entitled, "How *Avatar* Changed the Rules of Deliverables":

"In total, there were 18 different versions of *Avatar* created for the domestic market, plus an additional 92 for international markets, which were released in 47 languages. The international versions included more than 52 subtitled and 18 dubbed versions on

film, 58 subtitled and 36 dubbed versions in digital 3D, nine subtitled and eight dubbed versions in digital 2D, and 23 subtitled and 15 dubbed versions for Imax."

While the goal (for both DCI and DIGSS) remains universal interoperability, the physics of projecting 2D and 3D images on flat and dome screens – coupled with current limitations in digital cinema technology - will mandate the creation of multiple DCDM's for giant screens. Suggested wording to this effect (relating back to the DCI Spec, not the DCI Stereoscopic Addendum) would be:

…it is the content provider's responsibility to convert the DSM into the DCDM specification, defined in this section for both flat and dome 2D and 3D giant screens, before it can be used in the Digital Cinema system.

Moving on, the following section of the DCI Spec will need to be modified to include the 4:3 (or 1.33:1) aspect ratio that underlies the design of most traditional giant screen cinemas:

3.2.1. Image Concepts and Requirements

3.2.1.3. Center of Image

The center of the image structure shall correspond to the center of its image active pixel array. Horizontally, there will be an equal number of pixels to the left and to the right of the center point. Vertically, there will be an equal number of pixels above and below the center point. The center of the image structure will depend on the down stream mapping of the content (e.g., HDSDI or TIFF files). For a 4K 'scope (4096x1716) image structure mapped to a TIFF file, the center is between horizontal pixels 2047 and 2048 (note: pixel counts begin at (0,0)) and between vertical pixels 857 and 858. For a 2K 'scope (2048x858) image structure mapped into an HDSDI stream, the center is between horizontal pixels 1023 and 1024 and between vertical pixels 539 and 540.

The following requirements in the DCI Spec are not universally practiced on multi-projector fulldome systems, and it is unknown if they can be. For example, at present two of the major fulldome digital systems providers provide and project their final content in sRGB - not XYZ - color space. We would need to enlist their involvement in a transition to an XYZ (and higher bit depth) specification, or we could adopt a universal fulldome sRGB standard if we can prove – through a series of on-screen testing – that such a standard yields acceptable on-screen quality.

3.2.1.4. Colorimetry

The color encoding of the Digital Cinema Distribution Master (DCDM) embodies a device-independent, X'Y'Z' color space. Since the DCDM incorporates all of the creative color decisions and these decisions will be made on a calibrated projector in a controlled mastering room, it is by definition an output-referred image state as described in [CIE Publication 15:2004, Colorimetry, 3rd Edition]. The picture is colorimetrically defined for its intended display on the cinema screen.

3.2.1.7. Bit Depth

The bit depth for each code value for a color component shall be 12 bits. This yields 36 bits per pixel.

3.2.2.2. File Mapping

The DCDM Image Structure shall be mapped into the TIFF Rev 6.0 File Format and further constrained as follows:

- 16 bits each per X', Y', and Z' channel, stored in the nominal TIFF R, G and B channels.
- The DCDM gamma-encoded X', Y' and Z' color channels are represented by 12-bit unsigned integer code values. These 12 bits are placed into the most significant bits of 16-bit words, with the remaining 4 bits filled with zeroes.
- The image orientation shall place the first pixel in the upper left corner of the image.
- The DCDM picture file shall contain only the active pixels in the image. In other words, it is not allowed to pad the picture to the full size of the DCDM container.

There are many questions to be asked about Aspect Ratio:

Do we include a 16K spec?
Do we include an 8K spec?
Do we exclude 'scope in any/all resolutions?
Do we include resolutions under 4K?

There is no way to answer these questions within this document: they (and others) are the basis for discussions pending on-screen observations. For example, if animation and some CG imagery looks acceptable at 2K (begging the question: how do we define acceptable?), should we exclude 2K imagery from giant screens, or establish an unnecessary 4K minimum requirement on imagery that neither contains nor warrants 4K resolution?

Some of these questions can only be answered through on-screen testing. For example, we would need to demonstrate through testing that higher resolutions (e.g., 8K and 16K) result in a discernible increase in on-screen resolution for a statistically significant portion of the giant screen auditorium, enough to warrant a revised specification on resolution (pixel count).

At the very least, the following DCI Spec chart on Aspect Ratio would need to be amended as follows, to include the 1.33:1 aspect ratio:

3.2.1.8. Aspect Ratio

Some examples for the accommodation of images of various aspect ratios in the containers are as follows:

4096 x 1716 2.39
3996 x 2160 1.85
4096 x 3072 1.33

2048 858 2.39
1998 1080 1.85
2048 x 1536 1.33

The DCI Spec for Audio covers bit depth, sample rate, reference level and channel count. It also offers general parameters for channel mapping and suggested speaker layout for cinemas. These specs are generally applicable to giant screens as is, with the proviso that the DCI's suggested speaker layout be excluded from DIGSS. Following are 3 of the basic DCI parameters:

3.3.2.2. Bit Depth

The bit depth shall be 24 bits per sample. DSM Audio Material having other bit depths shall be justified to the most significant bit per [AES3-2003 Section 4.1.1].

3.3.2.3. Sample Rate

Irrespective of the associated image frame rate, the audio sample rate shall be either forty-eight or ninety-six thousand samples per second per channel, commonly expressed as 48.000 or 96.000 kHz. At 24 FPS playback, there are exactly 2,000 audio samples per frame for 48.000 kHz and exactly 4,000 audio samples per frame for 96.000 kHz. At 48 FPS playback, there are exactly 1,000 audio samples per frame for 48.000 kHz and exactly 2,000 audio samples per frame for 96.000 kHz.

A theater playback system shall have the capability of performing sample rate conversion as needed.

3.3.2.4. Channel Count

The delivered digital audio, contained within the Digital Cinema Package (DCP), shall support a channel count of sixteen full-bandwidth channels.

Finally, the DCI Spec goes on to establish DCDM specifications for Closed Captioning, Sub-titling and Show Automation, all of which may be relevant to DIGSS.

2 – DCP (DIGITAL CINEMA PACKAGE)

The DCI Spec defines the DCP as follows:

2.1.1.4. Digital Cinema Package (DCP)

Once the DCDM is compressed, encrypted and packaged for distribution, it is considered to be the Digital Cinema Package or DCP. This term is used to distinguish the package from the raw collection of files known as the DCDM.

It goes on to establish detailed parameters for Compression (DCI Spec Section 4) and Packaging (DCI Spec Section 5). The processes described are relatable to all Digital Cinema (see, for example, clause 4.1, below), but the Spec is specifically tied to 2K and 4K resolutions and XYZ color space. Even the current 4K specification may be selling 4K short, limited as it is to a maximum bit rate of 250 Mbits/sec. Resolutions in excess of 4K would require such massive compression (to meet the 250 Mbit/sec max.) as to potentially render the increase in the source DCDM's resolution meaningless. The main

challenge here will be to demonstrate through on-screen testing if less compression (higher bit rates) result in a discernible increase in on-screen resolution for a statistically significant portion of the giant screen auditorium at each proposed resolution, including 4K, and to follow-up that testing with discussions with manufacturers and exhibitors to determine what bit rates are practically achievable in commercial settings.

4. COMPRESSION

4.1. Introduction

Image Compression for Digital Cinema uses data reduction techniques to decrease the size of the data for economical delivery and storage. The system uses perceptual coding techniques to achieve an image compression that is visually lossless. It is important to note that image compression is typically used to ensure meeting transmission bandwidth or media storage limitations. This results in image quality being dependent on scene content and delivered bit rate. Digital Cinema image compression is much less dependent upon bandwidth or storage requirements, thereby making bit rate dependent on desired image quality rather than the reverse.

4.2. Compression Standard

The compression standard shall be JPEG 2000 (see [ISO/IEC 15444-1]).

These DCP decoder specifications will require amending based on our final decisions on DIGSS resolution and aspect ratio:

4.3. Decoder Specification

4.3.1. Definitions

- A 2K distribution – the resolution of the DCDM*7 container is 2048x1080.
- A 4K distribution – the resolution of the DCDM*8 container is 4096x2160.
- A 2K decoder outputs up to 2048x1080 resolution data.
- A 4K decoder outputs up to 4096x2160 resolution data from a 4K compressed file and outputs up to 2048x1080 resolution data from a 2K compressed file.
- All decoders shall decode both 2K and 4K distributions. It is the responsibility of the 4K projector to upres the 2K file. In the case of a 2K decoder and a 4K distribution, the 2K decoder need read only that data necessary to decode a 2K output from the 4K distribution. The decoder (be it a 2K decoder or a 4K decoder) need not up-sample a 2K image to a 4K projector or down-sample a 4K image to a 2K projector.

4.3.2. Decoder Requirements

- Once deployed, the decoder, for any given projector, shall not be required to be upgraded.
- The output of the decoder shall conform to Section 3.2 Image Specification. These images are basically:
- 4K = 4096x2160 at 24 FPS

- 2K = 2048x1080 at 24 or 48 FPS
- Color: 12 bit, X′Y′Z′
- Enhanced parameter choices shall not be allowed in future distribution masters, if they break decodability in a deployed compliant decoder.
- All decoders shall decode each color component at 12 bits per sample with equal color/component bandwidth. Decoders shall not subsample chroma.
- A 4K decoder shall decode all data for every frame in a 4K distribution. A decoder shall not discard data (including resolution levels or quality layers) to keep up.
- A 2K decoder shall decode 2K data for every frame in a 4K distribution and it shall decode a 2K distribution. It may discard only the highest resolution level of a 4K distribution. It shall not discard other data such as further resolution levels or quality layers.
- All decoders shall implement the 9/7 inverse wavelet transform with at least 16 bit fixed point precision.
- All decoders shall implement the inverse Irreversible Color Transform (ICT) using at least 16 bit fixed point precision.

5. PACKAGING

The following introductory notes from the DCI Spec section on "Packing" (of the DCP) are instructive:

5.1. Introduction

The DCDM, as stated in the System Overview, is a collection of files, such as picture essence files and audio essence files. These files, as they stand by themselves, do not represent a complete presentation. Synchronization tools, asset management tools, metadata, content protection and other information are required for a complete presentation to be understood and played back as it was intended. This is especially important when the files become compressed and/or encrypted and are no longer recognizable as image essence or audio essence in this state. Packaging is a way to organize and wrap this material in such a way as to make it suitable for storage and transmission to its destination, where it can be stored and then easily unwrapped for a coherent playback. In seeking a common interchange standard for Digital Cinema between post-production and exhibition, it is understood that there may be multiple sources of content, distributed by more than one distributor, shown in a single show. This will require special consideration to achieve DCP interchange. Thus, an interchange packaging structure is needed that operates across several domains. The section also provides a set of requirements for the Material eXchange Format (MXF) track file encryption. These requirements are complementary to the requirements in Section 9.7 Essence Encryption and Cryptography.

5.2.1. Functional Framework

For the purpose of documenting the specific requirements for a Digital Cinema Packaging system, it is helpful to divide the system into a set of components. The performance requirements for each of these components will be described in the following sections:

- Composition – A self-contained representation of a single complete Digital Cinema work, such as a motion picture, or a trailer, or an advertisement, etc.
- Distribution Package – The physical files and the list describing the files and providing a means for authentication as delivered in a Distribution Package (from Distributor to Exhibitor).

One of the basic precepts of the DCI Spec is a so-called "open standard" – a system that allows for playback of properly executed Digital Cinema Packages on all digital projectors. This is laid out in the following passage:

5.2.2.2. Open Standard

The Packaging standard is required to be based upon an open worldwide standard. This format is encouraged to be a license-free technology. It is required to be a complete standard that equipment receiving a compliant package can process and interpret unambiguously.

This call for an open standard is one of the thorniest technical and political issues to overcome in our deliberations governing the development of DIGSS. In the "non giant" digital cinema world, an open standard works because distributors, equipment manufacturers and exhibitors are serving a vast network, whose potential number of screens measure in the tens of thousands, not in the hundreds, as in the case of giant screens.

In the "non giant" exhibition world, the main suppliers of content – in the form of the 6 major Hollywood film studios – created the DCI, which in turn created the DCI Spec, to (among other things) maximize the distribution potential of digitally released titles. The sheer number of screens, and the considerable clout of the major Hollywood studios (not to mention the sizable budget they established for the DCI) made the DCI Spec possible. There is no analog in the giant screen world, where the only centralized player is IMAX Corporation, with no clear interest in establishing an open platform that would empower a more competitive projection and content environment.

Politics (and economics) aside, there are still considerable technical challenges to an open standard for digital projection on giant screens. First and foremost are those associated with the divide between flat and dome screens, and the wide ranging projection solutions – from tiled to overlapping, with resolutions ranging from low-end video to 4K – applied in a variety of ways by a multiplicity of vendors. Also to be considered are the ways in which content design, capture and finishing must, by necessity, be customized for various projection platforms.

Still, an open standard should remain a goal for DIGSS, in that – if achieved – it could serve to revitalize content providers, and help create a giant screen thematic and visual identity that goes beyond simply screen size.

The DCI Spec goes on to establish very detailed standards for the formatting of DCP's, as well as laying out requirements for metadata, playlist compatibility and encryption. The applicability of these additional specifications for DCP's relates back to the issue of an open standard, and the feasibility of a uniform code for giant screen DCP's. In short, it is a range of issues that require further deliberation.

LINK 4: DISTRIBUTION - NO SPECIFICATION

Author: John Jacobsen

Like DCI, DIGSS will make no stipulations about how programs are leased, distributed and transported from the encoding/DCP Process (Link 3) to the projection playback system (Link 6). Distributors and theaters may make whatever business and transport arrangements they want, including shipping hard drives and satellite transfers.

LINK 5: PROGRAM TRANSPORT

Author: Andrew Oran

5.1. Introduction

Transport refers to the movement of the packaged Digital Cinema content. This can be accomplished in many ways, such as physical media, Virtual Private Network (VPN), or satellite.

The DCI Spec's guidelines for the transport of digital cinema content are general, and applicable to all digital content regardless of resolution and with little specificity relative to formatting. As such, they can easily be incorporated into DIGSS with little or no revision.

LINK 6: SECURE MEDIA BLOCK: SPECIFICATION: DECODING THE DIGITAL CINEMA PACKAGE

Author: Ed Lantz

PROJECTOR RATIONALE/DISCUSSION

OBJECTIVE

These draft specifications attempt to reproduce the current state of the art in giant-screen analog film projection with digital projection technologies that can feasibly be deployed in the near term. Furthermore, they have been harmonized with the DCI Digital Cinema System Specification, v.1.2, to provide compatibility with major feature film releases and to obtain other benefits of DCI compliance.

Wherever appropriate, these specifications have mirrored the specifications developed by the Technical Task Force of the Giant Screen Cinema Association.[1] The development of these specifications also follows the basic methodology of the GSCA report, using James Hyder's database of all nonprofit giant-screen theaters in the US and Canada,[2] the *GSTA Theatre Membership Technical Standards* document (second draft), the *Fulldome Master Show File Standard* draft document,[3] and Ed Lantz's paper from the 2004 Fulldome Summit entitled *Display Specifications: A Proposal*.[4]

PROJECTION SPECIFICATIONS

Flat Screens:

6.1	**Aspect Ratio** of 1.33:1 must be supported for full GS compatibility without letterboxing. Masking to aspect ratios up to 2.39:1 is permissible to accommodate the full range of popular film formats. The 1.33:1 aspect ratio should be achievable without narrowing the screen width (from which critical theater design parameters are measured) if the theater is to reproduce the GS film experience with the full gamut of available GS films.
6.2	**Peak White Luminance** shall be maintained at 20–22 fL for 2D silver screens and 6–8 fL for 3D silver screens with polarizers. (Note: from GSCA Task Force report[5].) **Future Research Question**: Should off-axis seats at least have 12 fL luminance?
6.3	**Luminance Uniformity**. The peak-to-peak luminance variation over the screen surface shall be no greater than 20%. (Exceeds DCI). **Future Research Question**: Should off-axis seats still have 20% uniformity? Do we need an off-axis luminance uniformity spec? If so, what should it be?
6.4	**Narrow Angle Luminance Uniformity**. For systems that blend multiple projectors to form the giant-screen image, or that otherwise exhibit brightness variations over small angles, the image brightness uniformity across non-uniformities (worst-case peak-to-peak variation of brightness measured at three points along a line perpendicularly intersecting nonuniformity/blend region) shall be 5% or less. This specification applies to any image consisting of a uniform value of red, blue and green components (full white, full black, gray, or uniform color) across the measurement area. This specification can apply to edge-blends and to dome screen issues with dust collection in perforations except over support ribs.

[1] Andrew Oran, GSCA Technical Task Force Report, page 1. The report for the GSCA is based in part on recent data collected by surveys completed by its members, totaling 76 GS flat-screen theaters and 39 full-dome theaters. It is also based in part on data describing all of its members, including 107 GS flat-screen theaters and 26 full-dome theaters. The specifications have also been influenced by data pertaining to the worldwide inventory of both flat-screen and fulldome theaters.

[2] From the LF Examiner Database of Theaters and Films (as of May 1, 2010). Figures provided by James Hyder as a custom search for this project.

[3] Fulldome Master Show File, Version 0.5, Sept. 12, 2005

[4] Ed Lantz, *Display Specifications: A Proposal*, 2004 Fulldome Summit, Valencia, Spain, 2004

[5] Second Draft Technical Standards, GSTA Theatre Membership, January 2003

6.5	***Image Resolution*** *shall be 4096 horizontal pixels minimum, however resolution of 8192 horizontal pixels is recommended for an optimal giant-screen experience. (Exceeds DCI.) The 8192 pixel resolution will provide eye-limited resolution for viewers seated in the front row (assuming front row is 0.33 screen widths away from screen). However this specification is meaningless unless there are off-the-shelf systems available with 8193 pixel resolution. Therefore the 4K resolution is recommended as allowable with the 8K preferred but not required.* ***Future Research Question****: Minimum and recommended resolution of to be substantiated through butterfly screen testing.*
6.6	***Sequential Image Contrast*** *shall be 2000:1 minimum. Exceeds DCI specification that permits tolerance down to 1200:1 for exhibition.*
6.7	***Intra-Frame (Checkerboard) Contrast*** *shall be 150:1 minimum. Exceeds DCI specification that permits tolerance down to 150:1 for exhibition.* ***Future Research Question****: To be validated with in-theater tests.*
6.8	**Color Gamut and Color Accuracy.** Recommend DCI compliance.
6.9	**Pixel Structure**. The device structure (mesh) of the projector picture array must be invisible at the reference viewing distance. *No visible contouring* (DCI compliant specification.).
6.10	**Contouring.** Images shall not exhibit any contouring (step in luminance) or color deviation from the neutral gray. (DCI compliant specification.)
6.11	***Frame Rate.*** *The display shall be capable of refreshing unique image frames at 24 frames per second for 2D systems and 48 frames per second for sequential eye 3D systems; recommended additional rates include 30, 48 (2D), 60, 96 (3D) unique frames per second.*
6.12	***Ghosting.*** *For 3D systems, crosstalk between eyes shall be less than 15%, with a goal of less than 10%. This specification can probably be tightened — to be determined through future testing.* ***Future Research Question****: Maximum crosstalk to be substantiated through testing.*

Dome Screens:

6.13	*The* ***dome*** *shall display an* ***image*** *that is a minimum of 130º in the vertical field of view and a minimum of 180º in the horizontal field of view. It is recommended that the image fill 180º of the vertical field of view and 360º of the horizontal field of view.*
6.14	***Peak White Luminance*** *shall be 3–4 fL measured at a 45 degree elevation above the center front dome bottom. This specification was taken from the GSCA Task Force report.* ***Future Research Question****: Recommended brightness of 3–4 fL to be substantiated through testing.*
6.15	***Luminance Uniformity****. The peak-to-peak luminance variation over the screen surface shall be no greater than 20%. This specification exceeds DCI spec.*

6.16	***Narrow Angle Luminance Uniformity**. For systems that blend multiple projectors to form the giant-screen image, or that otherwise exhibit brightness variations over small angles, the image brightness uniformity across non-uniformities (worst-case peak-to-peak variation of brightness measured at three points along a line perpendicularly intersecting nonuniformity/blend region) shall be 5% or less. This specification applies to any image consisting of a uniform value of red, blue and green components (full white, full black, gray, or uniform color) across the measurement area. This specification can apply to edge-blends and to dome screen issues with dust collection in perforations except over support ribs.*
6.17	***Image Resolution** shall be 4096 horizontal pixels minimum, however 8192 horizontal pixels is recommended for an optimal giant-screen experience, 16,384 maximum. The 4096 pixel resolution will not provide eye-limited resolution even for viewers seated in the back row of the dome screen. However, just as standard GS films are screened in domes with their equivalent pixel resolution spanning a much greater field of view, it also makes sense to allow the minimum pixel resolution of GS digital systems to also be projected in a dome. The 8192 pixel resolution provides eye-limiting resolution for viewers seated approximately 0.25 radii behind dome center, and the 16,384 pixel resolution provides eye-limited resolution for viewers seated 0.66 radii from the front of the dome screen. The highest resolution digital domes are now approaching 8K pixels. **Future Research Question**: Minimum and recommended resolution to be substantiated through testing.*
6.18	***Sequential Image Contrast** minimum 2000:1 minimum (DCI compliant). Exceeds DCI specification that permits tolerance down to 1200:1 for exhibition. **Future Research Question**: To be validated with simulations or in-theater tests.*
6.19	***Intra-frame (checkerboard) contrast** shall be 12:1 minimum (noncompliant with DCI). This specification is very sensitive to dome screen reflectance and theater finishes. A 12:1 checkerboard contrast is achievable with a screen reflectance of approximately 0.35 or less. **Future Research Question**: To be validated with simulations or in-theater tests.*
6.20	**Color Gamut and Color Accuracy**. Recommend DCI compliance.
6.21	**Pixel Structure**. The device structure (mesh) of the projector picture array is required to be invisible at the reference viewing distance. *No visible contouring*. (DCI compliant.)
6.22	**Contouring.** Images shall not exhibit any contouring (step in luminance), or color deviation from the neutral gray. (DCI Compliant.)
6.23	***Frame Rate.** The display shall be capable of refreshing unique image frames at 24 frames per second for 2D systems and 48 frames per second for sequential eye 3D systems; recommended additional rates include 30, 48 (2D), 60, 96 (3D) unique frames/second.*
6.24	***Ghosting.** For 3D systems, crosstalk between eyes shall be less than 15% with a goal of less than 10%. Note: Maximum crosstalk to be substantiated through testing.*
6.25	**Dome Master mapping** shall be equidistant polar/azimuthal (from draft fulldome standard). This specification requires a simple spherical mapping between dome and digital image which deviates from the original Omnimax specification which cannot accommodate mapping onto a full hemisphere. It is compliant with the draft version 0.5 of the Fulldome Master Show File specification[6].

[6] Fulldome Master Show File, Version 0.5, Sept. 12, 2005 (www.imersa.org)

LINK 7: THEATER ENVIRONMENT SPECIFICATIONS

Author: Victor Becker

The term "reference seat" refers to the location of the eyes and ears of a viewer sitting on the centerline of the theater in a real or imagined seat exactly midway between the first and last rows of seats.

SPECIFICATIONS FOR ALL SCREENS:

7.1	The plane of the seating area shall be angled to the horizontal plane no less than 12° and no more than 30°. It is recommended that the tilt be 20° to 25°.
7.2	The eyes of the viewer in the reference seat of the theater shall be located above the bottom of the screen at a point between 0.28 and 0.33 times the height of the screen.
7.3	The screen surface shall be free from all visual defects, including scratches, dents, dirt, or any artifacts that can be detected by the human eye. The screen surface shall be spectrally neutral and free of visible specular reflections. The screen surface shall have a total variation of less than 2% in gain and color across its entire expanse.
7.4	The ambient interior and exterior noise that intrudes into the theater space shall not exceed Noise Criterion 25 (NC-25).
7.5	Neither the screen nor its support structure shall produce audible sound or sympathetic vibration in the presence of audio system energy of 105 dB at any frequency over a range of 20 Hz to 16,000 Hz, as measured at room center.
7.6	The reverberation time for sound in the theater shall not exceed 0.5 seconds for a theater with a screen narrower than 80 feet or a seating capacity of under 400. In any theater larger than this in size or capacity, it is recommended that reverberation time not exceed 0.8 seconds.
7.7	The intelligibility produced by the theater's audio system shall have an Articulation Loss of Consonants (ALCONS) of no more than 5% and/or achieve a Speech Transmission Index (STI) rating of no less than 0.68 for the reference seat.
7.8	The audio system shall have audio characteristics that conform to the relevant Digital Cinema Initiative specifications for bit depth, sample rate, and reference level (DCI Specification 3.3.2).
7.9	The audio system shall have 16 full-bandwidth channels and a physical placement of speakers in the theater shall that conform to the Digital Cinema Initiative specification of channel count and speaker placement (DCI Specification 3.3.3).

Flat Screens:

7.10	The screen width shall be not less than 70 feet (21.34 meters).
7.11	The screen height shall be no less than 50 feet (15.24 meters).
7.12	The eyes of the viewer in the farthest seat from the screen shall be no farther than the width of the screen.

7.13	The eyes of the viewer in the center seat of the row of seats closest to the screen shall be no closer than 0.33 times the width of the screen.
7.14	No seat shall be located outside of the space defined in plan by two lines that begin at the screen centerline and extend 45° in either direction for 2D screens and 35° for 3D screens. It is recommended for all screens that no seat be located outside of the space defined in plan by two lines that begin at the screen centerline and extend 35° in either direction.
7.15	No seat shall be located farther from the centerline of the theater than 0.45 times the width of the screen.

Dome Screens:

7.16	The diameter of the dome shall be no less than 60 feet (18.29 meters).
7.17	The eyes of the viewer in the center seat of the closest row of seats to a dome screen shall be no closer than 0.30 times the diameter of the dome.
7.18	No viewer's eyes shall be located within 4 feet (1.22 meters) of the inside edge (in horizontal plan) of the dome and/or dome lighting trough. It is recommended that this no-seat zone be increased as much as dome diameter and required seat count allow.
7.19	The dome and projection system shall display an image that is a minimum of 130w° in the vertical field of view, with 20° of that field below the horizon line of the reference seat and 110° above it and a minimum of 180° in the horizontal field of view. It is recommended that the image fill 180° of the vertical field of view and 360° of the horizontal field of view.
7.20	The dome and projection system shall display an image that is a minimum of 180° in the horizontal field of view. It is recommended that the image fill 360° of the horizontal field of view.
7.21	The dome shall maintain the integrity of it hemispherical characteristics at a surface variance of no greater than 1/2 inch (12.5 mm).
7.22	The dome shall have seams between its constituent panels that are invisible under full-color projection.
7.23	The center top speaker in a dome environment shall be assigned audio channel #9 of a minimum of the 16 available channels.

Design Guidelines Requiring Additional Investigation:

1. The degree of specificity in the range of angles for the tilt of a dome.
2. The determination of the distance between of the closest center front seat and the dome screen.
3. The creation of effective ADA-compliant experiences and their impact on theater geometry.
4. The development of effective theater entry and exit options.
5. The evaluation of the importance of the seating plane being parallel to the dome's spring line.

6 The impact of theater finishes on acoustics and ambient light control.

RATIONALE/DISCUSSION:

Objective

The primary objective of DIGSS is to develop for the worldwide network of science-based institutional giant-screen theaters a set of specifications for the physical architecture and environment of a theater experience that will satisfactorily accommodate existing analog and new digital cinema systems.

These specifications will guide the adaptation and renovation of existing theater facilities as well as the development of new theater spaces for the museum field.

Wherever appropriate, these specifications have mirrored the specifications developed by the Technical Task Force of the Giant Screen Cinema Association[7] and by the Digital Cinema Initiative.[8] The development of these specifications also follows the basic methodology of the GSCA report, using James Hyder's database of all nonprofit giant-screen theaters in the US and Canada.[9]

Principal Determinants of the Aesthetic Impact of the Visitor Experience

The fundamental determinant of the effective and satisfaction-producing immersiveness of the GS theater experience is the ability of the experience to draw viewers into a projected "reality" as if they were actually within the location or situation that the image and sound emulate. The principal determinant of the theater's ability to "fool" viewers is the filling of their eyes and ears with the desired image and sound, and removing from their eyes and ears any evidence of the reality of the theater or the projection and audio systems responsible for the experience.

The world of sound is well suited to pull off this aesthetic trick. "Simply" remove unwanted sounds (see discussions of acoustics later in this report), and provide an audio track with appropriate volume and reasonably dynamic movement and the listener's mind will happily engage in the "willing suspension of disbelief" that defines successful theater.

The world of vision is much trickier. The human eye can naturally see about 180° in the horizontal plane and 120° in the vertical plane,[10] making it much harder to direct. The selection of a more limited field of view that is able to convince the eye and the brain

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[7] Andrew Oran, GSCA Technical Task Force Report, page 1. The report for the GSCA is based in part on recent data collected by surveys completed by its members totaling 76 GS flat-screen theaters and 39 dome theaters. It is also based in part on data describing all of its members, including 107 GS flat-screen theaters and 26 dome theaters. The specifications have also been influenced by data pertaining to the worldwide inventory of both flat-screen and dome theaters.

[8] Digital Cinema System Specifications, Version 1.2, March 7, 2008.

[9] From the *LF Examiner* Database of Theaters and Films (2010, Jan. 1). Figures provided by James Hyder as a custom search for this project. The statistics reflect the 42 flat-screen GS theaters and the 36 dome-screen GS theaters culled from the database.

[10] Margaret M. Fleck, Research Associate Professor, Massachusetts Institute of Technology

becomes a central — perhaps the critical — decision upon which to base the geometry of a theater devoted to immersive experiences.

Imax Corporation determined early in its development of large screens that a workable minimum field of vision for its viewers was 53º. This standard has produced unarguably successful theater designs and has been assumed to be the standard for the minimum viewing angle for decades by multiple suppliers.[11] It will be assumed in the discussions that follow that the existing analog giant-screen theater layouts by multiple suppliers have created a body of empirical evidence that will inform DIGSS.

SPECIFICATIONS FOR ALL SCREENS

Angled Seating Plane #1

The plane of the seating area shall be angled to the horizontal plane no less than 12º and no more than 30º. It is recommended that the tilt be 20º to 25º.

This specification is intended to ensure the viewer's immersion in the experience projected on the screen. Seating planes angled less than 12º do not measurably enhance the human perceptions of orientation, space, and distance. Seating planes angled more than 30º are physically difficult for viewers to negotiate and present hard-to-resolve issues with building and safety codes.

This specification is not included in the GSCA specifications; no data are currently available to determine how many of the 78 theaters in Hyder's database meet this specification.

Angled Seating Plane #2

The eyes of the viewer in the reference seat of the theater shall be located above the bottom of the screen at a point between 0.28 and 0.33 the height of the screen.

This specification is intended to orient the eyes of the viewers to the screen image in an optimal manner that is consistent from theater to theater, giving the producer of the image and sound a predetermined physical point of view applicable to all audiences.

This specification is not included in the GSCA specifications; no data are currently available to determine how many of the 78 theaters in Hyder's database meet this specification.

Screen Quality: Visual

The screen surface shall be free from all visual defects, including scratches, dents, dirt, or any artifacts that can be detected by the human eye. The screen surface shall be spectrally neutral and free of visible specular reflections. The screen surface shall not have a total variation of more than 2% in gain and color across it entire expanse.

The "purity" of the GS theater screen is essential for the "willing suspension of disbelief" so central to good theater. Discoloration, stains, and wrinkles can quickly

[11] Andrew Oran, GSCA Technical Task Force report, page 2.

degrade the experience by constantly reminding viewers that they are in a theater (and one that has not been well maintained) rather than in the environment being portrayed.

This specification is not included in the GSCA specifications; no data are currently available to determine how many of the 78 theaters in Hyder's database meet this specification.

Sound (and Vibration) Isolation

The ambient interior and exterior noise that intrudes into the theater space shall not exceed Noise Criterion (NC)-25.

Isolation of the seating area from all external sound is important to maintain the immersive quality of the presentation. Police sirens, aircraft, trains, thunder, heavy rain, and hail are a few examples of the sounds that are certain to distract from the theater experience. Because retrofitting sound isolation in a theater is extremely difficult and expensive, it is important to ensure than the design and construction of a new facility is completed with the proper isolation materials and techniques.

It is also important that the theater in its entirety be protected from any source of external vibration that can create instability in the theater projector systems that could be amplified by the various factors of the location and throw distance for projectors. External vibration can originate from sources outside the control of the theater facility, such as subway trains, railroad lines, heavy truck traffic, and similar realities of urban life.

Internal noise is usually generated by the failure to meet the complex challenge of isolating the seating area from the theater and mechanical, electrical, and plumbing systems that serve the facility.

The materials and technologies for achieving this isolation are not new or complicated but they often entail a significant construction or renovation cost — a cost often hard for the owner to justify but very important for successful theater "magic." Competent acoustic engineers experienced with GS theaters will understand these challenges and will be able to meet them effectively and affordably.

Screen Quality: Audio

Neither the screen nor its support structure shall produce audible sound or sympathetic vibration in the presence of audio system energy of 105 dB at any frequency over a range of 20 Hz to 16,000 Hz, as measured at room center.

While arguably more important for dome screens with their many metal components, this specification is intended to eliminate any possibility that a screen could create distractions from the aural experience.

This specification is not included in the GSCA specifications; no data are currently available to determine how many of the 78 theaters in Hyder's database meet this specification.

Audio Characteristics of the Theater Space

The reverberation time for sound in the theater shall not exceed 0.5 seconds for a theater with a screen narrower than 80 feet or a seating capacity of under 400. In any theater larger than this in size or capacity, it is recommended that reverberation time not exceed 0.8 seconds.

The GS theater experience requires a significant amount of acoustical "deadness" — the control of sound reflections via sound absorption materials and techniques — for the magic of the theater to work. "The goal is for the sound (which has already been post-processed and mixed by the filmmakers) to reach the listener's ears with very few reflections and remain uncolored by the room itself."[12] This "calls for a very short reverberation time. The key design factor is engineering the proper amount of acoustical absorption for the room's surfaces so it performs within the specifications."[13]

This specification is not included in the GSCA specifications; no data are currently available to determine how many of the 78 theaters in Hyder's database meet this specification.

Performance of the Audio System

The intelligibility produced by the theater's audio system shall have an Articulation Loss of Consonants (ALCONS) of no more than 5% and/or achieve a Speech Transmission Index (STI) rating of no less than 0.68 for the reference seat.[14]

The generation of the audio signal inside the theater is, of course, based on the nature of the audio system installed in the GS theater. This specification is intended to guarantee the intelligibility of the sounds unfolding in the theater, increasing the human perception of the reality of the events that the sound is portraying or supporting. A high degree of clarity in the sound — even when the intent is to present chaos or confusion — can greatly increase the viewers' sense of immersion in the action or environment on the screen.

This specification is not included in the GSCA specifications; no data are currently available to determine how many of the 78 theaters in Hyder's database meet this specification.

Audio System Characteristics

The audio system shall have audio characteristics that conform to the relevant Digital Cinema Initiatives specifications for bit depth, sample rate, and reference level (DCI Specification 3.3.2).

This specification ensures that the digital quality of the sounds produced by the theater's audio system are consistent with the producer's intent. The DCI specifications clarify required bit depth, sample rate, and digital reference level for successful playback in the theater.

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[12] Kenric Van Wyk, *The Secret Lives of IMAX Theater Designers*", Acoustics By Design, Sept. 11, 2008

[13] Ibid.

[14] STI & ALCONS indexes suggested as applicable criteria of sound quality by Haines B. Cole, Calf Audio, Ithaca NY, May 20, 2010. The specifications of these two criteria have been adjusted as per comments at the DISCUSS colloquium.

Although the GSCA specifications acknowledge that a quality audio design is "essential," no specification is included in the GSCA specifications; no data are currently available to determine how many of the 78 theaters in Hyder's database meet this specification.

Audio System Equipment Parameters
The audio systems shall have 16 full-bandwidth channels and a physical placement of speakers in the theater that conforms to the Digital Cinema Initiatives specification of channel count and speaker placement (DCI S 3.3.3).

The intent of this specification is to orient the ears of the viewers to the audio environment in a manner that is consistent from theater to theater, giving the producer of the show's sound a predetermined and reliable physical source of sound for all audiences. It is particularly important that the location and/or the direction of movement of each implied sound source accurately portray the content producer's intent.

The specifications for the assignment of audio channels and the physical location of speakers are clearly laid out in Section 3.3.3 of the DCI specifications.[15]

This specification is not included in the GSCA specifications; no data are currently available to determine how many of the 78 theaters in Hyder's database meet this specification.

SPECIFICATIONS FOR FLAT SCREENS

Flat Screen Width
The screen width shall be not less than 70 feet (21.34 meters).

This specification conforms to the GSCA's specification for minimum width. When it is applied to the 42 nonprofit flat-screen GS theaters in the US and Canada (including one theater with a flat screen convertible to a dome), 38 meet the specification, two are inches narrower, one is two feet narrower, and one is five feet narrower. This small number of non-complying theaters suggests that there is no reason to differ from the GSCA specification.

Flat Screen Height
The screen height shall be no less than 50 feet (15.24 meters).

This specification is based on applying the "traditional" giant-screen aspect ratio (approximately 1.33) to the minimum screen width. The resulting 52.5 feet height was adjusted downward to 50 feet to accommodate nine theaters (21.5% of the total number of flat-screen theaters) with screen heights that fall between 50 feet and 52.5 feet. Of the 42 theaters, 40 meet this specification; the two that fail to meet it also fail to meet the minimum screen width specification.

[15] Digital Cinema Initiative, version 1.2, March 7, 2008, Section 3.3, pages 30–34

This specification is not included in the GSCA specifications; they instead specify that a screen that falls short of the minimum width can be considered a "giant screen" if it is at least 3,100 square feet (288 square meters) in area. Because this GSCA specification would allow screens to be significantly shorter than needed to establish the strong sense of vertical immersion considered essential by many in the museum field, a minimum screen height-based criterion is preferred over an area-based criterion. Note that the GSCA minimum screen area specification is met by all 42 nonprofit theaters, including the two theaters whose screens are both narrower and shorter than the proposed DIGSS.

Farthest Seat from a Flat Screen

The eyes of the viewer in the farthest seat from the screen shall be no further than the width of the screen.

This specification conforms to the GSCA specifications. All of the flat screen theaters for which this particular dimension is available (17 of the total of 42) meet this specification.

Closest Seat to a Flat Screen

The eyes of the viewer in the center seat of the row of seats closest to a flat screen shall be no closer than 0.33 times the width of the screen.

This specification is not included in the GSCA specifications. All but one of the flat screen theaters for which this particular dimension is available (15 of the 42) meet this specification. The lone exception is the same theater that does not meet the DIGSS screen criteria.[16]

Boundary #1 of the Seating Area

No seats shall be located outside of the space defined in plan by two lines that begin at the screen centerline and extend 45° in either direction for 2D screens and 35° for 3D screens. It is recommended that no seat be located outside of the space defined in plan by two lines that begin at the screen centerline and extend 35° in either direction for all screens.

This specification prevents seats that are close to the screen — whose view is somewhat impaired by the difficulty of taking in the full scope of the screen image — from being further impaired by viewing the screen at a significant angle. It limits the acceptable width of the first four or five rows of seats in the most theaters.

This specification is not included in the GSCA specifications; no data are currently available to determine how many of the 42 theaters meet this specification.

Boundary #2 of the Seating Area

No seat shall be located farther from the centerline of the theater than 0.45 times the width of the screen.

This specification prevents seats that are farthest from the screen — whose view is somewhat diminished by the reduced immersion created by distance from the screen

[16] That theater, however, does meet the GSCA flat screen area specification.

image — from being further impaired by viewing the screen at a significant angle. It limits the acceptable width of the most of the middle and rear rows of seats.

This specification is not included in the GSCA specifications; no data are currently available to determine how many of the 42 theaters meet this specification.

SPECIFICATIONS FOR DOMES

Dome Diameter

The dome diameter shall be no less than 60 feet (18.3 meters).

This specification conforms to the GSCA's minimum diameter specification. All of the 36 nonprofit dome screen giant-screen theaters in the US and Canada[17] meet this specification.

Closest Seat to a Dome Screen #1

For the GS theater experience, the eyes of the viewer in the center seat of the closest row of seats to a dome screen shall be no closer than 0.30 times the diameter of the dome.

The "sweet spot" of a dome screen image is generally accepted to be approximately 20° above a horizontal plane passing through the eyes of the center seat in the center row of the theater. The increase in the viewing angle of each row in front of the center of the theater (and the corresponding increase in the viewer's physical discomfort) can be partially alleviated by angling the seat backwards. At some point, this solution becomes untenable and the view of the dome becomes unacceptably acute. This specification is intended to prohibit seats with unacceptably compromised views of the dome image.

Note that this specification does not apply to non-GS theater uses of the theater.

This specification is not included in the GSCA specifications; no data are currently available to determine how many of the 36 theaters meet this specification.

Closest Seat to a Dome Screen #2

No viewer's eyes shall be located within 4 feet (1.22 meters) of the inside edge (in horizontal plan) of the dome or dome lighting trough. It is recommended that this no-seat zone be increased as much as dome diameter and required seat count allow.

When the end seats of each row get too close to the edge of the dome (whether or not that edge is further defined by a cove wall), the viewer becomes too aware of the physical presence of the dome and the immersiveness of the experience is significantly reduced. This loss of immersion is particularly evident in dome theaters where the radii of the rows of seats are shallow; the resulting orientation of the seat compounds the awareness of the dome. This specification is intended to prohibit seats with unacceptably compromised views of the dome image.

[17] From the *LF Examiner* Database of Theaters and Films (2010, Jan. 1). Figures provided by James Hyder as a custom search for this project.

Note that the gap at the perimeter of the dome created by this specification provides excellent potential for visitor circulation.

This specification is not included in the GSCA specifications; no data are currently available to determine how many of the 36 theaters meet this specification.

Field of View — Vertical

The dome and projection system shall display an image that is a minimum of 130º in the vertical field of view, with 20º of that field below the horizon line of the reference seat and 110º above it. It is recommended that the image fill 180º of the vertical field of view.

This specification is based on the traditional guidelines of giant-screen theaters, which appear to be consistent with the generally accepted height of the field of normal human vision as measured in degrees. In addition, it helps to codify the location of the horizon line of the reference seat and to ensure the sense of the image extending downward out of sight that is one of the components of the giant screen immersive qualities.

Field of View — Horizontal

The dome and projection system shall display an image that is a minimum of 180º in the horizontal field of view. It is recommended that the image fill 360º of the horizontal field of view.

This specification is based on the traditional guidelines of giant-screen theaters, which appear to be consistent with the generally accepted width of the field of normal human vision as measured in degrees. In addition, it helps to ensure the sense of the image wrapping around the audience that is one of the components of the giant screen immersive qualities. The recommended 360º field of horizontal view obviously ensures the greatest sense of immersion possible in that characteristic of the projected image.

This specification is not included in the GSCA specifications; no data are currently available to determine how many of the 36 theaters meet this specification.

Dome Integrity

The dome shall maintain the integrity of its hemispherical characteristics with a surface variance of no greater than 1/2 inch (12.5 mm).

This specification is intended to ensure clarity of focus on the dome by preventing parts of the dome from being either closer or further from the focal plane of the projector(s). It is also intended to prevent anomalies in the image when rapid or precise movements of objects or people are portrayed on the screen.

This specification is not included in the GSCA specifications; no data are currently available to determine how many of the 36 theaters meet this specification.

Dome Seam Invisibility

The dome shall have seams between its constituent panels that are invisible under full color projection.

Seams between adjacent panels of the dome must be overlapped. Panel joint seams must be overlapped by no more than 2 in., and must have an opaque flat black material of minimum thickness between the layers.

The seam-backing material must be such that reflectance of the seam areas does not change over time.

Seams must be invisible under full-color projection. This is a subjective test and some allowances may be made when white light is projected onto the screen but when a picture is presented, the seams must not be discernable.

This specification is not included in the GSCA specifications; no data are currently available to determine how many of the 36 theaters meet this specification.

Additional Speakers

The center top speaker in a dome environment shall be assigned audio channel 9 of the 16 available full-bandwidth channels.

This specification is intended to provide both the predictability of the effective source of the nine localized channels and room for the accommodation of many ancillary functions as specified in the DCI Specifications.[18]

This specification is not included in the GSCA specifications; no data are currently available to determine how many of the 36 theaters meet this specification.

[18] Digital Cinema Initiative, version 1.2, March 7, 2008, Section 3.3.3 Channel Mapping, pages 31–34