DISCUSS Proceedings

Including DIGSS 1.0

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White Oak Institute
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Executive Summary

DISCUSS PROCEEDINGS

Project Summary Description

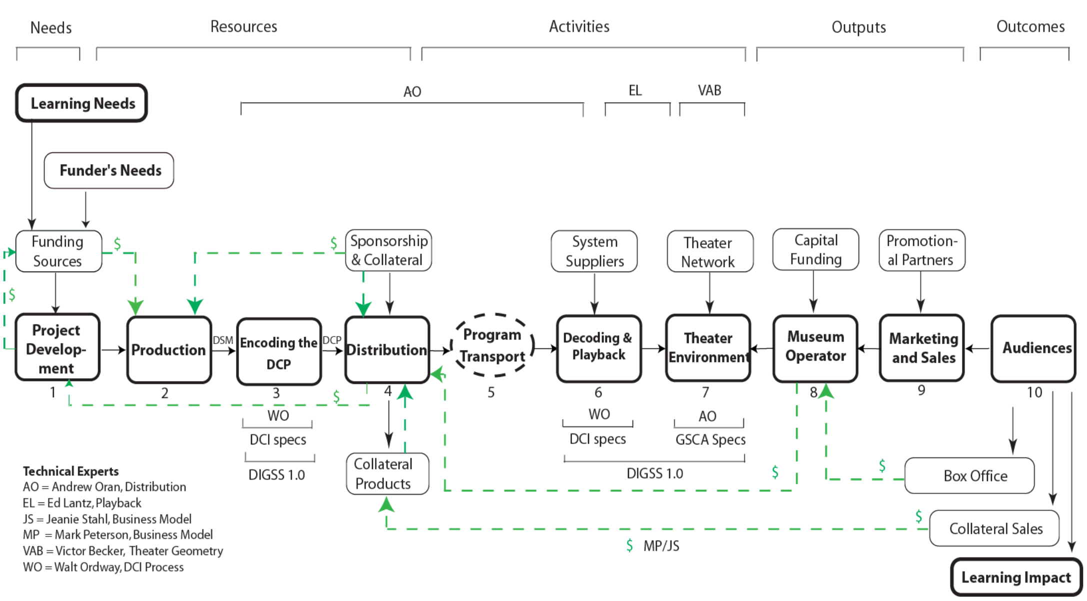
The White Oak Institute (WOI) and its team, including the Giant Screen Cinema Association (GSCA), the Institute for Learning Innovation (ILI), the LF Examiner, and the MacGillivray Freeman Films Educational Foundation (MFFEF), were awarded conference funding by the National Science Foundation (NSF-ISE 0946691) to bring together a team of giant-screen (GS) industry leaders and experts to reach consensus on the Digital Immersive Giant Screen Specifications (DIGSS).

The objective is a specification for immersive digital GS theaters that creates a viewer experience as good as or better than the film-based GS theaters now in place in museums and science centers. DIGSS aspires to address the challenges of the largest theaters through specifications for GS flat and dome screens, in 2D and 3D. Such shared protocols will set the stage for transformations and innovations in museum-quality equipment and productions in the digital age. DIGSS Draft 1c was open for professional comment and input on the DISCUSS wiki site from September 23 to November 7, 2010, attracting 79 visitors and 48 comments. Since then, the standards have been further refined by screen tests (Moody Gardens, Galveston, TX, Jan. 2011) and by industry discussion, resulting in the DIGSS 1.0 in this document. From this point forward, future iterations of DIGSS are intended to be in the hands of the GSCA.

DIGSS is built on the research and standards developed by the Digital Cinema Initiative (DCI), the existing global standard for conventional movie theaters established by seven Hollywood studios in 2005. Areas not unique to giant screens will default to the DCI specifications. There are key policy questions ahead, as well as screen tests and learning evaluation; however, the majority of the specifications are uncontested, and a logic rationale and research framework address the need for an evolving, flexible language of exchange. DCI and DIGSS are open-platform specifications.

The logic rationale establishes the numbering of the ten *links* in the production chain.

Logic Rationale: Museum GS Films & Theaters



Participant List: Project Advisors, Technical Experts and Colloquium Participants (project roles in bold):

Victor Becker, White Oak Associates, **Link 7**
Diane Carlson, Pacific Science Center, **Project Advisor**
David Duszynski, Cincinnati Museum Ctr., **Project Advisor**
John Fraser, Institute for Learning Innovation, **Evaluator**
James Hyder, LF Examiner, **Editor**
John Jacobsen, White Oak Institute**, PI, Other Links**
Valentine Kass, National Science Foundation
Mark Katz, National Geographic Society, **Project Advisor**
Doug King, St. Louis Science Center, **Project Advisor**
Jeff Kirsch, Fleet Science Center & **IPS Observer**
Ed Lantz, Visual Bandwidth, Inc., **Link 6**
Greg MacGillivray, MFFEF, **Project Advisor**
Toby Mensforth, Smithsonian Institution, **GSCA**
Andrew Oran, FotoKem, **Link 3**
Walt Ordway, CTO of Hollywood's **DCI Specs**
Mark Peterson, White Oak Associates, **Business Model**
Christopher Reyna, New Paradigm Prod., **Link 4**
Rebecca Robison, White Oak Institute, **Project Mgr**.
Tammy Seldon, GSCA
Jeanie Stahl, WOI, **Co-PI, Business Model**
Sandra Welch, National Science Foundation

Additionally, 61 other GS professionals signed up for the wiki, totaling 79 GS professionals engaged.

Summary of DISCUSS Colloquium Proceedings (By James Hyder)

For four decades giant-screen theaters have presented the highest quality motion picture experiences in the world. Based on 70mm film technology first developed by Imax Corporation in 1970, these theaters rapidly gained favor in museums, science centers, zoos, and other centers for informal science education. They spurred the production of hundreds of short-form documentary features that used immersive, high-resolution imagery and sound to make viewers feel that they were in the picture, taking them on adventures they could not experience otherwise.

In the past decade, dramatic progress has been made in digital projection for motion pictures, and the conversion of conventional multiplex theaters is well under way. That process was accelerated by the Digital Cinema Initiatives (DCI), a consortium of the major Hollywood studios that developed an open-source specification for digital projection. The DCI specs ensured image quality and sound that were better than 35mm prints and protected the filmmakers' intellectual property with strong encryption systems.

The giant-screen world has watched this process and yearned for the many operational, financial, and programming advantages that digital systems offer over film, not least of which is the elimination of $20,000 film prints. Until recently, most GS theater operators agreed that the image quality of conventional 2K digital projectors was insufficient to fill screens that average 60 by 80 feet.

However, the rapid pace of technological progress promises systems that will match, and ultimately, exceed, the quality of 70mm projection. This puts the GS industry on the threshold of a transformation unlike any in its history. Theater operators have many questions about digital projection and few clear answers.

The GS industry needs a process to help it manage its transition to digital projection while maintaining the reputation for "museum quality" imagery that has been its hallmark for 40 years. The Digital Immersive Screen Colloquium for Unified Standards and Specifications (DISCUSS) is the first step in that process.

The Colloquium brought together a panel of 21 advisors, technical experts, and others involved in the GS industry to begin developing Digital Immersive Giant Screen Specifications (DIGSS). DIGSS is intended to be a set of specifications, guidelines, and recommendations, comparable to the DCI specs, that will provide GS theater operators with information they need to select and install digital systems that provide experiences comparable to those offered by current film-based projectors.

Although begun by a small group of concerned industry leaders, the process of developing DIGSS 1.0 was not a top-down imposition of standards, but an open, collaborative effort that welcomed the participation of all stakeholders in the GS industry. The drafts were available online and interested parties were welcome to share their opinions via a wiki-style Web site.

The DISCUSS Colloquium

The Colloquium, held June 14–16, 2010 in Marblehead, MA, began with presentations by ten participants on subjects relating to DIGSS, interspersed with discussion sessions among the full panel of the subjects of the presentations. (*See Agenda, Attachment B.*) Following these presentations, breakout sessions were held in which participants discussed three topics in greater depth: theater geometry/playback, recording/distribution, and the business model. Each breakout session was conducted in two rounds, allowing for different sets of participants.

On the last day, the leaders of each breakout group presented a summary of the conclusions the groups had reached, and those topics were discussed by the whole group. The goal was to determine as many technical specifications as possible, and to identify others wanting further discussion or testing.

Following the Colloquium, the presentations of the participants, along with the provisional specifications and recommendations that had been drafted during the meeting, were posted on the DIGSS Online Forum. Those documents were discussed privately among the participants for the next three months, prior to the opening of the site to all GS professionals on September 23, 2010 for six weeks in anticipation of a presentation on the DIGSS process at the Giant Screen Cinema Association's annual conference.

[Also see the more detailed "Colloquium Description" Chapter 2]

Summary of Next Steps and Future Research

DIGSS 1.0 is intended to be the first important step in establishing a shared language of exchange among museum experiential theaters. During the run-up and follow-through with the DISCUSS project, participants established the foundations, and a first cycle of specifications, some of which are provisional pending screen testing, but most of which are uncontested.

The process has also revealed trade-offs, where policy decisions are needed by individual museum theaters and/or by the GSCA — ideally aligned. The trade-offs include security, which may be in conflict with multi-projector tiling, and the desire to have both Hollywood scope (2.39:1) and flat (1.85:1) format films <u>and</u> educational GS 4:3/dome films, which may require separate systems.

The specifications support a museum's mission of experiential learning through the immersive aspects of the giant screen experience, particularly with regard to screen size and image aspect ratio, the characteristics that most clearly differentiate the current global GS network from conventional movie theaters.

DIGSS is Developed by the Field

The museum GS field has developed DIGSS 1.0. It has gone through four drafts circulated among the DISCUSS participants, who represent the top experts and leaders of the field and who are independent of any system supplier. Co-Principal Investigators John Jacobsen and Jeanie Stahl outlined DISCUSS and DIGSS at the all-member meeting during the annual GSCA conference (Sept 25, 2010). DIGSS Draft C was opened for professional comment, with invitations to the DISCUSS wiki site sent by the Association Partners (GSCA, IPS and ASTC) to their members. Between September 23, 2010 and November 7, 2010, this Online Forum engaged 79 GS professionals with the draft and with the 48 discussion comments made. All these steps by GS professionals and experts have shaped the current specifications.

After DIGSS 1.0 is disseminated to the field and posted on ISE sites, it will be turned over to the GSCA for further development and later versions. The GSCA's Technical Committee has accepted responsibility for the screen testing.

Uncontested Frameworks

Built on earlier work by the field, the *DISCUSS Proceedings* include foundational frameworks that can now be used by the field for research and development, providing a shared language and evidence base:

- Front-end survey
- Bibliography of prior work
- Glossary, derived from DCI for consistency
- Purpose of DIGSS
- Inventory of GS theaters globally as of May 1, 2010

- Literature review and future research agenda re: Learning in immersive environments
- Survey of current (2010) business model
- Future business model scenarios based on survey results
- Logic rationale, establishing 10 links along the chain from project development (link 1) to audience (link 10). DIGSS 1.0 is organized by these links, which are derived from DCI's organizing scheme.
- *GSCA 2010 Conference Attendees Awareness and Attitudes Towards DIGSS* by the Institute for Learning Innovation

AREAS REQUIRING POLICY CHOICES

The DISCUSS Colloquium addressed many policy choices affecting DIGSS, but since then, a few new, interrelated issues arose that will need policy guidance for future versions of DIGSS.

1 Do GS films really need DCI security? DCI security requires the "media block" (a black box that unencrypts the signal, meaning it is no longer secure) to be hard-wired in a physically secured area inside the projector, which means multiple projectors can not be used unless multiple Digital Cinema Packages ("DCPs") are created. DISCUSS Advisors participating in a November, 2010 conference call believe DCI security will be needed, but prefer to wait for a single source projector over tiling.

2 If tiling projectors is the answer for larger flat and dome screens, and if DCI-compliant projectors cannot be tiled, will those theaters who want to show both GS and Hollywood films have to have separate systems? DISCUSS Advisors are waiting for either a) successful (seamless) demonstration of tiled projectors of live action bright motions, or b) a single source DIGSS projector.

3 Should DIGSS be set up to serve all museum experiential theaters (GS digital planetariums and 16:9[1] 3D theaters), perhaps in different sub-categories? DIGSS 1.0 is the aspiration for the most challenging format (large domes), but it could be open to other categories. Or should DIGSS be just for those large GS theatres that fit the GSCA (BBB[2]) definition? DISCUSS Advisors want DIGSS to be aspiriational and concern itself only with GS theaters.

4 How do we build the inventory of DIGSS theaters in order to get an exchange market large enough to support continuing popular programming? Current estimates are around 200 leasing digital theaters – about the size of the current analog GS market.

5 How will the next versions of DIGSS happen?

[1] DCI's native aspect ratio is actually 17:9 or 1.9:1
[2] Bigger, Bolder, Better

6 How does DIGSS liaise with the sources of the specifications? The primary DCI standards are a suite of SMPTE documents, and AES is where intelligibility work is done. Brian McCarty, Managing Director of Coral Sea Studios Pty. Ltd. in Australia is a member of SMPTE's audio committee, and is interested in assisting.

UNCONTESTED SPECIFICATIONS

58% of the 73 core specifications are uncontested. The remainder are provisional, pending screen and other testing.

ADVISORY ONLY SPECIFICATIONS

Seven of the ten links are "advisory only" at this stage; the other three are "core." Advisory specifications may be developed and formalized by the GSCA later if it wishes.

PROVISIONAL SPECIFICATIONS AND SCREEN TESTING

One or more experts have suggested that about 42% of the core specifications (links 3, 6, and 7) should be tested, usually on screen in butterfly tests or in the theater with meters. These are listed in the document in *italics.* The GSCA Technical Committee will undertake some of these tests over the next few years; meanwhile, the expert opinion will serve as an interim specification.

DIGSS 1.0: SUMMARY SPECIFICATIONS, RECOMMENDATIONS AND TESTING

This summarizes more detailed analysis developed by the DISCUSS team of technical experts available in Chapter 6.

DIGSS 1.0 specifications in *italics* are *provisional*; they are based on expert opinion pending research and screen testing.

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.

GENERAL (Note: This section is freely adapted from the DCI, Section 1.4)		
	0.1	DIGSS shall have the eventual capability to present a theatrical experience that is perceived as good as or better than what one could achieve now with a traditional 70mm 15 Perf ("15/70") Answer Print and in a giant screen theater meeting GSCA's definition.
	0.2	This system should be based around global standards, or "DIGSS", that are embraced around the world so that content can be distributed, played and experienced anywhere in the world as can be done today with 15/70, 8/70 or 10/70 film prints. These standards should be open, published industry standards that are widely accepted and codified.
	0.3	To the extent that it is possible, DIGSS shall emulate and improve on theater operations and the institutional GS theater business model, as it exists today.
	0.4	DIGSS projection and audio systems shall be capable of operating in several modes: • DIGSS Mode (the subject of this spec): Giant screen experiences compatible with others and able to carry the "Bigger, Better, Bolder" identifier • DCI (Digital Cinema Initiative) Mode: Conventional movies based on the Digital Cinema System Specification, v.1.2 (March '07, 2008) plus addenda and/or later versions. This may require a separate projector. • Open Mode: to handle other digital inputs and innovative programming, from PowerPoint to satellite feeds, to fulldome productions and lower-resolution inputs

	0.5	DIGSS has specifications for Flat 2D/3D and Dome 2D/3D			
	0.6	Playback System Reliability (up-time) shall be 99.5% or better.			
	0.7	DIGSS follows all DCI specifications except those listed in DIGSS			
	0.8	DIGSS is open access, although branded services may choose to operate within DIGSS			
	0.9	DIGSS may be achieved with tiling projectors if no seams are visible in projecting live action photography, but it is the supplier's responsibility to map a DIGSS compliant Digital Cinema Package(DCP) to their array. The on-screen output of multiple projectors shall meet DIGSS on-screen specifications as measured from the reference seat.			
LINK 1: PROJECT DEVELOPMENT (ADVISORY ONLY)					
	1.1 1.2	Be scientifically and historically accurate and culturally sensitive Meet audience appropriate standards			
LINK 2: PRODUCTION (ADVISORY ONLY)					
	2.1 2.2 2.3	Specifications to be determined in a future step Production should be recorded for use in GS domes and flat screens with dimensional sound. Production to result in a Digital Source Master (DSM) of sufficient quality that it can be converted into a DIGSS-compliant Digital Cinema Package (DCP) during Link 3.			
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 3.2	Compression Frame Rate (unique frames)	JPG2000 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)*	DCI testing complete
	2D Flat Screen				
	3.3.1 3.4.1 *3.5.1* 3.6.1	*Resolution* Color Bit Depth *Bit Rate Compression (maximum; studios can use lower)* Brightness (measured off screen)	*4K All screen* 12 bit *250 mb/s* 20:22 FL for 2D silver screens 6–8 FL. for 3D silver screens	*8K* *500 mb/s*	*To be tested* Must be even multiples — 4K, 8K, 16K to use JPG 2000 *To be tested* GSCA Task Force
	3D Flat Screen				
	3.3.2 3.4.2 *3.5.2* 3.6.2	*Resolution* Color Bit Depth *Bit Rate Compression (maximum; studios can use lower)* Brightness (measured off screen)	*4K All screen* 12 bit *250 mb/s* 20:22 FL for 2D silver screens 6–8 FL. for 3D silver screens	*8K* *500 mb/s*	*To be tested* Must be even multiples — 4K, 8K, 16K to use JPG 2000 *To be tested* 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*

			Specifications	Recommendations	Notes
	3D Dome Screen				
	3.3.4	*Resolution*	*8K*	*16 K*	*To be tested*
	3.4.4	*Color bit depth*	*8 Bit*	*12 Bit*	*To be tested*
	3.5.4	*Bit rate compression (maximum; studios can use lower)*	*250*	*500*	*To be tested*
	3.6.4	*Brightness*	*3-4 fL*		*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			
LINKS 4 & 5: DISTRIBUTION AND TRANSPORT					
	5.1	Like DCI, DIGSS makes no stipulations about distribution arrangements or how programs (DCP's) are sent (hard drive, satellite, etc.) to the theater.			DCI Compliant
LINK 6: DECODING AND PLAYBACK (PROJECTION & AUDIO SYSTEMS)					
	Flat Screens				
	6.1	Aspect ratio	1.33:1 (4:3)		DISCUSS advisors' & experts' vote
	6.2	Peak White Luminance	20:22 FL for 2D silver screens 6–8 FL. for 3D silver screens		
	6.3	Luminance Uniformity Variation	No greater than 20% for the projected image	15%	
	6.4	Narrow angle luminance uniformity for measuring tiling seams from overlapping projectors)	5% or less		
	6.5	*Image Resolution*	*4K*	*8K*	*To be tested*
	6.6a	*Sequential Image Contrast Ratio (from projector)*	*2000:1 minimum*		*To be tested*
	6.6b	*Sequential Image Contrast Ratio (in theater)*	*To be measured*		*Take readings in current theaters*
	6.7a	*Checkerboard Contrast (from projector)*	*150:1 minimum*		*To be tested*
	6.7b	*Checkerboard Contrast (in theater)*	*To be measured*		*Take readings using StEM footage*

			Specifications	Recommendations	Notes
	6.8	Color Gamut and Color Accuracy	DCI compliance		
	6.9	Pixel Structure	Invisible at the reference viewing distance.		DCI compliant
	6.10	Contouring	DCI compliant		
	6.11	*Frame Rate: refreshing unique image 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)*	*To be tested*
	6.12	*Ghosting: For 3D systems, Crosstalk between eyes*	*Less than 15%*	*less than 10%*	*To be tested*
Dome Screens					
	6.13	*Dome image*	*A minimum of 130° in the vertical field of view and a minimum of 180° in the horizontal.*	*The image should fill 180° of the vertical field of view and 360° of the horizontal field of view.*	*To be tested Matches 7.19 and 7.20*
	6.14	*Peak White Luminance*	*3–4 fL measured at a 45 degree elevation*	*3–4 fL*	*Substantiated through testing*
	6.15	*Luminance Uniformity Variation*	*No greater than 20% for the projected image*	*15%*	*To be tested*
	6.16	*Narrow Angle Luminance*	*5% or less*		*To be tested*
	6.17	*Image Resolution*	*4K*	*8K*	*To be tested*
	6.18a	*Sequential Image Contrast* (from projector)	*2000:1 minimum*		*DCI compliant to be validated*
	6.18b	*Sequential Image Contrast Ratio (in theater)*	*To be measured*		*Take readings in current theaters*
	6.19a	*Checkerboard Contrast*	*12:1 minimum*		*To be tested*
	6.19b	*Checkerboard Contract (in theater)*	*To be measured*		*Take readings using StEM footage*
	6.20	Color Gamut and Color Accuracy	DCI Compliant		
	6.21	Pixel Structure	Invisible at the reference viewing distance		DCI compliant
	6.22	Contouring	DCI Compliant		
	6.23	*Frame Rate: refreshing unique image 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)*	*To be tested*
	6.24	*Ghosting 3D systems, crosstalk between eyes*	*Less than 15%*	*Less than 10%*	*To be tested*

			Specifications	Recommendations	Notes
	6.25	Dome Master mapping	Equidistant polar/azimuthal		Draft fulldome master standard
LINK 7: THEATER GEOMETRY					
	All Screens				
	7.1	Angle of the seating plane	No less than 12° no more than 30°	20° to 25°	
	7.2	Height of the reference seat	0.28 and 0.33 the height of the screen.		
	7.3	Screen quality: surface	Free from all visual defects detected by the human eye: spectrally neutral, free of visible specular reflections: not more than 2% in gain and color		
	7.4	Ambient sound	Shall not exceed Noise Criterion 25 (NC-25)		
	7.5	Screen quality: audio	Neither the screen nor its structure shall produce audible sound.		
	7.6	Reverberation time	0.5 seconds when screen narrower than 80' or a seating capacity of under 400	Not exceed .08 seconds in any theater larger in size or capacity.	
	7.7	Intelligibility	ALCONS of not more than 5%. Speech Transmission Index (STI) rating of no less than 0.68 for the reference seat.		
	7.8	Sound characteristics	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	Audio systems channel count and the placement of speakers	The audio system shall have 16 full-bandwidth channels and a physical placement of speakers in the theater that conform to the Digital Cinema Initiative specification of channel count and speaker placement (DCI Specification 3.3.3).		DCI specs 16 channels: 8 for audio and 2 or more for hearing impaired and visually impaired signals
	Flat Screens				
	7.10	Screen width	Not less than 70' (21.34meters).		4:3 Proportion
	7.11	Screen height	Not less than 50' (15.24 meters).		4:3 Proportion
	7.12	Farthest seat from a flat screen	No farther than the width of the screen.		
	7.13	Center seat of the row or seats closest to the screen	No closer than .33 times the width of the screen		

			Specifications	Recommendations	Notes
	7.14	Seat location: front	No seat between the screen and a 45° line extending from the center of the screen	35° in either direction	
	7.15	Seat location: width	No seat farther from the centerline of the theater than 45% the width of the screen.		
	Dome Screens				
	7.16	Dome diameter	No less than 60' (18.3 meters)		
	7.17	Center seat of the closest row of seats to the dome	No closer than 0.30 times the diameter.		
	7.18	Seat location: perimeter	No viewer's eyes shall be located within 48" of the inside edge of the dome		
	7.19	Dome and projection system image: vertical	A minimum of 130° in the vertical field of view	The image fill 180° of the vertical field	
	7.20	Dome and projection system image: horizontal	A minimum of 180° in the horizontal field of view	The image fill 360° of the horizontal field	
	7.21	Dome quality: surface variance	No greater than 12.5 mm		
	7.22	Dome quality: seams.	All seams invisible under full color projection		
	7.23	Center top speaker in a dome environment	Audio channel #9 of a minimum of 16 available channels.		
LINKS 8 & 9: OPERATIONS, MARKETING & SALES (ADVISORY ONLY)					
	8.1	Maintain the integrity of the GS Theater experience			
	8.2	Record operating data internally according to GSCA accepted data definitions.			
	9.1	Represent the Theater and the Programs accurately			
LINK 10: AUDIENCE (ADVISORY ONLY)					
	10.1	At a minimum, the audience in a GS theater shall be three (3) years or older.			

Purpose of the Digital Immersive Giant Screen Specifications

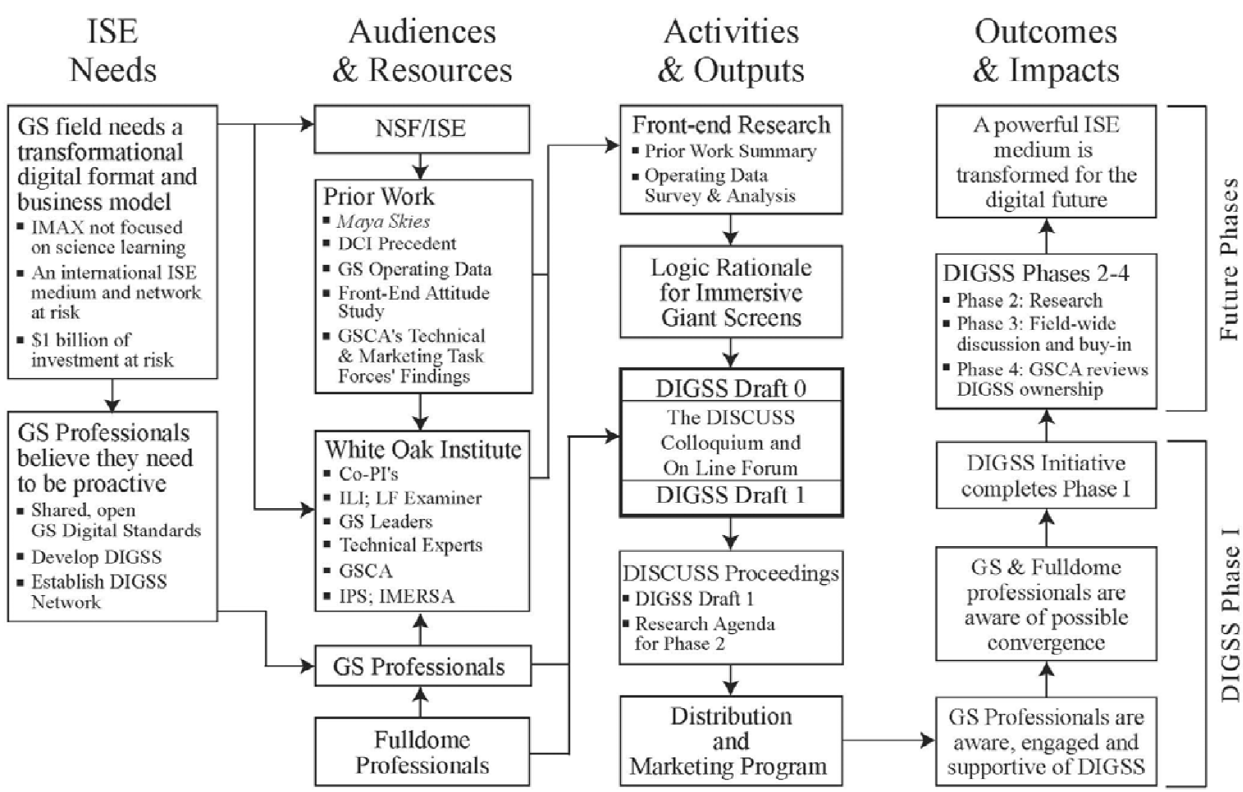
DISCUSS PROCEEDINGS

Chapter 1

BY John W. Jacobsen

This chapter outlines the orientation and parameters provided beforehand to the DISCUSS participants. It told them what the DISCUSS initiative is doing and why, along with the underlying assumptions, so that the advisors and technical experts were focused and worked to the same end: coming to consensus on why and how to differentiate museum digital giant screens from conventional movies – a process that evolved into DIGSS 1.0.

It started with the logic model and objectives stated in the NSF proposal.



PROJECT OBJECTIVES

The learning objectives of this phase of the DIGSS initiative are: a) to build *awareness* of the need for shared standards and specifications in the *primary professional audience* (GS professionals); b) to develop *interest* in what those specifications might be; and c) to build *understanding* of a possible convergence (or thoughtful divergence) among both fulldome and GS theater professionals. One of the outcomes of the Colloquium and Online Forum is a better understanding of how much additional effort will be required to establish a global network of compatible Digital Immersive Giant-Screen Theaters. While there is much about the DISCUSS colloquium which is innovative and daring, the project also has an element of risk, which is justified by the potential strategic impact.

ASSUMPTIONS AND GROUND RULES

1. Giant-screen experiences are different from conventional movie experiences, and that difference is important to science education.
   a. Conceptually, what is the difference we are after, expressed in learning outcomes?
   b. Is that difference easily communicated and compelling to audiences?
2. We are focused on the needs of institutional (museums and science centers) giant-screen theaters
   a. As of May 1, 2010, 207 of the world's 549 GS theaters potentially qualified as institutional. 259 are known to meet the GSCA's recent definition of "giant screen." (Hyder, 2010).
   b. Other theaters will be considered, particularly those with a leasing history similar to institutional theaters.
   c. Fulldomes will be considered in light of possible convergence.
   d. We are working toward base specifications broad enough to address flat and dome screens and 2D and 3D programs, in order to enable the largest institutional network possible.
3. We are building on and advancing the GSCA technical and marketing definitions of "giant screen."
4. We are developing digital specifications to facilitate exchange and distinguish museum digital theaters. Our output will be the Digital Immersive Giant Screen Specifications (DIGSS).
5. DIGSS will address flat 2D, flat 3D, dome 2D and dome 3D; eventually the International Planetarium Society may elect to add fulldome 2D and 3D.
6. Once they are reviewed and adopted by GSCA, DIGSS will be open to any distributor, manufacturer, theater and producer that can meet the specifications.

a Since system manufacturers and suppliers have the greatest potential for conflict of interest in determining specifications, they were not included in the early phases of DISCUSS, but did participate in the Online Forum.

7 Compliance with DIGSS is voluntary, but confers benefits (to be determined) that make the "upgrade to DIGSS compliance" attractive to museums that currently operate analog giant-screen theaters and/or fulldomes.

8 For purposes of researching the current business model, the following surveys were conducted in April-May, 2010:

- **Survey 1**: Sent to about 60 qualified U.S. non-profit, STEM institutions with GS theaters, according to the GSCA definition, with 24 responding
- **Survey 2**: Case Studies: GS Theater Operations
- **Survey 3**: Case Studies: Film Producers and Distributors

Results are summarized in "Business Model," Chapter 5.

CORE RESEARCH QUESTION

What is the least we need to specify in order to differentiate a giant-screen learning experience from entertainment venues and to create a sustainable network of institutional GS digital theaters and a library of programs? What are those specifications?

SECONDARY AND FUTURE RESEARCH QUESTIONS

- Calculate how large the network of compatible GS theaters needs to be to keep new films coming.
  - How many viewers per year are needed globally?
- What are the *best* practices and *recommended giant-screen* conditions? How can producers and theaters move from minimum to ideal?
- What screen and trial tests are needed to confirm or modify DIGSS 1.0?
- Define a manageable and affordable transition to an open-source digital platform that is:
  - Attractive enough that theaters will want to transition to compliance with the minimum specs;
  - Supports enough new, educational ("classic") films per year to keep attendance up.
- How can the investments in the existing analog library best be transitioned into the digital world?
- What kinds of learning experiences happen more effectively in immersive media than on conventional screens?

- Are immersive learning media environments more or less
    - Effective?
    - Popular?
    - In 3D? in domes?
- How can the business model evolve to sustain the whole giant-screen industry's economy?
- How can the public value and learning impact of the global network of institutional theaters be maximized? How can the impact be measured?

DIGSS FUNDAMENTALS

Note: This section is freely adapted from the DCI, Section 1.4.

At the onset of writing a specification for a digital giant-screen cinema experience, the DIGSS initiative acknowledges certain fundamental requirements, which are:

- DIGSS shall eventually have the capability to present a theatrical experience that is as good as or better than what could be achieved with a traditional 15 Perf , 70mm (15/70) answer print in a giant-screen theater that meets the GSCA's definition. While this goal may not be achieved by DIGSS 1.0, it is the goal of future versions and the recommendations.
- This system should be based on standards that are embraced globally so that content can be distributed, played, and experienced anywhere in the world as is done today with 15/70, 8/70 and 10/70 film prints. These standards should be open industry standards that are widely accepted and codified by national and international standards bodies such as ANSI, SMPTE, and ISO/IEC. To the extent that it is possible, the DIGSS shall emulate and improve on theater operations and the theater business model as it exists today.
- DIGSS shall address the minimum standards for Links 3, 6, and 7 in the DISCUSS Logic Rationale.
- The system specification, global standards, and formats should be chosen so that the capital equipment and operational costs are reasonable and exploit, as much as possible, the economies of scale associated with equipment and technology in use in other industries and the existing capital investments in giant-screen theaters and the analog film library.
- The hardware and software used in the system should be easily upgraded as advances in technology are made. Upgrades to the format shall be designed in a way so that content may be distributed and compatibly played on both the latest DIGSS-compliant hardware and software, as well as earlier adopted DIGSS-compliant equipment installations.

- The DIGSS system shall provide a reasonable path for upgrading to future technologies. It shall be based upon a component architecture (e.g., mastering, compression, encryption, transport, storage, playback, projection, theater design) that allows for the components to be replaced or upgraded in the future without the replacement of the complete system. It is the intention of this specification to allow for advances in technology and the economics of technology advancement. It has been recognized that these advances may most likely affect the mastering and projection of giant-screen content. Therefore, this document will specify, for example, a resolution and color space that may not be obtained in a present day mastering or projection system. However, it is the intent that the rest of the DIGSS system be capable of transporting and processing up to the technical limits of the specification.
- This document specifies a baseline for the implementation of a DIGSS system. The goal of backwards compatibility in this context is to allow, for example, new content at higher resolution and color space to be played out on a projection system that meets the baseline implementation.
- The DIGSS system shall not preclude the capability for alternative content presentations.

Summary of DISCUSS Colloquium Proceedings

DISCUSS PROCEEDINGS

CHAPTER 2
BY JAMES HYDER

The Colloquium, held June 14–16, 2010 in Marblehead, MA, (*see "Agenda," Attachment B*) consisted in the first part of presentations by ten participants on subjects relating to the DIGSS, interspersed with discussion sessions among the full panel of the subjects of the presentations.

In the second part of the Colloquium, breakout sessions were held in which participants discussed three topics in greater depth: theater geometry/playback, recording/distribution, and the business model.

In the final part, the results of the breakout sessions were discussed, preliminary conclusions were reached, and strategies and future actions were discussed.

This summary allows the ten presentations, most of which were illustrated with PowerPoint files that stand on their own, and condenses the main topics of the discussions that followed each. We do not attempt to summarize the breakout sessions, presenting instead the conclusions reached and the matters left to be acted upon.

MONDAY, JUNE 14

Following welcoming remarks by Sandra Welch of the National Science Foundation and Jeanie Stahl of the White Oak Institute, Toby Mensforth, chair of the Giant Screen Cinema Association, spoke about the desire of the association's members, mostly science-based informal educational institutions, to define themselves in a rapidly changing marketplace. Under the direction of Andrew Oran (a Colloquium participant), the GSCA had earlier formed a Technical Task Force to define the term "giant screen." That work ties in well with the work of the DIGSS process, which will refine it further. Mensforth said that the members of the GSCA want the process to succeed to assure the longevity of the industry and the medium.

1a. John Fraser: Evaluation Process and Front-End Findings

1b. John Jacobsen: Colloquium Purpose, Prior Knowledge Review and Advisory Links 1, 2, 8, 9 & 10

1c. Walt Ordway: Digital Cinema Initiatives, A Case Study

The panel felt that the advisory links should be written as open as possible, specifically removing advisory guidelines for film length and educational content.

TUESDAY, JUNE 15

2a. John Fraser: Research on Learning in Immersive Environments

2b. Victor Becker: Theater Geometry (Link 7)

2c. Ed Lantz: Digital Playback (Projection and Audio) Technologies (Link6)

At the end of his presentation, Lantz expressed concern that the manner in which digital planetarium productions are projected is significantly different from the way DCI-compliant systems handle encrypted content. Planetarium producers have not traditionally been concerned about piracy or encryption, and so allow their master files to be divided up by each theater for as many projectors it uses to tile the dome. This is a more complex process if every projector has to be secure. He suggested that the DIGSS spec be more "black-boxish," specifying the kind of image desired, and allow the system vendors to accomplish that as they will. (The group discussed this topic and the question of encryption in depth on the following day.)

Kirsch asked about interpolation of low-res material to higher-res systems. Ordway replied that the DCI spec requires that 4K projectors must have scalers that up-res a 2K image to 4K. Although not required by DCI, scalers could also be applied to the alternative content channel for enhancing non-DCI programs.

Jacobsen asked Fraser if there is any evidence for the relative learning impact of different GS films. Fraser said that the only studies comparing different formats that he knows of were done on virtual reality systems. Welch added that PBS TV stations found that their primetime audiences could tell the difference between HD and standard-def programming, and complained about the latter when it appeared in primetime.

Jacobsen asked about relations between IMERSA and GSCA. Lantz is the liaison between the organizations, and Mensforth (GSCA chair) has been discussing the issues with Lantz and Paul Fraser, a GS veteran who is on the board of IMERSA.

Jacobsen asked Lantz about the business model for digital domes. Lantz explained that analog planetariums — long seen as white elephants in their museums — have been revitalized by conversion to digital, which offers much greater programming flexibility. Instead of shows that may be years out of date, they can show cutting-edge scientific data taken from today's headlines. These technical potentials are driving conversion, not box office revenues, like GS growth. Many planetariums produce their own shows, and on a budget of $500,000 to $1,000,000 can make a profit from their own receipts, or with help from sponsors and limited distribution to other planetariums. Katz pointed out that most such bookings are flat-fee, not percentage deals.

Duszynski raised the question of whether the quality of the dome screen is or should be part of the specs. He has found that his audience responded very positively to the installation of a seamless dome, and believes it adds a great deal to the immersive nature of the experience.

3a. Andrew Oran: Digital Distribution Technologies (Link 3)

3b. Chris Reyna: Digital Recording (Capture) Technologies (Link 2)

Regarding the aspect ratio question, Katz pointed out that, from a business perspective, most ancillary uses of giant-screen material are "not friendly" to the 4:3 ratio. Oran replied that producers could shoot in the 4:3 ratio, while keeping the other ratios in mind, but that he felt that the GS industry is probably heading toward the 4:3 ratio because "otherwise it's just slightly bigger digital cinema."

Kirsch raised the issue of multiple projectors, because fulldomes require 4K by 4K resolution or higher, which will require more than two projectors. Theater geometry also has to be taken into account because placement of projectors can limit the placement of seats.

Lantz asked at what resolution digital intermediates (DIs) for GS films are currently mastered, and asked why the DIGSS projectors should have more pixels than the DIs. Oran replied that 4K is the current standard because most film recorders max out at 5.5K. "You can film out at 8K, but you don't see a difference between an 8K and a 5.5K film out, and very little difference between a 4K and a 5.5K film out, but you have an awful lot more data to deal with." In other words, printing a high-res 8K digital master to film provides very little visual improvement over a 5.5K master, but nearly quadruples the amount of data that must be handled, transferred, and stored.

Lantz asked whether it was therefore premature to specify an 8K projector. Oran said that once film is eliminated and all theaters are digital, you won't be limited by what happens at a CRT film recorder. There are 35mm film recorders that use lasers, but the 65/70mm recorders use CRTs, which is a limiting factor.

Ordway said that he had heard from the American Society of Cinematographers that that organization would be interested in working with the GS industry to produce Standard Evaluation Materials (STEM). Hyder asked if it would be possible to use existing footage instead of shooting original material, as had been done for DCI. This would be less expensive and quicker. Reyna said that to test for all the issues that need to be evaluated, it is more efficient to shoot material specifically for that purpose.

5a. James Hyder: Data & Trends: GS and Fulldome Inventories

5b. Jeanie Stahl and Mark Peterson: Current and Future Business Models

Hyder ended his presentation by pointing out that in the pre-digital world, Imax did not have a closed system. Producers could make and distribute 15/70 films without any involvement of Imax Corporation at all. But the digital IMAX system is proprietary: filmmakers must go to Imax to have their films converted, and theaters are at the mercy of Imax, which will decide which films will be available. It is contrary to the spirit of the DCI process and a fundamental change to the way the GS industry has operated until now.

MacGillivray said that in the early days, Imax required films to be shot in 15/70, to protect the brand's reputation for quality, but gave up that requirement when it started converting Hollywood films with the DMR process. He said audiences responded to that 15/70 quality and that's why smaller formats like 8/70 were never as successful as IMAX.

Following the presentation by Stahl and Peterson, there was some discussion of the statistical reliability of the conclusions from the small number of responses from the producers/distributors survey, as opposed to the full response to the theater operators survey. The presenters admitted that the four films surveyed did not provide enough data to come to strong conclusions, but they did show the range and they expressed greater confidence in the aggregated theater data.

Peterson said that many theaters were booking more films for shorter periods because it was the simplest thing to do, compared to developing more creative or sophisticated marketing programs. Mensforth said he has found that it is hard to make the business model for DMR films work at the Smithsonian's three IMAX theaters, because of the high lease rates and loss of screen time to classic films. Some titles, like *U2 3D*, have generated strong incremental income by being popular in times when the theater would otherwise not be full.

Carlson added that selling popcorn can improve a theater's bottom line with DMR films.

A difficulty in building a general business model for theaters is that each one handles financial factors like staffing, utility allocation, member tickets, and other issues differently. Jacobsen said that the GSCA could be helpful in standardizing how such information is reported. He also said that a "fundamental conundrum" of the industry is that although theaters all say they want quality films, the only way to make a theoretical production break even on purely lease revenues is to budget it at $2–3 million, presumably at a lower quality level than the preferred $5–8 million. Katz corrected this by saying it had to have "exposure," after non-equity participation, of about that amount. This improves the outlook somewhat.

WEDNESDAY, JUNE 16

Theater Geometry/Playback Team Recommendations

On theater geometry, Becker suggested that the DIGSS specs should provide a goal for GS projection, explain how existing theaters can meet it (with the possibility of "grandfathering" some theaters that can't easily meet all aspects of the spec), and guide the construction of future theaters.

In discussion on the topics in bold face, the following conclusions were provisionally agreed upon, or the subject was tabled to allow time for other subjects.

Seating deck angle: Dome theaters should be angled between 20 and 30 degrees.

Audio channels: The DCI spec provides for 16 channels, but the consensus was that more will be needed, particularly for domes. If 24 audio channels are to be placed around a dome, the system should have even greater capability, to allow for auxiliary channels such as foreign languages, visual description (for the blind), etc. As many as 32 channels may be needed.

Channel assignment, speaker placement: The assignment of content to certain audio channels must match the placement of speakers in the theater, but there is some variation between the standard practices of film-based IMAX theaters, digital IMAX theaters, the DCI spec, and planetariums, which often have many more than the standard 5.1 or 6 channels. After some discussion, ***the topic of the number of audio channels needed, and their placement, was tabled.***

Becker felt that the following issues should also be considered in the future: ADA design compliance, entrance and exit sequences, relationship of the seating plane to the springline, and theater finishes and how they affect how much light is bounced back on the screen.

Screen luminance: Lantz proposed that there should be no more than 20% variation in luminance across the screen. This exceeds the DCI spec. If theaters will be using multiple projectors and edge blending, some provision for "Narrow Angle Luminance Uniformity" will be needed to minimize the visibility of the blends. ***The topic of luminance was tabled.***

Resolution: The panel provisionally set 4K (4096 pixels) as the minimum horizontal resolution, with 8K (8192 pixels) recommended. The latter exceeds the DCI specifications. Lantz pointed out that most digital intermediates for GS films are 4K and asked why a projection system would need to be greater than that. MacGillivray said that few films are using DIs and that the image looks "horrible." "If you want the experience you have to have the sharpness." Reyna agreed that 4K printed to film looks bad, but suggested that a 4K master projected on a 4K digital projector might look much better, and that this should be tested. Peterson said that calculations based on the average resolving power of the human eye and the standard distance from the screen to the first row of seats suggested that about 4.3K was all that was needed. MacGillivray said that Imax co-founder Bill Shaw had done tests that indicated that that 8K or more was needed. After some further discussion, ***the topic of resolution was tabled for further testing.***

Sequential Image Contrast: A minimum ratio of 2,000:1 is required. Reyna pointed out that projectors today already exceed this, offering up to 2,700:1.

Color Gamut, color accuracy, pixel structure, contouring: The panel chose to adopt the DCI specifications.

Frame rate: Systems must support legacy content at 24 fps, but should aspire to higher rates, up to 60fps for 2D and 120 fps for 3D.

Dome field of view: the question of whether a dome projection system must be capable of covering 180 degrees in the vertical dimension was discussed. IMAX Dome theaters cover between 120 and 160 degrees. It was decided to move this into the theater construction section, with a **requirement of at least 110 degrees vertically and a recommendation for a full hemisphere**.

Projector testing: Oran outlined the possibilities for comparing images of various resolutions against film and each other. Requiring the DIGSS system have a 1.33 ratio requires tiling the images of several digital projectors (which have a native ratio of 1.9). A side-by-side test against a film projector can simulate a digital image from a tiled system or a 4K projector or higher by using a 2K projector to fill only part of the screen. He proposed a three-tiered series of tests that look at systems available now, can make recommendations for the next step, and suggest possibilities for an ideal future system.

Lantz and Jacobsen suggested that there is a need to test film against 8K or higher resolutions, and not be satisfied with 4K simply because it is available now. Oran agreed, but said that this would have to be in a second round of testing, since it would not be possible to arrange such a test in the short term.

There was an extensive discussion of the difficulties involved in tiling an image with DCI-compliant systems, because of the encryption required by the DCI spec and the need to divide the full image up among multiple projectors while maintaining the security of the whole image. ***This question will need further discussion and study.***

Oran said that the parameters that need to be tested, in three resolutions (4K, 6K, and 8K), are color bit depth, compression rates, and frame rates. For the first tests, the benchmark should be a 15/70 print from an original 15/70 negative.

Aspect ratio: Hyder said that while the proposed 4:3 aspect ratio would suit the legacy films that have been made for GS theaters, most material produced in the future will be in wider formats. He said it isn't clear that the 4:3 ratio is critical enough to the GS experience to justify the more complex and expensive tiled projection systems it will require. For practical reasons, many theaters may choose to give up on the 4:3 ratio in favor of a single-projector system. No one has yet tested a 4K projector on an 80-foot-wide screen to see if it provides a giant-screen experience.

Jacobsen said that he personally felt that the 4:3 ratio was "foundational" to the differentiation of giant-screen theaters from other media, and that the absence of a perceived frame around the image is responsible for the powerful effect that GS films have. MacGillivray agreed, saying that the aspect ratio is one of the reasons that the 15/70 format has succeeded and others have failed.

After further discussion, Jacobsen asked for a show of hands on the aspect ratio question. Of sixteen votes cast, **fourteen were in favor of the 4:3 aspect ratio, one (Katz) was**

against, and one (Hyder) abstained. After additional discussion, Katz switched his vote.

Fraser pointed out that the effectiveness of the aspect ratio is a "testable question," and that, currently, there is no empirical evidence to show that 4:3 is the best ratio for immersiveness.

Business Model Team Recommendations

Stahl said that, for producers and distributors, the current film leasing business model is not working well, and may be broken. Under current standard lease terms, it is difficult for films to make money, so attracting investors is problematic. She outlined the results of the business model from the breakout groups: based on a number of assumptions, including an average production budget of $6.5 million (50% equity, 40% sponsorship and 10% loan) and a static number of theaters, the industry can support about 3.9 films per year. (Further analysis and discussions after the colloquium refined this number to 4.4, see Chapter 5).

For producers, the digital conversion will not significantly increase the market of classic giant-screen theaters, although ancillary income from other distribution outlets may increase their total revenues. But there will continue to be competition from Hollywood films, from the new alternate content sources, and from other quarters. For theaters, these new forms of programming will allow them to differentiate their theaters further.

She said she felt that museum directors need to get more involved with the theaters, as they had been in the heyday of GS theaters. She also asked whether theaters should continue be seen as the major revenue generators they traditionally have been, or if they should be treated more like exhibit halls, part of the whole package that a museum offers.

Welch asked about the role of the Internet in programming digital GS theaters, to which Reyna replied that networking these theaters could provide the "flash and pizzazz" needed to excite both the public and the museum directors. Lantz said that this is already being done in the planetarium world, where it is called domecasting. Jacobsen pointed out that there needs to be a business model that accommodates this kind of programming, and Reyna said that traditional GS film producers have to be creative in adapting their existing film assets to the new medium: adding an interactive networked component to film screenings.

Katz expressed skepticism on this point, saying that the people with the expertise to create these new media are unlikely to be the film producers, and that the film business model needs to reflect that reality. MacGillivray thought that it would be possible to mix the formats with events like interactive film premieres that feature, for example, a film's stars speaking live to audiences at multiple networked theaters. Jacobsen said that shorter versions of films could be combined with interactive experiences in a way that might sustain a transitional business model.

Implementing DIGSS

The discussion turned to how to further the process of getting DIGSS accepted by the giant-screen community. A presentation at the September conference of the GSCA was planned, along with further education of theaters about digital cinema in general. Mensforth said that theaters have several choices: stay with their existing film system, install a digital system along with the film projector, or switch completely to digital, whether IMAX or not. MacGillivray stressed that it was important to explain to theaters why they should wait until there is a digital system good enough to replace their film projectors.

Jacobsen proposed an "accord" that theaters would sign, signifying their intent to choose a DIGSS-compliant system when they convert to digital. Hyder pointed out that this would be equivalent to saying they were not going to select the current IMAX digital system, since it is proprietary and the DIGSS system is defined as open, like the DCI spec. Hyder pointed out that the current multiplex IMAX digital system shows non-IMAX, DCI-compliant movies through only one of its two projectors (i.e., half brightness) and cannot show DCI-compliant 3D material, only IMAX-formatted 3D programs. Imax has said a digital system for its giant-screen film theaters will be available in 2012 or 2013, and it is assumed that it will also be proprietary.

Some discussion of the proprietary nature of the IMAX system followed, with Ordway pointing out that originally only the labs like Technicolor or Deluxe that prepared the Digital Cinema Packages were supposed to be able to send decryption keys directly to theaters. But Imax is getting the keys, modifying the files, and issuing new keys, a nominal violation of the DCI rules that is overlooked by the studios.

Jacobsen expressed the view that it might be possible for Imax to create a DIGSS-compliant system that was also capable of showing proprietary IMAX content.

The political aspect of an accord that implicitly excluded Imax was discussed, Carlson saying that she wouldn't be comfortable signing it. Mensforth said that it would be making a clear statement that the industry wants open standards, and that if Imax chooses not to offer such a system, "that's their choice." Jacobsen asked the theater managers on the panel if they would help draft an accord that would answer the concerns that other theater managers might have on this point.

Tabled list

The session closed with a brief review of the topics that had previously been tabled pending screen testing in the future. They included:

- Audio channels, number and placement
- Luminance and brightness
- Screen resolution
- Defining the alternate content channel

- Security

Note: Several of these have made progress in the drafts after the Colloquium, and/or the affected specifications have been called *provisional*, relying on the experts' opinions in the interim until testing is completed.

Current Context of the Institutional Giant Screen Field

DISCUSS PROCEEDINGS

Chapter 3

by James Hyder, DISCUSS Proceedings Editor

Before discussing the worldwide inventory of giant-screen theaters, a few words on what theaters are being counted in this report.

LF Examiner's database consists of a) all stationary (non-motion-base) theaters with 8/70, 10/70, or 15/70 film projectors, b) a handful of theaters that formerly used those formats and have recently converted to digital, and c) all IMAX[1] digital theaters. Even though the vast majority of IMAX digital theaters are not giant-screen theaters, they are included because of Imax Corporation's dominant role in the GS community, and because they have played a few classic films distributed by Imax. As joint-venture partners with Imax, they are essentially *required* to show them, but they are otherwise not potential clients for independent, educational GS films. Hence, many of the references in this chapter to "giant screen" include these smaller IMAX digital screens.

The database does not include any of the new premium digital theater systems introduced by major exhibitors like Cinemark, Regal, AMC, or Cineplex, even though these systems may be roughly equivalent to an IMAX digital multiplex system. Since they book only Hollywood films, they play no part in the institutional sector.

The database does not include more than 500 fulldome digital planetariums, at least 50 of which probably qualify under the GSCA's new theater geometry specifications for giant screens. In what DISCUSS is trying to accomplish, fulldomes represent significant potential partners and could play a major role in expanding the size of the digital giant-screen market.

This chapter breaks down theaters into two subsets under the total global inventory and the U.S. inventory: theaters that show classic films, and those that both lease classic films and meet the GSCA's recently approved theater geometry specifications.

Classic films are those that a) are produced specifically for giant-screen theaters, b) run an hour or less, and c) have science, technology, engineering, or math (STEM) content.

Current inventory of giant-screen theaters

As of May 1, 2010, there were 549 giant-screen theaters (including IMAX digital screens) in 50 countries around the world. Of these, 395 lease classic films, although this number

[1] IMAX and The IMAX Experience are registered trademarks of IMAX Corporation.

includes most of the IMAX digital theaters, which have shown one or two of Imax's classic films like *Under the Sea* or *Hubble 3D*, but none from any independent producers. Of these, 259 meet the GSCA specs.

Theater Inventory: As of May 1, 2010

	Global	U.S.
Total GS Theaters	549	292
Lease at least one classic film	395	237
Lease classic films *and* meet GSCA specs	259	126
Institutional (Museum) Theaters	207	94

Table 1
Source: *LF Examiner*

Table 2 shows the segments over time. Institutional theaters are declining. Many of the recent closures are in Asia — China, Taiwan, and Japan — locations that had not been actively leasing giant-screen films for some time. Some of them were conversions of GOTO 10/70 systems to a GOTO digital planetarium system, which are not counted.

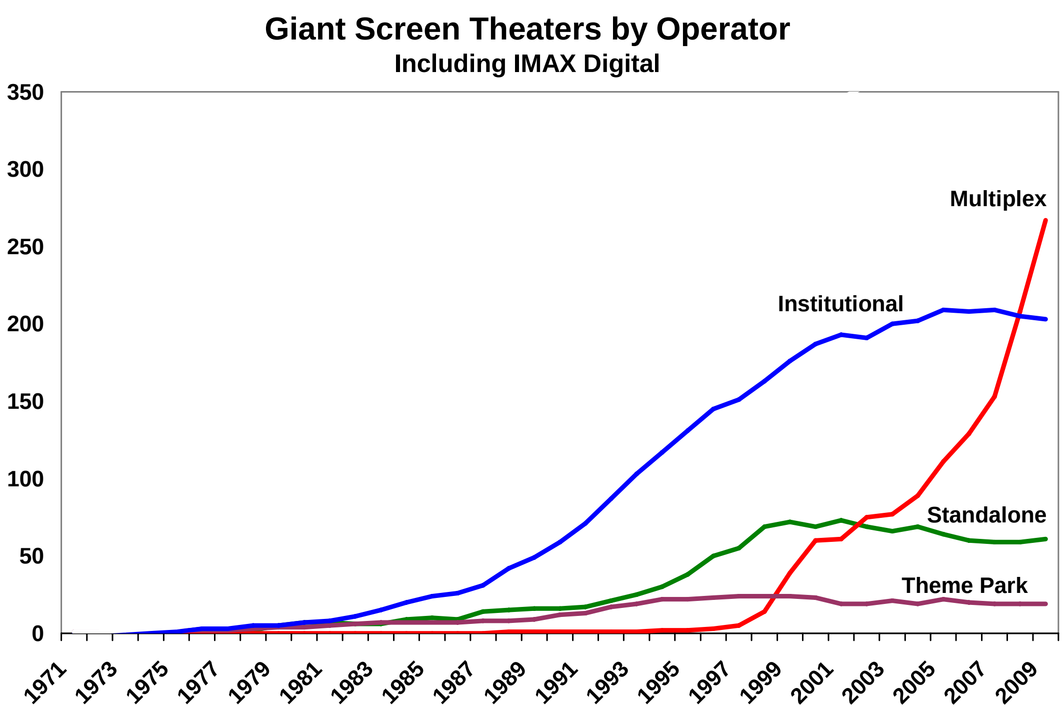


Table 2
Source: *LF Examiner*

Relatively few are Western museums that have simply shuttered their GS theaters, although that has happened, too: in 2008, Science Station in Cedar Rapids, Iowa, closed its IMAX SR theater, and a few months earlier, the Kansas City Zoo closed its IMAX theater.

Meanwhile, multiplex theaters are taking off, although virtually all of these are IMAX digital theaters that do not meet the GSCA specs for giant screens. The standalone and theme park segments are stagnant or declining.

THE IMAX DIGITAL SYSTEM

Imax Corporation's current digital system is nominally intended for theaters with flat screens no larger than 70 feet wide and about 40 feet tall. The ratio of the screens varies from about 1.5 to 2.2. The system is not intended to fill a dome screen of any size.

It uses two high-powered Christie 2K projectors, and a proprietary "image enhancement engine" that IMAX claims improves the quality over a conventional digital image. The company holds patents on technology that could conceivably be used to increase the resolution and/or contrast of the native projectors, but it hasn't published any details or specifications or allowed any side-by-side tests that would allow any kind of objective comparison with other systems.

Photo Credit: IMAX Corporation

Unlike its film systems, and unlike DCI-compliant digital systems in multiplexes, Imax's digital systems are proprietary. In other words, filmmakers who want their films screened as a branded IMAX Experience in IMAX digital theaters must have them converted by Imax. The IMAX digital system only permits non-IMAX, DCI-compliant, 2D programs to be screened at half-brightness, using one of the two projectors with an automatic disclaimer slide and announcement that state that the presentation is not an IMAX Experience. It does not permit non-IMAX 3D presentations to be shown.

IMAX digital theaters are therefore limited in what they can show as an IMAX Experience to films that Imax has chosen to convert. This is in contrast to the film era, when GS filmmakers could make films and theaters could book them without any necessary involvement of Imax Corporation.

It is also in contrast to the way the conventional movie industry made its rapid and successful transition to digital cinema over the past ten years. The movie studios got together and established the DCI specs, which stated that digital cinema would be entirely open and non-proprietary.

Under DCI, studios don't have to go to a particular post-production house to get their movies converted to digital, they can go anywhere they want. Theaters don't have to choose from a limited menu of films available, they can get any title they want. And no one is taking a cut of every booking of every film in every theater, thereby adding to the cost of every ticket sold. This is in contrast to Imax's business model for its digital system.

To date, the IMAX digital system has been installed in 159 theaters, at least three of which are purpose-built theaters with full 40x70-foot screens. The rest are retrofitted multiplex auditoriums with screens that are much smaller than that, according to measurements *LF Examiner* has taken in more than 40 of them. They average about 32x58 feet, less than 40% the size of the average GS screen.

Because they are existing 35mm auditoriums, most are much deeper than one screen-width. A few are one screen-width deep, but most are 1.5 screen-widths or more. Since most people tend to sit toward the back of any auditorium they enter, the majority of the audience is usually outside the one-screen-width limit. This segment of the audience does not get the immersive experience of sitting less than a screen width away.

Imax Corporation has recently installed the current digital system in larger theaters, including three that were formerly equipped with GS systems, in Mumbai, India; Lodz, Poland; and Sandy, Utah. The last switched to IMAX digital in early May of this year, the first GS in North America to do so. Its neighbor in Salt Lake City, the ATK IMAX Theatre at the Clark Planetarium, will also be converting to digital by the end of this year. Although located in a planetarium facility, it is not a dome theater, but an SR-equipped theater with a 55x70 foot screen. Unlike the other three, it is an institutional theater, and expects to show classic films, as well as Hollywood titles.

But it may not be the first institutional IMAX digital. To date, four museum theaters have signed deals to convert from IMAX 15/70 to IMAX digital.

In addition to the three or four conversions from IMAX to IMAX digital, there have been a few cases of non-IMAX digital systems installed side-by-side with IMAX film projectors: Europe led the way, with three dome theaters — Stockholm, Copenhagen, and Paris — adding fulldome digital and/or 3D digital on the front of the dome. Also, both Nuremberg and Lucerne have added 3D digital systems to their IMAX flat-screen theaters. In doing so, Lucerne dropped the IMAX brand name in an agreement with Imax.

In the U.S., Moody Gardens in Galveston, TX, is the first (and so far, only) theater to add non-IMAX 3D digital to its IMAX theater. After the March 2010 GSCA Film Expo, it hosted side-by-side test that this author was able to attend. Although 2K digital doesn't equal 15/70 yet, it is surprisingly good, in his opinion.

Several non-IMAX theaters have recently been converted to digital. The Natural History Museum in San Diego, the North American Museum of Ancient Life, in Lehi, UT, and the Zion Canyon Giant Screen Theater have recently removed their film projectors.

THE FUTURE

Last year, Texas Instruments announced its next generation of DLP chip, with 4K resolution, four times the information presented by a 2K chip. Projectors using the chip should be in conventional theaters early next year, and DLP licensees Christie, Barco, and NEC have already released new 2K models that are upgradeable to 4K. TI and the OEMs say that projectors powered with this chip will be able to fill screens up to 100 feet wide. But, of course, that will be with a 1.9-ratio image, not a 1.33.

Imax has said in conference calls that a digital system for domes and the largest 15/70 screens may not be available for at least two or three years. In the meantime, the company is offering film-based institutional flat-screen customers its existing 2K-based system with an option to upgrade to 4K at a future date. Imax has said the upgrade to 4K will not be available until late 2011. This suggests that it will be an intermediate system between the current 2K system and one intended for giant screens and domes that will come out a year or two later.

Most experts agree that existing 2K digital cinema systems, whether off-the shelf DCI-compliant or IMAX digital, do not match the quality of 15/70 or even 8/70 film when projected on screens 60 by 80 feet or larger. They do not have the resolution, the contrast, or the brightness. But the experience of Moody Gardens shows that the technology is getting closer and it may be good enough already for smaller giant screens.

The next step, 4K, should improve on all of those characteristics, and even though it doesn't match, much less exceed, the quality of GS film, it may be "good enough" for all but the most finicky purists. There may be further developments, 6K, 8K, or higher, but at this point it seems unlikely that such systems will be economically viable in the current business model.

Then there's the question of whether the giant-screen industry would accept solutions that use multiple projectors to fill a giant screen which is another way to increase resolution and address the size and 4:3 aspect ratio. It is technically feasible, and can be done far more easily and reliably in the digital age than was possible 40 years ago, when the founder of Imax invented the 15/70 format just so they wouldn't have to deal with the problems of multiple film projectors. It is very common in the planetarium/fulldome world, but there seems to be a preference for a single-projector solution among GS theaters.

THE QUALITY QUESTION

In August 2009, Robert Capps wrote an article in *Wired* magazine called "The Good Enough Revolution." He said that most consumers "now favor flexibility over high fidelity, convenience over features, quick and dirty over slow and polished. Having it here and now is more important than having it perfect." (Capps, 2009)[2]

This may be a problem for an industry that has identified itself as the highest quality movie experience ever, especially since GS theaters number in the hundreds, not hundreds of millions. In consumer products, if only one percent of buyers are interested in high-quality products, that still yields a market with millions of people. Enough to support manufacturers of audiophile stereo systems and so-called "prosumer" still cameras.

But if the majority of GS theater operators were to behave as ordinary people do, and favor "cheap" and "good enough" in making the transition to digital, the remaining quality-minded operators might not constitute a large enough market to support the development of high-end digital systems that approach or exceed the quality of our current 70mm images.

This could lead to a tipping point in the transition to digital that would force even those who would prefer to hold onto their film projectors to switch to digital, whether an equivalent digital replacement is available or not. The economics of making 70mm prints could ultimately become unsustainable, and the lack of new product could put film theaters at a competitive disadvantage. [3]

At the moment, the shoe is on the other foot. More than 200 classic titles are currently available in 70mm. The number available in standard digital format is a few dozen, and in IMAX's digital format less than ten. The question is, how long will it be before the numbers reverse?

It is important that the industry in general know that there is no need to rush to convert to the first digital systems available. In moving into the digital age, we are abandoning technology that has been virtually unchanged for decades and entering a world in which technical improvements come thick and fast. It behooves the industry to act thoughtfully and deliberately.

[2] www.wired.com/gadgets/miscellaneous/magazine/17-09/ff_goodenough

[3] However, according to the DISCUSS Front End Survey (Jacobsen, 2008) and the Theater Operators Survey (Jacobsen, 2010), the majority of U.S. theater managers believe they have over four years before they will have to convert to digital.

GIANT SCREEN FILM AND SCIENCE LEARNING

DISCUSS PROCEEDINGS

CHAPTER 4

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ABSTRACT

The authors review the literature supporting the notion that giant screen film has unique attributes that contribute to science learning. They propose that the industry has relied on claims that four core attributes of giant screen films contribute to higher learning outcomes: dimensions that create the sense of immersion by eliminating peripheral views; the first person perspective that contributes to the sense of telepresence in the film; narrative logic in story structure; and the sense of kinesthetic learning invoked through the triggering of mirror neurons resulting from the prior three. Based on this overview, they assess the literature for findings that support these claims and demonstrate that most of these claims are without support in empirical research but do cite some recent data suggesting there is reason to believe that these claims may be supported. The authors conclude with a gap analysis of what research is needed to support any claims of incrementally higher levels of science learning from the high production cost of Giant Screen film over conventional film and recommend a research agenda to address this deficit in the literature.

INTRODUCTION

Giant Screen films (GS), such as the brand name IMAX® or other proprietary technologies for displaying films on very large screens and domes like planetariums and variations in between have become an important part of the informal science learning landscape (Association of Science-Technology Centers 2008). The National Science Foundation and others have invested an estimated billion dollars films distributed through a global network of 207 institutional GS theaters and over 215 educational films (LF Examiner 2008; National Science Foundation, 2009), many still in distribution. Through National Science Foundation funding, evaluation studies of GS projects have shown demonstrable STEM learning outcomes but the vast majority of these evaluations have been conducted as within-subjects studies using stand-alone, pre/post outcome measures for specific topics (Flagg, 2005), without comparison of the large screen formats to other learning environments, delivery techniques, or content types. A few studies have assessed some attributes to these films, but those studies remain within-subjects comparisons (i.e. Detenber & Reeves, 1996; Greb et al, 1999). This global industry had been built on the claim that the expense associated with the production and distribution of giant screen films has a direct impact on increased science learning, much to the chagrin of those museum professionals who believe that museums are, first and foremost, about authentic experiences with objects (Freudenheim, 2010). Additionally, changes in technology are leading to potential obsolescence of the film-based projection systems for many of the large screen systems in place today. Before the industry makes a determination about new digital technologies and implements costly transitions, it would be important to have greater understanding of the actual impacts of the large screens on viewers related to science learning and response compared to other screen formats. This paper reviews the literature supporting the claims that these types of science learning experiences have incremental benefits to increased science learning and, based on this literature, proposes a research agenda in order to pursue empirical studies that can confirm or refute any unsubstantiated claims.

BACKGROUND

This paper responds to the growing question of cost accountability in pursuing the development of new materials to support advancement in science learning. The ongoing lament that science literacy, regardless of the way in which it is defined, is dwindling in western nations, most notably in the USA (e.g. Gonzales, P., Williams, T., Jocelyn, L., Roey, S., Kastberg, D., and Brenwald, S., 2008) has been used to support claims about the urgent need to create tools that can more effectively enhance science learning for the next generations. While this urgency may be recognized, the challenge to redress this deficit has emerged alongside the political expectation for increased scrutiny to ensure that all spending, whether public finance or private philanthropy, achieves the intended public outcomes at the lowest possible cost.

Visual media dominate how people take in information; these media have become the primary foundation for how individuals and society form fact and opinion today (Barry, 2005; 2008). GS films are reported as offering "gripping" portrayals of scientific concepts from anatomy and astronomy to marine biology and zoology. In museums and science centers, these theaters have been described as an excellent tool for communicating and teaching science to the general public (Koster, 2005). Koster also claimed that the value of giant screen cinema in museums and science centers extends well beyond the entertainment provided to visitors by invoking lasting change in their scientific knowledge.

The GS industry was founded by a radical experiment in immersive films in the 1970s where large format films and proprietary equipment developed by the IMAX corporation created the first truly GS large flat screen theater that immersed the viewer into the filmed scene. IMAX and a host of other technology providers built on that technology in the 1990s with the development of dome theaters that are now used to project both 2D and 3D formats although domes are not adapted to "stereoscopic 3D" with alternating images in each lens of special glasses (IMAX, 2010; Shaw & Lantz, 1998).

In conjunction with the shifting politics around the development of science learning materials, the GS industry is now facing a radical shift in technologies at a scale not seen since the advent of *Cinemascope*, a landscape film format that highlighted horizons and promoted place-based natural history films. A consortium of major cinema industry studios ("Hollywood") invested millions of dollars to develop the Digital Cinema Initiative (Digital Cinema Initiatives 2007, 2008), a shared, open-source specification published in July 2005 to ensure predictive conditions for encoding and decoding of digital format film. Since January 2007, the major Hollywood studios exclusively deliver DCI compliant versions of their movies, even though these standards would deliver a distracting pixilated image when expanded to fill the screens of a typical Giant Screen theater (Digital Cinema Initiatives 2007, 2008). At the same time, the IMAX Corporation has worked to create their own proprietary digital technology to support commercial film using the highest resolution projectors currently available, although these films systems do not fully reach the dimensions and resolutions provided by their analog forebears.

This radical shift in commercial technology is directly impacting the museum GS theater industry. At this time, museums are being called on to consider whether to invest in upgrading their theaters to smaller digital projection without the immersive experiences, retaining existing formats with the recognition that the GS film inventory may not continue to grow, and risk mechanical failure before abandoning the theater due to an increasingly unsupported format, or join with colleagues to develop new GS digital standards and help invest in a new technology that retains the unique attributes of the former film-based projection experiences. Clearly, the justification for the latter new investment strategy will emerge only if the theater is perceived as a potential source of new revenue or if the learning experience for visitors is uniquely capable of helping the museum deliver on an important aspect of its mission, the question that we address in this review.

FINDINGS ABOUT THE LEARNING EXPERIENCE

There is growing consensus that GS experiences have unique attributes with direct impact on science learning, and a slowly emerging body of evidence suggesting that immersion, presence, and narrative are the key components necessary for ensuring effective learning outcomes. A review of the methods used to assess learning outcomes attributed to the existence of these components, and the findings from these studies suggest there remain a number of gaps that continue to challenge the claims made by those in the industry. Specific needs for research and evaluation must be defined to determine whether, in fact, the digital giant screen cinema experience in museums has an incrementally higher benefit that cannot be accomplished through other means. To redress this deficit, the National Science Foundation supported an effort to bring together experts from the GS community at the Liberty Science Center in New Jersey to develop new theory about the value of these formats for promoting science learning (NSF DRL- 0803987). Although the intention of that symposium was not to define unique attributes of the GS format, the publications resulting from this symposium[i] suggested that there were three distinct attributes of the format that promote unique types of science learning: perceived immersion within the film environment; perceived presence of the self within in the film (that is, point of view), and narrative structure within those sensory experiences. In the following section, we describe these theories.

IMMERSION

Immersion has been defined as the degree to which a system delivers information about the virtual world to the senses (Arsenault, 2005; Fiore, Harrison, Hughes, & Rutstrom 2009; Nunez, 2004). Those who defined immersive environments as learning places, describe the format as having the ability to dominate the viewer's senses, focus the viewer's attention on the stimuli, provoke the senses, and cause the viewer to become absorbed by the story and characters. Lantz (2007) has extended this theory to include the GS format as immersive based on these attributes. Immersive environments have also been described as a complement and enhance traditional learning experiences because they have the ability to offer a simulated experience with place-based information in the context of other types of science learning (Yalowitz, 2010).

A search of the literature on immersive environments, including online immersive environments, zoos/aquariums, and museums, reveals that studies on learning through immersion in video games, online games such as Second Life, and virtual reality are much more prolific than studies on the learning outcomes from the different type of immersion that can be described as sitting in the center, mid-theater, or on the outer edges of the audience in a giant screen theater experience. de Freitas and Neumann (2009) extend Kolb's (1984) four-step experiential learning model (ELM) to cover learning in immersive environments. The ELM is a descriptive model of how people learn; positing that learning by individuals is contextual and constructed. The ELM modified to cover learning in immersive environments suggests five steps-- versus Kolb's original four step model-- an individual goes through while acquiring new information:

1 Experience – an individual first must have an experience either real or virtual.

2 Exploration – after the experience, an individual gains through further exploration of the newly acquired knowledge. This is done through communication, learning activities, social interaction, and observation.

3 Reflection – supports the transition of knowledge from abstract to real. Through reflection individuals construct meaning from what they have learned.

4 Forming abstract concepts – the learner makes meaning from the knowledge gained and forms more abstract concepts, allowing for transfer to other situations.

5 Testing (experimentation/reinforcement) - supports learning by allowing the learner to test acquired knowledge in a variety of contexts. Through successful experimentation, the learner ultimately constructs meaning and determines where the knowledge can or cannot be applied.

A descriptive model should then allow for analysis and testing of the components of the model, and the impact of the model on the desired outcome. Examining the actual learning assessed in GS films, it appears that heightened levels of immersion allow learners to more easily understand scientific concepts. Comparative study of learning from two-dimensional (2D) and three dimensional (3D) representations have demonstrated that 3D representations were more likely to have increased understanding of spatial relationships (Angelov, Smieja, & Styczynski, 2007;Barab et al., 2000; Barnea & Dori, 1999; Keating, Barnett, Barab, & Hay, 2002; Murphy, 2004; Yeung, 2004). Murphy in particular, found that students using 3D maps were able to learn basic concepts of elevation with greater ease than those using a 2D map. In general it is thought that Earth and space science concepts lend themselves to being effectively communicated through immersive environments such as 3D, and noted that concepts such as elevation and land formations may be conveyed much more effectively in immersive environments.

Researchers also suggest that immersive environments can contribute to increased interest, engagement, and motivation for learning scientific concepts. Korakakis, Pavlatou, Palyvos, and Spyrellis (2009) found evidence that exploring middle school chemistry concepts in 3D film enhanced student interest in the topic and made the material more appealing to the students. Sumners, Reiff, and Weber (2008) documented that students in grades 3-12 experienced significant gains in knowledge of Earth science concepts after viewing a show in an immersive digital dome. The authors also suggested that enhancing an immersive experience through discussion or hands on activities would make the learning experience even more powerful. Both these quasi-experimental studies using school groups suggest that immersion has an impact on cognition but the authors also not the limitations of this as a study of school audiences in a GS experience.

Planetariums are also immersive environments, but may not necessarily have the same narrative structure as other immersive environments, and can include live, interactive presentations (Jacobsen, in press; Lantz, 2005; 2007). Recent research (Plummer, 2009) has suggested that the rich virtual environments of planetariums facilitate knowledge gained by elementary students on the topic of celestial motion. Bishop (1980) found planetariums to be helpful in teaching the concepts of day-night cycle and phases of the moon to school groups; similarly, Mallon and Bruce (1982) suggested that planetariums can be part of an effective school curriculum on constellations and perhaps improve attitudes toward astronomy. But again, these researchers focused on the school rather than informal science learning audiences

After more than thirty years of research, it has become clear that immersive environments enhance science learning outcomes. The literature suggests that the sensory provocation, in combination with sensation of being within an experience rather than observing that experience from outside a frame has both cognitive and affective impacts.

PRESENCE (CONNECTIVITY, LOGIC AND SELF-INVOLVEMENT)

The prime distinction between presence and immersion is the view that the viewer is implicated in the narrative. Immersive experiences in a dome presentation of the Milky Way may create the sense of immersion, but the impossibility of the viewers ability to be in that place or use of graphic representations of constellations may mitigate presence without denying immersion. Presence, or telepresence as it has been defined in some publications, can be thought of as an experience *"in which a media consumer has the sensation of being with and connecting to people, objects, and events"* (Lombard, 2008, p2). Lombard and Ditton (1997) have operationalized this concept by defining six dimensions of experience that lead to the perception that there is no intermediary between the world depicted in the media and the viewer. Presence is distinct from immersive experiences in general because it implicates the body and relative scale of the self to an environment. In the case of full-dome theaters, presence may be debatable or lacking depending on the degree of abstraction perceived by the viewer. For example, Lombard notes that effective use of presence employs most sensory perceptions, but also aid in drawing the viewer physically into the media by denying any reminders that the production is delivered through a secondary media through narrative, sound and the lack of perceived edges to a depicted environment.

Increasing presence has been linked to physiological and psychological effects in consumer response studies including arousal, a sense of motion, enjoyment, involvement, learning, improved task performance, desensitization, persuasion, and changes in social judgment (Lombard, 2008). Lombard and Jones (2007) identify over 1800 cross discipline publications that have been produced focusing on the concept of presence. As with immersion there is a notable lack of research on the effects of telepresence in giant screen cinema in museums even though the concept has been defined through studies of television, computers games, robotics, and telecommunications, and has been linked to increased screen size.

Prior research into the sense of presence without immersion has shown that increases in screen size (from 12 to 46 inches) can increase the effects of presence (Lombard, Ditton, Grabe, & Reich, 1997; Lombard, Reich, Grabe, Bracken, & Ditton 2000). Lombard and Ditton (2007) infer that giant screen cinema, like all other forms of immersive media that they study, is likely to cause a greater sense of presence based on the scale of the images, and propose that GS film could be a powerful medium to promote changes in attitudes knowledge towards science in viewers due to the following characteristics:

- high resolution images;
- large image/field of view;
- color;
- 3D;
- normal to loud volume levels;
- multi-channel surround sound audio;
- unobtrusive medium/environment (dark room);
- relatively high social realism;
- relatively little use of media conventions; and
- subjective camera angles.

Presence is tied to the sense of immersion, but the dimensions of presence may not necessarily require a full immersion experience with bodily engagement and multi-sensory support to produce the effects identified by researchers. The comparison between the effect of presence compared to immersion on the viewer remains without empirical research. Moreover, the published results do not necessarily demonstrate that the outcomes have a linear relationship to scale that is without limit, and may cease to have incremental value. Since the advent of HD digital formats for film projection, the findings associated with resolution challenge whether higher levels of presence can continue to be achieved as screen size increases since the technical limits produce a pixilated image that may negate the incremental increase in learning outcomes.

NARRATIVE (STRUCTURE AND HIERARCHY, SEQUENTIAL LOGIC, COHERENCE)

Variation in story structure and sequence are a third aspect of the film experience centrally implicated in learning outcomes. Storytelling is an area in which film creators have the ability to direct attention, compare or contrast phenomena, or shape an explanation that will enhance or undermine the impact of a giant screen film. How content is presented is a key component to achieving viewer presence (Lombard 2008) and has been identified as the third central factor contributing to learning that appears to result from viewing a giant screen film (Apley 2008) but may not be distinct from other forms of film.

Research has shown an interesting interrelationship of narrative, presence, and knowledge outcomes from observing a GS film. Some findings related to narrative showed that realism in objects, events, dialogue and acting contribute to the ability of an audience to make a connection with the film (Biocca, Harms, & Burgoon, 2003; Giles, 2002; Horton & Wohl, 1956). Presence itself can be developed through topics made to appear interesting or compelling, that is, constructed through editing and production rather than from an inherent attribute of the phenomena captured on film (Lombard, 2008). It would appear that presence can be enhanced by an audience's previous familiarity with a topic or by priming the audience prior to the film experience through stimuli such as sounds and images related to the topic. Atkins (2008), discussing the communication of breakthroughs in the field of engineering, stated that "giant screen films would be more successful if they spent more time on the story, not just the audio-visual experience (p.1)."

In her summary of past studies of knowledge gain demonstrated through the evaluation of six giant screen films funded in part by the National Science Foundation, Apley (2008) reports that successful delivery of scientific content could be attributed to effective storytelling tactics. She notes this effectiveness is not universal across all giant screen films. Apley further states that the most notable increases in learning outcomes found in her work were achieved when the storytelling effectively complemented the technology, and that the technology is central to the phenomena in question. These conditions extend beyond narrative structure to embrace camera angle and narration, through "character" development. Apley offers six guidelines for the best practice of science communication in giant screen films based on her evaluation experience:

- Storytelling matters –quality characters and an opportunity to find personal relevance within the matter to an audience.
- Reinforce audio and visual with one another.
- Exploit different film formats including diverse source material and different genres.
- Visualize what cannot ordinarily be seen and what is difficult to imagine, such as scientific theories and processes.
- Expand the notion of landscape to include internal worlds and familiar things made new.
- Address content in terms of a larger take-away message, as well as through the development and exploration of individual themes and stories (2008).

These attributes of storytelling, while central to an effective giant screen film, can also be considered central to any type of learning film and may not necessarily distinguish the giant screen format from other types of learning film. Storytelling does relate to the perceived quality of a science learning film. Further, storytelling itself may need to be implemented in slightly different ways based on format, such as the sensory impact of high speed, quick motion or fast editing of a dome or GS films can exceed comfort limits for viewers. In itself this does not necessarily suggest that high quality giant screen films have unique attributes that make them unique science learning tools. However, the results of recent studies may suggest new areas for investigation that might uncover the unique value of giant screen science learning films and whether narrative structure has distinct attributes as a format.

THEATER GEOMETRY

Lastly, another attribute that has emerged within the GS industry, but not covered during the 2008 symposium, is associated with the physical design of the theater. The jargon for describing theater seats often refers to a "sweet-spot"[ii] where the viewer is in the ideal relationship to the screen (Jacobsen to provide citation). Theories of immersion and presence may be directly impacted by theater geometry, but all studies of these conditions appear to be anecdotal and held within the industry rather than rigorously reviewed in the peer-reviewed literature (Lantz, personal communication). Furthermore, these analyses appear to have focused on satisfaction with the view rather than learning outcomes. It would seem warranted to consider, beyond the average viewer, how location in a theater and peripheral, sharply angled or non-immersive seating locations in immersive theaters impact learning outcomes. It may be that the immersive giant screen experience achieves varied outcomes depending on where viewers are located in these types of experiences, and that location in combination with presence and sense of immersion have direct impact on perception; that is, that geometry creates the immersive experience that activates mirror neurons which translate into cognitively mediated kinesthetic learning experiences. However, without comparative data on seating location, the theory supporting learning outcomes for all audience members no matter where they are seated can only be assumed to be equivalent to the average responses to surveys and remain speculative at best.

At present, a consortium of technical experts is collaborating with the Giant Screen Cinema Association to develop specifications that will describe the physical scale, size and resolution necessary for Giant Screen Films (NSF-ISE# 0946691). This group has committed to considering both the specifications for the digital film, but also theater scale and geometry. While an important step toward resolving what a digital film may need to be as a technical projection, this National Science Foundation supported effort will not resolve the question of whether the geometry has any impact on the learning outcomes that can be attributed to the format.

RECENT EVALUATION FINDINGS

There appears to be a dearth of *publicly available research* on the learning outcomes of giant screen films or comparing the learning outcomes between giant screen film and other mediums. Citing Flagg's (2005) article summarizing the results of evaluation studies on ten giant screen films as the most comprehensive publication on the topic to date, Ucko and Ellenbogen (2008) report that there are few studies on narrative media in museums, including giant screen film.. Further, a scan of the evaluations available through public dissemination websites suggests that the educational value ascribed to giant screen films can be solely attributed to evaluations undertaken for NSF funded films rather than any other types of giant screen media or subject matter. The results of these evaluations, however, do suggest there may be some unique attributes of the giant screen experience that have an incremental value beyond learning from traditional non-immersive film or private, immersive virtual worlds.

Apley's (2008) investigation of three GS films suggests several attributes that may be useful in considering the value of giant screen film. In the film *Dinosaurs Alive* (2007), a combination of archived footage of an actual expedition with computer generated images of dinosaurs created memorable educational experiences with scientific phenomena that aided understanding of the relationship contemporary birds have to extinct dinosaurs and the role of climate in fossil preservation. *The Human Body* (2001) film explored different body systems throughout the day and across the lifecycle. The film produced direct increases in positive appreciation for how the body functions, and viewers retained the core messages in the film in delayed-post evaluation undertaken up to six weeks after the experience. Apley (2008) credits the giant screen experience of the Human Body film with successfully transforming the ordinary into an engaging learning experience based on standard film techniques of storytelling, live footage and animation, but was unable to separate out the impact of the giant screen experience. Lastly, the film *Wired to Win* (2005) explored human brain functions based on the Tour de France bicycle race. In post-viewing measurement, Apley reports that audience members consistently noted a sequence from the movie on how the body experiences and attends to pain as being the most effective at communicating science content. Apley concludes that *the areas of greatest learning generally coincided with 1), extended discussion of science content in the narration, which was 2) motivated by the characters' activities and included 3) characters' first-person reflections on their experiences, in 4) combination with the "clear visuals,"* attributes that reinforce the concept of narrative as a central learning attribute in giant screen film.

In a review of reports from 10 different National Science Foundation funded giant screen films, Flagg (2005) found that learning outcomes evaluation has primarily focused on a change in verbal knowledge, or the ability to explain certain scientific concepts, with all 10 films studied showing a significant increase from pre- to post-measures of populations in unmatched samples. In nine out of the ten studies, pre- and post-tests for knowledge gains by middle schools students were statistically significant.

Two out of 5 films that measured pre-to post-interest in their topic (*Stormchasers* and *Dolphins*) revealed statistically significant increases in interest. For the six films that included delayed-post interviews with participants, approximately half of the participants felt the film had influenced their thoughts or actions in the week following viewing the film including discussions with others, and recommendations of the films to others. Unlike the conclusions and recommendations of Sumners, Reiff, and Weber (2008), Flagg's review suggests that companion material (e.g. exhibits and activities designed to further enhance learning of the content) had little to no impact beyond the film itself. Flagg found that four of the evaluations of companion materials had "little to no impact" for adult viewers and only two of the nine films with associated classroom activities produced a significant gain in knowledge attributed to these activities for the students participating in the study. Flagg's report suggests that the most efficient and effective learning was attributed directly to the giant screen film format, but notes that her study represents a review of a somewhat limited set of evaluations.

Apley, Streitburger and Scala's (2008) assessment of the film *Dinosaurs Alive* found that there may be unique attributes distinguishing science learning outcomes in giant screen films depending on whether the presentation was in 2D versus 3D formats. Preliminary findings suggest that cognitive learning outcomes are perceived to be higher by 2D viewers while 3D viewers were more likely to focus on entertainment value and affective learning, derived from variations in responses to several themes explored in the study. 3D viewers seemed to focus on environmental themes and the narratives about organizational interactions, whereas 2D viewers became more engaged with comparative assessment of species diversity and evolutionary principles. The authors caution however that the two samples used in these studies were not matched, represented unique populations from different cultures and that further research is necessary to understand the true comparative value of the formats. They recommend that research include a particular focus on scene by scene tactics used to take advantage of the two formats.

A summative evaluation of Sea Monsters: A prehistoric adventure (Knight Williams, Inc. 2008), completed the same year as the Dinosaur's Alive evaluation, also raised questions about the use of 3D and, in this case, an investigative dramatic storyline to educate viewers about the Late Cretaceous period and marine animals. Viewers who participated in focus groups immediately after viewing the film applauded not only that the film used 3D, but how it used 3D, in this case praising it for offering an engaging, lifelike, and realistic views of the Late Cretaceous period. In fact, some couldn't imagine not seeing the film in 3D. Whether viewers would have experienced the same level of enthusiasm or fascination with the Late Cretaceous period and marine animals without the 3D element, the evaluators noted, was uncertain as their evaluation was not specifically designed to address this question, and the film's use of investigative dramatic storyline also clearly played a role in viewers' enjoyment of the film. Among other issues, the evaluators suggested future research explore the relative value of 3D, given the appeal it generated in this context, as weighed against its cost and feasibility.

Currently, the authors at the Institute for Learning Innovation (ILI) are conducting a study of how different formats can be compared to assess the unique outcomes that can be attributed to versions of a dome theater production entitled Tales of the Maya Skies (Heimlich, Sickler, and Yocco, 2010). This study not only considers the stated outcomes, but also includes an assessment of the physiological impacts of watching the production by measuring body temperature and conductance as measures of stimulation during each type of experience. Preliminary results suggest that immersion in the giant screen experience does result in heightened body temperature and that response to the GS is more positive when compared to those viewing traditional screens or large television versions of the film. Other findings from the Maya Skies project suggest that immersion and presence are necessary attributes that increase attentiveness and concentration when compared to traditional displays such as a standard flat screen movie theater or a 42" television monitor. While we are continuing to analyze these results, we believe we have sufficient evidence to suggest that there are unique learning experiences that can be attributed to the giant screen format.

Lastly, NSF has committed funding to support giant screen film production and two new studies that engage in comparative study of giant screen films. The first will assess the comparative value of giant screen film to classroom multi-media projections astronomical phenomena (Gates Planetarium), and further advancement of the comparative learning outcomes that can be attributed to 2D versus 3D formats (Maryland Science Center). These two studies promise to reveal new understanding about the unique attributes of film.

Assessing the Research Gap

The differences in response to screen size that have been advanced surrounding the learning value of giant screen film and the findings from the limited evaluations conducted thus far suggest there may be unique aspects of giant screen film that would justify the cost of production and effort for learners to commit time and resources to seeing these films. However, there remain challenges in making the claim that these films are demonstrably unique and contribute significantly to science learning without further comparative research.

As noted in the discussion on immersion and presence, resolution remains an untested question for giant screen experiences. The evolution of new digital standards for Hollywood and the associated equipment may not be adequate for accomplishing the experience of immersion and telepresence possible through traditional film. Comparative study of projection resolution, scale, depth and projection image is necessary before it is assumed that current GC film experiences will translate to the new media. Additionally, there appears to be a substantial deficit in research that would recommend focused study surrounding the specific variables of immersion, presence, narrative, and as implicated by narrative, the appropriateness of a specific science topic. Determining the explanatory variables of both immersion and presence in different screen sizes with similar narratives that distinguish learning outcomes is necessary to support claims of value in production. Likewise, study of different audiences, e.g. non-school groups, families, adult visitors, comparing screen size and/or shape would provide important data for understanding the full potential of these media. The evaluation of learning outcomes from various rendering resolutions remains anecdotal despite the efforts of many evaluators with specific films. It would seem that within-subjects study of learning outcomes, and controlled production of test films that can play in various formats for those research participants is necessary in order to truly claim that there are unique attributes in the competing formats.

As noted earlier, the current studies of geometry do not fully engage in comparing the impact of full dome vs flat screen for the same film by individuals, nor by different groups. It would appear from the evidence emerging in evaluation for various formats, that topic, fit of topic to the format, and display technique are all variables that would benefit from within-subjects controlled experimental design in order to assess the unique learning outcomes that can be attributed to the giant screen film, and whether the incremental learning benefit exceeds the value of that same topic on more traditional media.

Lastly, the lead author is aware of preliminary results from a consumer study focused on Entertainment Trends in America by the NPD Group where half of respondents seeing 3D films object to the glasses necessary for viewing. While there is clearly a resurgence in the use of 3D in film based on new technology, there remains a question as to why there may be such a large level of dissatisfaction and whether that dissatisfaction is associated with the format itself or if the dissatisfaction can be traced to minor or major physiological conditions related to the viewer's vision. One fairly dated study *of college students* (Coutant & Westheimer, 1993) suggested that while most, 97.3 percent, were able to see depth at higher binocular disparities, only 80 percent were able to experience the effect using a smaller disparity. Lack of binocular vision capacity has been reported to be as high as 12% (Ivan, 2010), a discomfort explicitly outlined in section 17 of the Sony Playstation terms of service (Sony Computer Entertainment America LLC, 2010). This deficit has been reported to be a physiological/neurological challenge that can be remediated (Barry, 2009) but those remedies have only recently emerged and most people with this challenge may not be aware of the remedies nor that they suffer from this deficit until they are viewing a 3D movie. Further study of this phenomenon may help to illuminate why some films may be successful for some viewers but cannot achieve the same outcomes for all audiences and how these vision limitations impact evaluation and learning outcomes.

CONCLUSION

We have suggested that the making meaning from experiences with giant screen films, whether cognitive or affective, may contribute to science learning, but the degree to which that learning is possible, and the incremental value of the various giant screen formats remains without definitive empirical research that can justify the investment cost as educational films. We have demonstrated how and why individuals can learn from immersive environments including giant screen films and the three attributes that may be implicated in this learning. The lack of substantial research on how individuals learn from giant screen films, and the dearth of comparison studies showing that the unique learning value that has been attributed to giant screen films is verifiable will continue to challenge the industry. Facing the tremendous changes in projection technology and the high cost of conversion of facilities or obsolescence of existing, very expensive facilities and projection systems, the informal science education community must make important decisions using very little empirical data. We believe that there is a need for more comparative research in order to form a sound argument in favor of the learning benefits of giant screen cinema to justify the continued public support of this format. The evidence is starting to emerge, but given the radical shifts facing the industry as film becomes digitized, sound scientific results will help to inform the future of this science learning tool.

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[i] For full the collected papers presented at the symposium, see: http://www.giantscreencinema.com/MemberCenter/SymposiumMaterials.aspx).

[ii] " Steve Bishop, vice president of science and Imax programs, claims that a GS theater's "sweet spot" is located dead center, halfway up and halfway across because he claims those seats offer the most balanced sound experience." http://blog.pennlive.com/life/2010/05/wheres_the_best_seat_to_view_a.html

Current and Potential Business Model

DISCUSS PROCEEDINGS

CHAPTER 5

BY JEANIE STAHL AND MARK PETERSON

Overview

As part of the DISCUSS project, two economic surveys were conducted by the Co-PIs and the Business Model Experts (Jacobsen, Stahl and Peterson, 2010) in order to quantify the current business model for GS theaters and film producers showing and producing classic films and to use that as the basis for developing future business models for a global network of DIGSS-compliant digital leasing theaters. One survey was sent to U.S. Giant Screen theaters showing STEM-related films. It had 24 respondents (May, 2010). The second survey was sent to film producers and distributors and had four respondents. The aggregate data and the range of data from these surveys was shared with those attending the June 2010 DISCUSS Colloquium, whose participants, among others, included theater managers, museum directors, film producers and distributors. Aggregate data from the surveys and a draft of the future business models were reviewed in breakout groups and the assumptions for the future business model were refined.

This chapter presents the results from the two surveys and develops a framework for a new business model for a DIGSS-compliant theater network that can support five new classic film releases per year (one film fewer than the yearly average number of six films released each year from 2005 through 2009. The assumption for the future is that five new films per year will meet the needs of GS Theaters showing STEM-related films, and the future business model calculates how many theaters are needed to support five films at varying production budget levels.

The surveys and business models focus on operations and film production and not on the capital costs for constructing new DIGSS theaters or converting existing theaters from analog to digital.

The authors and the DISCUSS project team would like to thank the theater representatives, filmmakers, and distributors who participated in the surveys and/or were participants at the June 2010 DISCUSS Colloquium. Their input was invaluable and without them this part of the project could not have been carried out.

CRITICAL CONSIDERATIONS FOR DEVELOPING A NEW BUSINESS MODEL

- Build on the current business model to define a future GS digital business model that works for all aspects of the Logic Rationale, which includes all sectors of the GS industry chain, from investors to theaters.

- Determine the key components of the business model necessary to sustain the whole economic ecosystem.
- Determine how many films per year are needed from the perspective of the theater operators.
- From the perspective of the filmmakers and distributors, determine how large the network of compatible digital GS theaters needs to be to support an average of five new classic film releases per year based on varying film budget levels.

SOURCES OF DATA INFORMING THE ANALYSIS

- DISCUSS Survey of U.S. Institutional Theaters (May 6 – 25, 2010) — 24 respondents, plus additional input from Colloquium attendees representing theaters in an institutional setting
- DISCUSS Film Producer/Distributor Survey (May 6 – 25, 2010)— four respondents, plus additional input from Colloquium attendees representing filmmakers and distributors
- Additional data collected from selected DISCUSS survey respondents via phone and email (May – June, 2010)
- Digital Immersive Giant Screen Specifications Front-end Survey (July, 2008)
- Giant Screen Cinema Association (GSCA) annual attendance data from their member survey *Theater Attendance Reporting* (TAR) (as of May 1, 2010).
- GSCA Specification Data for DISCUSS Respondents (as of May, 2010)
- *LF Examiner* Film and Theater Databases (as of May 1, 2010)
- White Oak Associates' Databases and Theater and Museum Studies (as of May 1, 2010)

SUMMARY FINDINGS: CURRENT BUSINESS MODEL

The summary findings are based primarily on the first two DISCUSS surveys listed above and conducted as part of the DISCUSS project, plus the GSCA's attendance data, the *LF Examiner's* databases and White Oak's databases on museum and theater operations. More detailed findings and tables are presented later in this chapter.

GS THEATERS SHOWING STEM-RELATED PROGRAMMING

The survey of U.S. institutional theaters was based on identifying theaters that show STEM-related films. There were 66 U.S. theaters that met the criteria [1]. Sixty-four DISCUSS surveys were sent to theater personnel by the GSCA and 24 completed or partially completed surveys were returned. Additional data were collected from five of the responding theaters to clarify responses or add missing data.

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[1] The 66 U.S. theaters identified as showing STEM-related programming were identified by White Oak and *LF Examiner*, based on their knowledge of the theaters and their programming.

The inclusion of DMR films has a significant impact on a theater's operating numbers and, as a result, classic film data and DMR data were calculated separately. Based on screening hours per year, the theaters were divided into two groups: Those showing predominantly classic films and those showing predominantly DMR films.

Overall, based on the averages for the respondents showing predominantly classic films, classic film-only programming had 2,515 hours of screening time (assuming one hour per screening) and served 189,000 public and school visitors who collectively paid $1.0 million in gross admissions revenue, or $5.25 per individual served (the ATP). Another way to look at the data is per screening hour. Average data showed $403 of admissions revenue and 76 visitors per screening hour.

For theaters showing predominantly DMR films, the DMR film-only programming had average annual screening hours of 2,473 hours (assuming two hours per DMR screening), served an average of 151,000 visitors, who collectively paid $1.7 million in gross admissions revenue, or $11.33 per individual served. Per screening hour, the median data calculated to $637 in admissions revenue per hour and 99 visitors in seats.

Table 5.1 presents these summary findings and breaks out classic versus DMR data for each of the two theater groups. Based on averages, those showing predominantly classic films had lower annual attendance, admissions revenue, average ticket price and number of screenings. The average ticket price (ATP) for DMR showings was $11.33 for theaters showing predominantly DMR films, more than double that of their classic showings. On a per hour basis, the classic showings had a higher average ATP than DMR shows, although the median for one group was higher for DMR showings

Even with higher lease costs (DMR films do not have actual print costs, though they may have some "virtual" print costs), the admissions revenue net of lease and print costs for the DMR films was significantly higher than for the classic only showings. Yet annual admissions revenue per screen hour, net of print and lease costs, were higher for classic films. The costs do not take into account other expense categories for programming such as additional staff, 3D glass cleaning, cost of 3D glasses, advertising costs (generally higher for classic shows), maintenance, etc.

Of the respondents in both groups that show both classic and DMR, screening hours totaled more than 3,000 hours for seven of the eight theaters. For the six theaters showing classic only films, only two theaters had annual screening hours of 3,000 or higher. The range was 1,276 to 3,200.

Summary Findings from DISCUSS Survey of GS Theaters (Averages)[2]

	Theaters Showing					
	Predominantly Classic			Predominantly DMR		
Categories Present Data Averages	Classic Only	DMR Only	AVG both Formats	Classic Only	DMR Only	AVG both Formats
Screen Hours per Year (DMR 2 hours)	2,515	632	2,768	1,144	2,473	3,617
% of Screenings Hours per Year	n/a	n/a		36%	64%	100%
Annual Theater Attendance	189,000	23,000	202,000	83,000	151,000	235,000
Visitors in Seats per Screen Hour	76	72	n/a	74	99	n/a
Annual Admissions Revenue	$1,021,000	$255,000	$1,170,000	$405,000	$1,714,000	$2,119,000
Average Ticket Price (ATP)	$5.25	$8.94	n/a	$5.13	$11.33	n/a
Less AVG Lease and Print Costs/Capita	$ 3.77	$ 4.52	n/a	$ 2.88	$ 4.68	n/a
Net ATP after Lease and Print costs	$1.48	$4.43	n/a	$2.25	$6.65	n/a
Admisssions Revenue/Screen Hour	$403	$222	n/a	$468	$637	n/a
Less Lease and Print Costs/Screen Hour	$108	$95	n/a	$191	$394	n/a
"Net" Admisssions Rev./Screen Hr.	$295	$127	n/a	$276	$243	n/a

Table 5.1

Source: DISCUSS Survey of U.S. GS Theaters and the White Oak Institute

Other findings from the research and analysis indicated:

- Declining attendance and revenue, at least for classic film programming.
- DMR films are helping institutional theaters (at least in the short run) but are not mission-related and have higher lease fees.
- Although average ticket prices are higher for DMR films, they run about two hours, compared to less than an hour for classic films. On a per-hour basis, classic film average ticket prices are higher than DMR average ticket prices for theaters showing both types of programming.
- Commercial multiplexes are competing with institutional theaters.
- IMAX theaters are no longer consistently the "cash cow" helping to support other museum programs, so the theaters may not be as valued by the institution as they were previously.
- There are not enough quality Classic films.
- On average, more DMR films are being released per year than STEM-related films.

Table 5.2 presents more detailed data for each category and includes average, median, maximum and minimum data. Overall, with a relatively small number of respondents, the average and median data do not reflect the large range of statistics for individual theaters, thus maximum and minimum data points are included in the table.

[2] The averages for all theaters showing predominantly DMR programming will total the sum of the classic only and DMR data. That will not be the case for the theaters showing predominantly classic programming because of theaters that have no DMR data.

That table also includes numbers for lease fees and media buys/media production costs. In addition to differences between the two groups cited above, there were also variances in annual lease fees, which are significantly higher for DMR films, as distributors of Hollywood films command much higher rates and include print costs and marketing.

Media buys and associated production materials are much less for those showing predominantly DMR since theaters doing day-and-date releases are supported by national advertising campaigns and thus require less direct advertising spending by the theaters. Five of the five theaters showing primarily DMR indicated that they were doing mostly day-and-date releases.

Findings from the DISCUSS Survey of U.S. Giant Screen Theaters

	Theaters Showing					
	Predominantly Classic			Predominantly DMR		
	Classic Only	DMR Only	AVG both Formats	Classic Only	DMR Only	AVG both Formats
# Respondents	*10-14*	*4-7*	*12-14*	*3-5*	*3-5*	*3-5*
AVG Annual SCREENING HOURS (DMR 2 hrs)	2,515	632	2,768	1,144	2,473	3,617
Median SCREENING HOURS (DMR 2 hours)	2,656	697	2,979	1,168	2,361	3,594
Maximum	3,210	1,080	3,590	1,501	2,954	3,823
Minimum	1,276	54	1,276	739	2,216	3,456
Average Annual ATTENDANCE	189,000	23,000	202,000	83,000	151,000	235,000
Median Annual ATTENDANCE	197,000	18,000	216,000	100,000	117,000	235,000
Maximum	334,000	48,000	334,000	119,000	311,000	411,000
Minimum	64,000	2,000	95,000	41,000	42,000	98,000
Average Annual ADMISSIONS Revenue	$1,021,000	$255,000	$1,170,000	$405,000	$1,714,000	$2,119,000
Median Annual ADMISSIONS Revenue	$1,109,000	$153,000	$1,259,000	$393,000	$1,626,000	$2,079,000
Maximum	$2,012,000	$678,000	$2,012,000	$574,000	$3,391,000	$3,965,000
Minimum	$300,000	$10,000	$450,000	$193,000	$472,000	$665,000
Average "AVERAGE TICKET PRICE"	$ 5.25	$ 8.94	$ 5.81	$ 5.13	$ 11.33	$9.81
Median "AVERAGE TICKET PRICE"	$ 5.01	$ 8.69	$ 5.22	$ 5.15	$ 11.22	$9.59
Average "AVERAGE TICKET PRICE" PER HOUR	$5.25	$ 4.47	n/a	$ 5.75	$ 5.66	n/a
Median "AVERAGE TICKET PRICE" PER HOUR	$5.01	$ 4.35	n/a	$ 4.47	$ 5.61	n/a
Maximum ATP per HOUR	$ 7.30	$ 7.32	n/a	$5.75	$ 6.19	n/a
Minimum ATP per HOUR	$ 3.39	$ 1.97	n/a	$4.47	$ 5.24	n/a
Average ANNUAL LEASE FEE	$203,000	$129,000	$273,000	$145,000	$1,145,000	$1,290,000
Median ANNUAL LEASE FEE	$213,000	$60,000	$260,000	$146,000	$1,084,000	$1,248,000
Maximum	$375,000	$390,000	$456,000	$206,000	$2,112,000	$2,281,000
Minimum	$58,000	$6,000	$75,000	$84,000	$301,000	$384,000
AVG MEDIA BUYS/PRODUCTION Costs/Visit	n/a	n/a	$ 0.63	n/a	n/a	$ 0.24
Median MEDIA BUYS/PRODUCTION Costs/Visit	n/a	n/a	$ 0.45	n/a	n/a	$ 0.20
Maximum	n/a	n/a	$ 1.63	n/a	n/a	$ 0.51
Minimum	n/a	n/a	$ 0.24	n/a	n/a	$ 0.09

Table 5.2

Source: DISCUSS Survey of U.S. GS Theaters and the White Oak Institute

FILMMAKERS AND DISTRIBUTORS

The DISCUSS team identified the STEM-related classic films released between January 1, 2005 and December 31, 2009 (5 years). A questionnaire was sent to the film producers regarding their film. The number of survey responses to the survey was low, with only four firms responding. However, two of the firms have produced and distributed many films and have years of experience in the industry. Follow-up discussion and clarification of data was conducted with some of the respondents. Additional input was received from filmmakers and distributors attending the DISCUSS Colloquium.

There was a broad range in the answers from the respondents in all categories including film budget and funding sources. The responses informed the ranges used in the future business models. An analysis of the survey responses indicated the following:

- Many classic films require "free money" as part of the production budget. Free money includes funds from grants, sponsors, and other partners who are not equity participants. Without these funds, film production budgets most likely would need to be lower to mitigate risk for investors, and lower budgets could jeopardize the quality of films.
- Based on a film budget of $6.5 million, and the assumptions in the last table in this chapter, the industry network currently can support only 4.77[3] new films annually, yet the actual number produced per year has been higher in recent years.
- In the current economy debt financing is very difficult.
- Current estimated classic film production costs for both "bare bones" and optimal budgets
  - 2D films: $2 to $5 million for a "bare bones" budget
    $2 to $8 million for an optimal budget.
  - 3D films: $3 to $6 million for a "bare bones" budget
    $4 to $12 million for an optimal budget.
- The distributor's share of box office income is in the range of 20–25%, though the percentage can be higher.
- Marketing and print costs are generally not included in classic leases but are included in DMR leases.
- Estimated distribution costs from start-up through opening day range from a bare-bones budget of $150,000 for a 2D film to $1.5 million for 2D and 3D films.
- With the network supporting only a small number of films per year, theaters need to limit the number of films that they show annually so that the filmmakers and distributors have the ability to recoup their and their partners' investments. Otherwise there will be little incentive to produce new films.

GLOBAL FILM RELEASES

Between 2005 and 2009 the number of new releases for STEM-based films declined while the number of DMR films released increased.

[3] Input from DISCUSS advisors, as of November 2010, indicates that this number may now be closer to 3.5-4 films annually due to continual loss of screen time.

Global Film Releases 2005–2009

	All	STEM	DMR
Number of Films Released over 5 Years	83	30	34
Calculated Average Number of Films Released per Year	16.6	6.0	6.8
Number of Films Released in 2009	19	5.0	11

Table 5.5

Source: Derived by White Oak from the *LF Examiner* databases, Number of STEM Classic films based on White Oak's and *LF Examiner*'s knowledge of the films.

395 Global Theaters That Have Leased Classic Films, by Type of Theater

Type	Number	% of Total
Institutional	176	45%
Multiplex	161	41%
Stand Alone	49	12%
Theme Park	9	2%
Total	395	100%
Less multiplex not regularly leasing classic films	(161)	
Less others currently inactive lessees	(41)	
Total Actively Leasing Classic Films	**193**	

Table 5.6

Source: *LF Examiner* Database of Theaters (as of May 1, 2010)

The 161 multiplex theaters in Table 5.6 do not regularly lease classic films and 41 other theaters are currently inactive lessees of films, (Hyder, 2010).

SUMMARY FINDINGS: FUTURE BUSINESS MODEL

As of May 2010, the number of theaters actively showing classic films was 193 worldwide. Based on an analysis of the survey findings, and assumptions detailed at the end of this chapter, that network of theaters appears to support 4.77 classic film releases annually, though, on average, six were produced, from 2005-2009. With an average film production budget of $6.5 million, the current model relies on non-equity funding from sources such as sponsors and grants.

Three future business models were developed based on three different film budgets, each of which has two funding options, resulting in six scenarios. The differences in the funding options have to do with the amount of non-equity funds (sponsors, grants, etc.) supporting the film production budget. The two funding scenarios were 35% non-equity funding or 0% non-equity funding. The film production budgets for the three models were $9 million (assuming a 3D film), $6 million and $3.6 million.

Currently the business model for film production does not work without non-equity funding. The debt financing market has also been very tight in recent years, making it more difficult to borrow funds for new films. The number of theaters showing primarily

STEM-related films is declining and the expected convergence, after their conversion to digital, with fulldomes is currently viewed as limited, though with technical advances over time that could change. Showing 3D films on GS domes has been problematic, though recently a few theaters have installed 3D in their dome theaters, projecting films on only part of the screen.

A key assumption driving the model is that five film releases per year are needed to sustain the global network and the programming needs of the theaters and that is based on the assumption that the number of theaters showing STEM-related programming will not grow. The six scenarios show that a network of as few as 144 global theaters to as many as 323 are needed to support five films, depending on the funding options and film budget assumptions. With the assumption of relatively small growth in the global market of GS theaters showing STEM-related films, it is difficult to see how a steady stream of high- budget, high-quality films can be sustained without continued non-equity funding. If the 193 current GS theaters showing STEM programming (as of May, 2010) all converted to digital, that would support only three of the scenarios – the two with the $3 million film production budget and one with 35% non-equity funding for a $6 million film. Even if the digital network of GS theaters showing STEM-related films grows there may be increased competition for screen time with the capability of new types of presentations – live simulcasts, astronomy shows, live internet feeds and lectures, competitions and more.

Table 5.7 presents the results of the future business model and its six scenarios. The assumptions behind the models appear at the end of this chapter.

Current and Future Business Models

	Analog Current Scenario	Digital - Future Scenarios					
		1	2	3	4	5	6
ASSUMPTIONS (in 2010 Dollars)	35% non-equity funds	35% non-equity funds	0% non-equity funds	35% non-equity funds	0% non-equity funds	35% non-equity funds	0% non-equity funds
Average number of films per year	4.77	5.00	5.00	5.00	5.00	5.00	5.00
Film Productions Costs	$6,500,000	$9,000,000	$9,000,000	$6,000,000	$6,000,000	$3,600,000	$3,600,000
RESULTING MODELS BASED ON THE ASSUMPTIONS							
Summary of Goal for Return on Investment and Start-up Distribution Costs							
Start-up Distribution Costs per Film	$850,000	$850,000	$850,000	$850,000	$850,000	$850,000	$850,000
Debt Repayment - Principle and Interest	$747,500	$1,035,000	$1,035,000	$690,000	$690,000	$414,000	$414,000
Equity Funds to pay back	$3,575,000	$4,950,000	$8,100,000	$3,300,000	$5,400,000	$1,980,000	$3,240,000
Return on Equity to pay back investors	$1,358,500	$1,881,000	$3,078,000	$1,254,000	$2,052,000	$752,400	$1,231,200
Total Minimum Needed for Net Revenue per Film	$6,531,000	$8,716,000	$13,063,000	$6,094,000	$8,992,000	$3,996,400	$5,735,200
Calculated Annual Lease Fees and Producer's Net Revenue							
Current Model Based on Total 193 Theaters in Network Showing Classic Films on a Regular Basis							
Future Model Based on Assumption of # of Thtrs in Network, 5 Films / Year and Revenue Goal per Film							
Total U.S. annual lease payments for all Classic Films per Year	$15,671,600	$20,170,080	$30,161,740	$14,128,800	$20,787,200	$9,938,880	$13,251,840
Total International annual lease payments for all Classic Films per Year	$22,096,956	$28,439,813	$42,528,053	$19,921,608	$29,309,952	$14,013,821	$18,685,094
Total Global Annual lease payments for all Classic Films per Year	$37,768,556	$48,609,893	$72,689,793	$34,050,408	$50,097,152	$23,952,701	$31,936,934
Plus Ancillary Revenue	$3,776,856	$9,721,979	$14,537,959	$6,810,082	$10,019,430	$4,790,540	$6,387,387
Total Revenue to Distributor	$41,545,412	$58,331,871	$87,227,752	$40,860,490	$60,116,582	$28,743,241	$38,324,321
Less Distributor's share (exclusive of start-up distribution costs) 25%	$10,386,353	$14,582,968	$21,806,938	$10,215,122	$15,029,146	$8,622,972	$9,581,080
Producer's Net Revenue and Pre-Distribution Start-Up Costs	$31,159,059	$43,748,904	$65,420,814	$30,645,367	$45,087,437	$20,120,269	$28,743,241
Producer's Net Revenue and Start-up Distribution Costs per Film	$6,531,000	$8,749,781	$13,084,163	$6,129,073	$9,017,487	$4,024,054	$5,748,648
Goal for Producer's Net Revenue and Start-up Distribution Costs per Film	$6,531,000	$8,716,000	$13,063,000	$6,094,000	$8,992,000	$3,996,400	$5,735,200
Variance	$0	$33,781	$21,163	$35,073	$25,487	$27,654	$13,448
Annual # Films supported by the network	4.77						
Goal of Annual # Films Supported by the Network	n/ap	5.02	5.01	5.03	5.01	5.03	5.01
Number of Theaters Needed to Support 5 Films	n/ap	216	323	174	256	144	192
Calculated Total Network Annual Attendance	36,477,000	n/av	n/av	n/av	n/av	n/av	n/av
"Free Money" Needed / Yr (grants, sponsors, etc.) (free $ x films / yr)	$10,853,906	n/av	n/av	n/av	n/av	n/av	n/av
Cost of Impact / Visitor (free $ / total attendance)	$0.30	n/av	n/av	n/av	n/av	n/av	n/av

Table 5.7

Source: DISCUSS Survey of U.S. GS Theaters and White Oak Institute

DETAILED FINDINGS: SURVEY OF U.S. INSTITUTIONAL GS THEATERS

Twenty-four completed or partially completed surveys were received from the 64 surveys sent out by the GSCA. Additional data were collected from five of the responding theaters to clarify responses or add missing data. Four of the 24 U.S. theaters who responded to the survey were excluded from the group data calculations: two because they were closed for part of the year, one because they are a destination attraction showing predominantly one film, and the fourth because they are primarily a planetarium. In some instances individual theaters were excluded from a particular calculation because of significant anomalies in the data or apparent errors in the way the data was reported. Respondent data were for 2009 or 2010. Of the 20 theaters included in the calculations, twelve show both classic and DMR films and eight show only classic films. Two of the respondent museums have two IMAX theaters each. It is important to remember that the survey of theaters was for only one year of data, though 13 of the 20 respondents included in the calculations indicated that it was a “typical” year. Several theaters stated that in the 12-month period for which they were reporting, they added more DMR® programming (Hollywood feature films enhanced by IMAX) than usual with the intent to counter the economic downturn. Several reported that popular DMR films helped boost attendance in the reporting year. The inclusion of DMR films has a significant impact on a theater’s operating numbers and, as a result, classic film data and DMR data were calculated separately. Based on screening hours per year, the theaters were divided into two groups: Those showing predominantly classic films and those showing predominantly DMR films.

COMMENTS REGARDING THE SURVEY DATA AND RESPONDING THEATERS

- Some respondents had conflicting data regarding expenses for lease fees. In some cases it was unclear whether the amounts included print costs or not.
- Multi-year trend data for attendance were derived from GSCA member surveys.
- The DISCUSS survey covers only one year, which may not represent a typical operating year for each theater, though 14 of the 24 respondents stated it was a “typical” year and 10 stated it was “not a typical year.” Anomalies included:
  - Several popular DMR films.
  - Two venues partially closed for renovation (and removed from calculations for average and median data).
  - Some theaters added more DMR films than usual with the intent to counter the economic downturn.
  - One theater is located at a major national destination attraction, and its data, especially attendance, was excluded from many of the calculations for average and median data.

Abbreviations used throughout this chapter are as follows:

- STEM = U.S. Institutional Theaters that show STEM-related (science, technology, engineering and math) programming
- GLOBAL = 395 Global Theaters leasing classic films (from the *LF Examiner* Database)
- DISC = DISCUSS Survey Respondents
- ATTD = Attendance
- ADMISS = Admissions

CHARACTERISTICS OF DISCUSS SURVEY THEATER RESPONDENTS COMPARED TO OTHER GS THEATERS

The following two tables compare the characteristics of the 20 DISCUSS survey respondents, for which data were analyzed, to the 66 theaters showing STEM-related programming and the estimated global network of 395[4] giant-screen theaters that have ever shown one or more classic films.

Compared to the group of 395 global theaters, the DISCUSS survey respondents had a much higher percentage of dome theaters and a higher percentage of 2D theaters. The DISCUSS respondents also had a higher percentage of 15/70 theaters and did not have any 10/70 or digital theaters.

[4] As of May 1, 2010. Calculated from the *LF Examiner* database.

Theater Characteristics of DISCUSS Survey Respondents
(Note: One U.S. "STEM" theater and five global theaters have dual screens, dome and flat, which results in a count higher than the number of theaters indicated in the first row.)

	DISCUSS Survey GS Theaters		U.S. STEM GS Theaters		GLOBAL GS Theaters	
Number	*20*		*66*		*395*	
DOME	8	40%	33	50%	100	25%
Flat	12	60%	33	50%	300	75%
Imax	17	85%	53	80%	326	83%
Non-Max	3	15%	13	20%	69	17%
2D	9	45%	44	67%	152	38%
3D Capable	11	55%	22	33%	243	62%
1570	18	90%	56	85%	254	64%
870	2	10%	10	15%	50	13%
10/70	0		0		10	3%
Digital	0		0		81	20%
Total	20	100%	66	100%	395	100%

Table 5.8
Source: DISCUSS Survey of U.S. GS Theaters and the White Oak Institute

RESULTS OF QUALITATIVE SURVEY QUESTIONS

The White Oak Institute conducted a front-end survey in 2008 prior to the NSF award of the DISCUSS grant. The survey was sent to institutional theater managers, asking qualitative questions regarding conversion to digital and future brand preference. The same questions, also sent to institutional theaters, were asked as part of the DISCUSS survey.

Regarding theater conversion, the field thought that theater conversion from analog to digital was as many years off as they did two years before. The front-end survey had 40 respondents to this question versus 21 in the most recent survey.

- 52% of theater respondents thought they would convert to digital within 4–7 years, compared to 53% in the front-end survey.
- 22% believed they might convert within 0–3 years, compared to 18% in the front-end survey.

Regarding theater brand:

- 29%, or 7 of the 24 respondents, would like to be IMAX-branded, with projector ownership and no programming restrictions, versus 28%, or 12 of the 43 respondents in the front-end survey.

- 42%, of respondents in the recent DISCUSS survey said that brand did not matter, provided that:
  - It served their specific needs even if it limited the number of GS theaters with which they could share films (4 respondents)
  - The brand is like many other GS theaters (3 respondents)
  - Other comments (3 respondents)
    1. *Allows us the maximum number of giant-screen titles as well as flexibility to show other non-GS digital format material*
    2. *Prefer not IMAX branded and serves our needs but doesn't limit shared films with digital GS theaters*
    3. *It is important that content can be shared and run across all platforms*

The *LF Examiner* conducted a survey in the spring of 2011 using similar questions as the White Oak 2008 survey. There were 53 international respondents from commercial and institutional and standalone theaters. The survey results were published by the *LF Examiner* in its May 2011 issue (Vol. 14, No.5). Results indicated that larger percentages of respondents thought conversion to digital should happen as soon as possible and some theaters had already converted. A higher percentage of respondents felt that they would have to convert sooner than respondents in the 2008 survey. In the 2008 survey 40% of theater managers felt they should start the conversion process when Imax had a digital projector equivalent in image quality to 15/70 film and the *LF Examiner* survey indicated that only 26% felt that way. And in 2008, 42% wanted an IMAX branded theater (whether leased or owned) and in the 2011 survey only 21% indicated they wanted an IMAX. In 2008, 44% said they didn't care about brand and in 2011, 68% said brand was in unimportant to them.

ATTENDANCE

[INCLUDES DATA DERIVED FROM BOTH THE DISCUSS SURVEY, THE GSCA MEMBER SURVEYS AND WHITE OAK'S INTERNAL DATABASES.]

Multi-year attendance data were plotted for three groups: 1) 13 GS theaters that participated in the DISCUSS survey and shared attendance data for 2002 through 2008; 2) 17 GS theaters with data for 2002–2007 and; 3) 30 to 64 theaters reporting attendance to the GSCA. The theaters in the first two groups are not proportionately representative of the field, as they include higher percentages of flat screens and 3D theaters. All are 15/70 IMAX theaters. Two of the theaters are in Canada; the remainder are in the U.S.

- Between 2002 and 2008, *cumulative* attendance for 13 GS theaters in the DISCUSS survey declined by 26%.
- Between 2002 and 2008, *average annual* attendance for 13 GS theaters declined by 35%.

◆ Between 2002 and 2008, average annual attendance declined by 23% for 30 to 64 theaters reporting to the GSCA.

Attendance by Type of Programming for DISCUSS Survey Respondents

	Theaters Showing					
	Predominantly Classic			Predominantly DMR		
	Classic Only	DMR Only	AVG All Programming	Classic Only	DMR Only	AVG All Programming
# Respondents	*10-14*	*4-7*	*12-14*	*3-5*	*3-5*	*3-5*
Average Annual ATTENDANCE	189,000	23,000	202,000	83,000	151,000	235,000
Median Annual ATTENDANCE	197,000	18,000	216,000	100,000	117,000	235,000
Maximum	334,000	48,000	334,000	119,000	311,000	411,000
Minimum	64,000	2,000	95,000	41,000	42,000	98,000

Table 5.9
Source: WOI: DISCUSS Survey of U.S. Institutional Theaters

Cumulative Theater Attendance Trends
(Includes both Classic and DMR Programming)

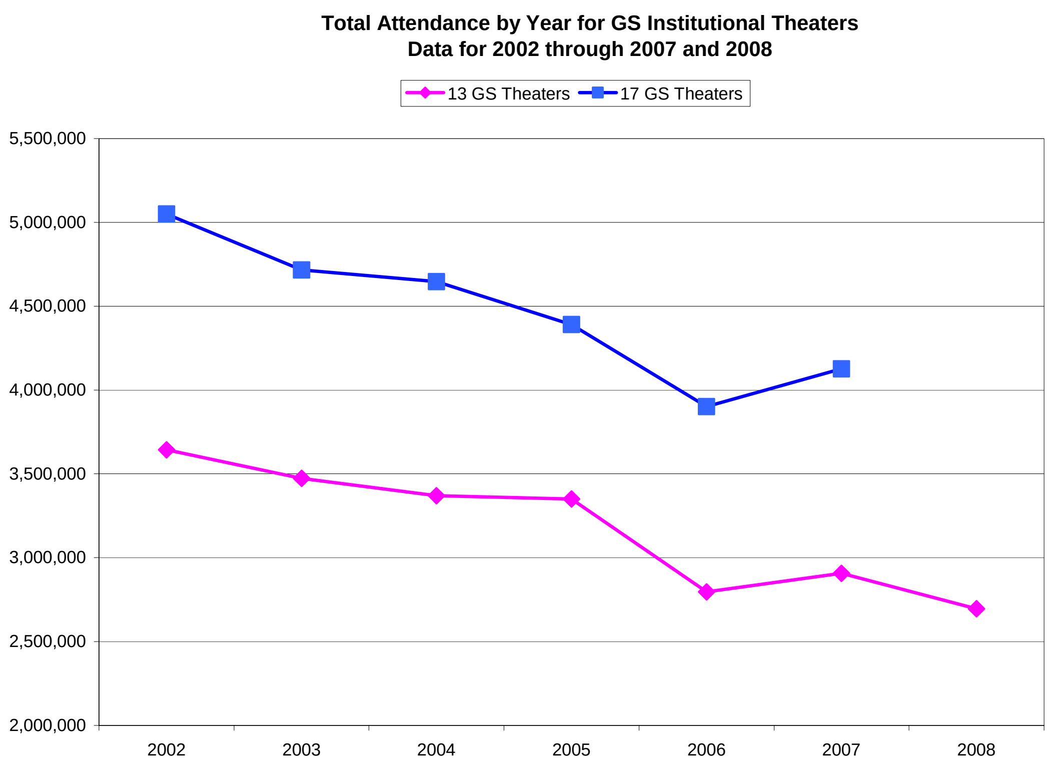


Chart 5.10
Source: GSCA Attendance Surveys and White Oak

Attendance Data presented in Chart 5.12 includes 30–64 institutional theaters. Data were derived from the GSCA Web site. The number of theaters reporting per year was as follows:

Number of Member Theaters Reporting Attendance Data to the GSCA

Year	Respondents
2000	40
2001	44
2002	51
2003	60
2004	63
2005	63
2006	62
2007	64
2008	45
2009	30

Table 5.11
Source: Giant Screen Cinema Association

Average Attendance Trends
(Number of Respondents Varies per Year)

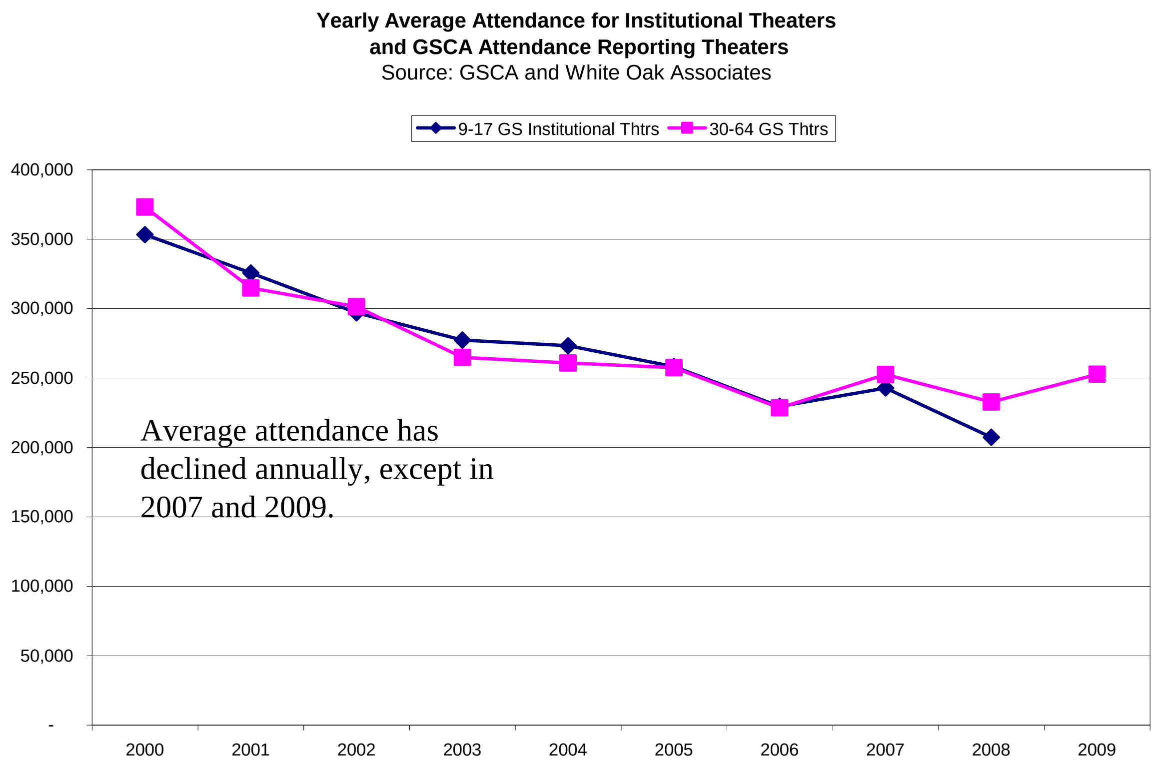


Chart 5.12
Source: GSCA Attendance Surveys and White Oak

Average Attendance 2D versus 3D Theaters

(Data for 10 Institutional Theaters from 2000–2009)

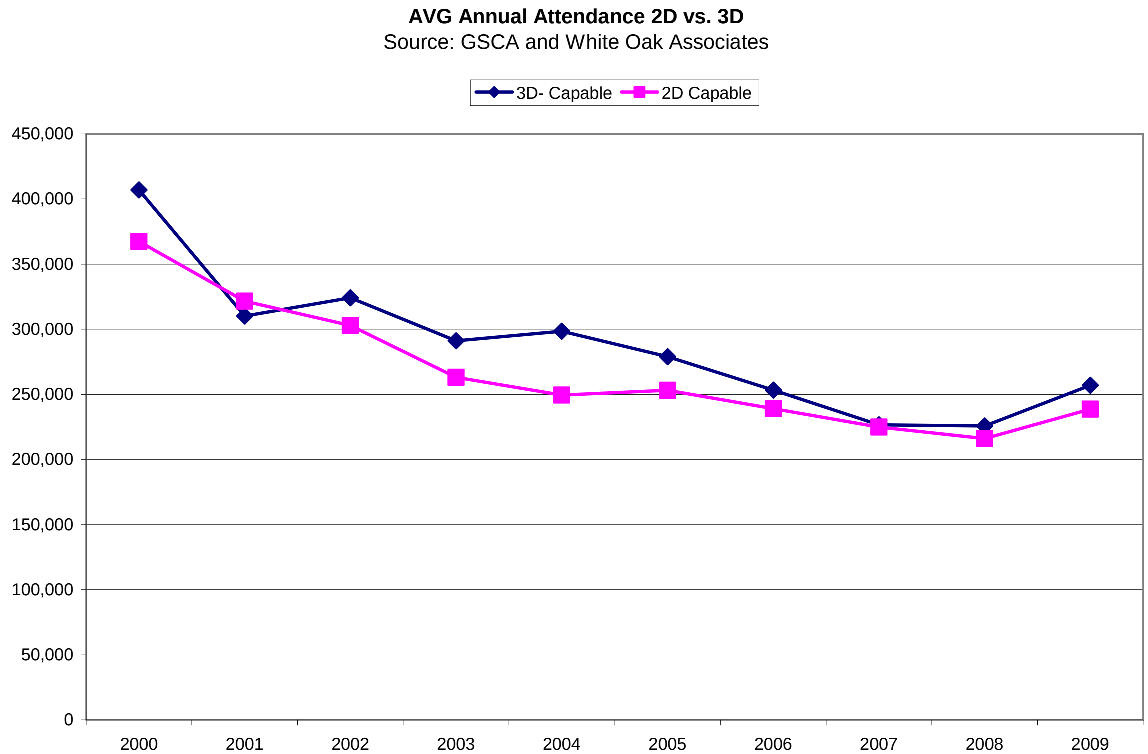


Chart 5.13

Source: GSCA Attendance Surveys and White Oak; includes two Canadian theaters

ADMISSIONS REVENUE AND AVERAGE TICKET PRICE (ATP)

- GS theater admissions revenue is still an important contributor to earned revenue, contributing on average 45% (median 42%) to overall museum admissions.
- The ATP for DMR films is almost twice that of classic films, but that is over a two-hour time frame, compared to the shorter classic films. On a per-hour basis, the average ATP for classic films is higher, though the median for classic films was lower in the group of theaters showing predominantly DMR films.
- Average annual admissions revenue for theaters showing predominantly DMR ($2.1 million) was higher than for theaters showing predominantly classic films ($1.2 million). Three theaters had DMR admissions revenue of over $2 million, which represented 85%–86% of their annual giant-screen admissions revenue.

Admissions Revenue and Average Ticket Prices

	Theaters Showing					
	Predominantly Classic			Predominantly DMR		
	Classic Only	DMR Only	AVG All Programming	Classic Only	DMR Only	AVG All Programming
# Respondents	*10-14*	*4-7*	*12-14*	*3-5*	*3-5*	*3-5*
Average Annual ADMISSIONS Revenue	$1,021,000	$255,000	$1,170,000	$405,000	$1,714,000	$2,119,000
Median Annual ADMISSIONS Revenue	$1,109,000	$153,000	$1,259,000	$393,000	$1,626,000	$2,079,000
Maximum	$2,012,000	$678,000	$2,012,000	$574,000	$3,391,000	$3,965,000
Minimum	$300,000	$10,000	$450,000	$193,000	$472,000	$665,000
Average "AVERAGE TICKET PRICE"	$ 5.25	$ 8.94	$ 5.81	$ 5.13	$ 11.33	$9.81
Median "AVERAGE TICKET PRICE"	$ 5.01	$ 8.69	$ 5.22	$ 5.15	$ 11.22	$9.59
Average "AVERAGE TICKET PRICE" PER HOUR	$5.25	$ 4.47	n/a	$ 5.75	$ 5.66	n/a
Median "AVERAGE TICKET PRICE" PER HOUR	$5.01	$ 4.35	n/a	$ 4.47	$ 5.61	n/a
Maximum ATP per HOUR	$ 7.30	$ 7.32	n/a	$5.75	$ 6.19	n/a
Minimum ATP per HOUR	$ 3.39	$ 1.97	n/a	$4.47	$ 5.24	n/a

Table 5.14
Source: WOI: DISCUSS Survey of Theaters and Producers/Distributors

SCREEN TIME BY CATEGORY AND NUMBER OF FILMS SHOWN PER YEAR

The DISCUSS survey asked questions regarding the number of screenings for the reporting year, the number of screenings for Classic and DMR films, and for those showing DMR, whether the DMR releases opened day-and-date or were delayed. Delayed release means that the first showings occurred after the DMR film was released nationally, usually because of the presence of another theater in the same market with exclusive rights to day-and-date releases. The majority of those showing DMR films indicated that they did mostly day-and-date releases; only five of the 14 respondents who show DMR films said they did only delayed release.

DISCUSS Survey Respondents — DMR Release Schedule
(14 of the 22 respondents show DMR films)

# Respondents	14	14
Mostly Day and Date	8	57%
Only Delayed Release	5	36%
Some Day and Date	1	7%
Total	14	100%

Table 5.15
Source: WOI: DISCUSS Survey of U.S. Institutional Theaters

In the following two tables showing screening hours, the assumption was made that each Classic screen showing is one hour, and that, on average, DMR films are two hours. On average those showing predominantly DMR films had more screening hours per year.

Show Schedule — Hours per Year For Theaters Showing Both Classic and DMR Films
(DMR screening number doubled to reflect 2-hour running time)

	Theaters Showing					
	Predominantly Classic			Predominantly DMR		
Categories Present Data Averages	**Classic Only**	**DMR Only**	**AVG All Thtrs**	**Classic Only**	**DMR Only**	**AVG All Thtrs**
Screen Hours per Year (DMR 2 hours)	2,515	632	2,768	1,144	2,473	3,617
% of Screenings Hours per Year	n/a	n/a		36%	64%	100%

Table 5.16
Source: WOI: DISCUSS Survey of U.S. Institutional Theaters

DISCUSS Survey Findings: Annual Data for Theaters Screening both Classic and DMR Films
(Screening hours assume one hour for classic and two hours on average for DMR.)

	Screening Hours		Admissions Revenue		Attendance	
Tthr	**Classic**	**DMR**	**Classic**	**DMR**	**Classic**	**DMR**
Showing Predominantly DMR						
1	36%	64%	37%	63%	57%	43%
2	39%	61%	32%	68%	50%	50%
3			15%	85%	31%	69%
4	31%	69%	29%	71%	41%	59%
5			14%	86%		
6	20%	80%	14%	86%	24%	76%
Showing Predominantly Classic						
7	63%	37%	61%	39%	64%	36%
8			53%	47%	80%	20%
9			31%	69%	60%	40%
10			99%	1%	99%	1%
11	98%	2%	99%	1%	98%	2%
12	77%	23%	93%	7%	96%	4%
13	82%	18%	88%	12%	93%	7%

Table5.17
Source: DISCUSS Survey of U.S. GS Theaters and the White Oak Institute

Number of Classic Films Shown 2005–2009

THEATER	# FILMS SHOWN	CALCULATED PER YEAR
1	16	3.2
2	25	5.0
3	17	3.4
4	10	2.0
5	13	2.6
6	13	2.6
7	21	4.2
8	6	1.2
9	44	8.8
10	15	3.0
11	16	3.2
12	12	2.4
13	19	3.8
14	26	5.2
15	11	2.2
16	16	3.2
Average	19	3.8
Median	17	3.4

Table 5.18
Source: WOI: DISCUSS Survey of U.S. Institutional Theaters

SELECT THEATER OPERATING COSTS

The following three tables present findings from the DISCUSS survey in regard to lease fees, media buys and print costs.

Lease fees for DMR films are considerably higher than for Classic films

Classic vs. DMR Annual Film Lease Fees

	Theaters Showing					
	Predominantly Classic			Predominantly DMR		
Average ANNUAL LEASE FEE	$203,000	$129,000	$273,000	$145,000	$1,145,000	$1,290,000
Median ANNUAL LEASE FEE	$213,000	$60,000	$260,000	$146,000	$1,084,000	$1,248,000
Maximum	$375,000	$390,000	$456,000	$206,000	$2,112,000	$2,281,000
Minimum	$58,000	$6,000	$75,000	$84,000	$301,000	$384,000
AVG MEDIA BUYS/PRODUCTION Costs/Visit	n/a	n/a	$ 0.63	n/a	n/a	$ 0.24
Median MEDIA BUYS/PRODUCTION Costs/Visit	n/a	n/a	$ 0.45	n/a	n/a	$ 0.20
Maximum	n/a	n/a	$ 1.63	n/a	n/a	$ 0.51
Minimum	n/a	n/a	$ 0.24	n/a	n/a	$ 0.09

Table 5.19
Source: WOI: DISCUSS Survey of U.S. Institutional Theaters

Annual Print Costs for Classic Films

	All Theaters	Thtrs Showing Mostly Classic	Thtrs Showing Mostly DMR
# Respondents	15	12	4
Average Print Costs	$63,000	$58,000	$63,000
Median Print Costs	$55,000	$55,000	$53,000

Table 5.20
Source: WOI: DISCUSS Survey of U.S. Institutional Theaters

Annual funds spent on marketing and advertising (media buys and production of materials) averaged $134,000 for the group showing predominantly classic films and $42,000 for the other group. The average spending per capita was $ 0.63 for the group showing predominantly classic films and $.24 for the predominantly DMR group $0.29.

Only five theaters spent more than $100,000 on media buys and production materials, and three theaters spent less than $25,000. Note that the majority of advertising for DMR films released on a day-and-date basis is paid for by the studios as part of their national campaign.

Annual Costs For Media Buys and Production of Materials

	Theaters Showing			
	Predominantly Classic	Predominantly DMR		
	Classic Only	Classic Only	DMR Only	Combined
# Respondents	*11*	*5*	*5*	*5*
Average Media Buys/Production Costs per Capita				
Average Costs per Capita	$ 0.63	n./av	n/av	$ 0.24
Median Costs per Capita	$ 0.45	n/av	n/av	$ 0.20
Maximum	$ 1.63	n./av	n/av	$ 0.51
Minimum	$ 0.24	n./av	n/av	$ 0.09
Annual $ Media Buys/Production				
Average Annual	$134,000	n./av	n/av	$42,000
Median Annual	$80,000	n/av	n/av	$48,000
Maximum	$440,000	n./av	n/av	$60,000
Minimum	$45,000	n./av	n/av	$25,000

Table 5.21
Source: WOI: DISCUSS Survey of U.S. Institutional Theaters

BRANDING AND CONVERSION TO DIGITAL

Several qualitative questions in the DISCUSS 2010 survey were about attitudes toward converting to digital and manufacturer brand preference. A similar survey was conducted by the White Oak Institute two years prior, in 2008. In both surveys, the majority of managers believed they had more than four years before the lack of analog films would make it necessary to convert to digital.

Opinions on When Conversion to Digital Will Need to Happen
2008: Front-end Survey Pre-Grant Award; 2010: DISCUSS Survey

	2008	2010	2008	2010
# Respondents	40	22	40	22
0–3 Years	7	4	18%	18%
4–7 Years	21	12	53%	55%
8–12 Years	10	3	25%	14%
12+ Years	2	1	5%	5%
Not Sure		1	0%	5%
Never		1	0%	5%
			100%	100%

Table 5.22
Source: WOI: DISCUSS Survey of Theaters and Producers/Distributors

Future Theater Brand Preference
2008 Front-end Survey Pre-Grant Award; 2010 DISCUSS Survey

	2008	2010	2008	2010
Total # Respondents	43	22	43	22
Owned IMAX: no programming restrictions	12	7	28%	32%
IMAX-similar business model to now	6	1	14%	5%
Combination of above	18	8	42%	36%
Not Sure	6	5	14%	23%
Don't Care as Long As…	19	9	44%	41%
			100%	100%

Table 5.23
Source: WOI: DISCUSS Survey of Theaters and Producers/Distributors
Columns may not total 100% because of rounding.

Other qualitative comments from DISCUSS survey respondents include:

- *3D definitely has an impact on sales. Anytime we can show a 3D film we see a 6–8% increase in sales.*
- *Theater audiences, including school groups, increasingly expect 3D. IMAX 3D film is a better visual experience than standard digital 3D and helps to differentiate our theater from these others.*
- *I believe it could be helpful to show commercially appealing films as an incremental line of business during evening hours. But I believe the core business of Classic/STEM films during the day should be preserved to work with the museum's mission as well as work best within the type of visit time frame and expectations of the museum visitor.*

CURRENT AND FUTURE BUSINESS MODEL SCENARIOS

CAVEAT AND NOTICE OF LIMITATIONS OF THE BUSINESS MODELS

This section is not intended to help calculate potential financial returns or other quantified calculations. The intended purpose of the economic models is to determine the size of the global network of digital giant-screen theaters needed to create a sustainable global network capable of supporting sufficient ongoing new programming. It is intended to look at the interaction of a few principal variables: a) network size; b) film budget; c) films per year; and; d) share of non-equity funds, recognizing that there are many other variables that can have an impact on the network's sustainability. Further, the methodology treats the behavior of sectors of the field as aggregated averages, when in fact every film is different, as is every theater and its market and operating context. The sample size is stronger for theater operations, but relatively thin for production/distribution data, although the latter include data from organizations with many years of experience and many completed and distributed films. When looking at the relative impact of key variables, we believe these anomalies cancel out and the aggregated methodology is appropriate. However, applying this business model to make forecasts for a specific project would not result in an appropriate analysis. ***This study model should not be used as a financial forecasting tool.***

Currently the business model for film production does not work without non-equity funding. The debt financing market has also been very tight in recent years, making it harder to borrow funds for new films. The number of theaters showing primarily STEM-related films is declining and the expected convergence, after their conversion to digital, with fulldomes is currently viewed as limited, though with technical advances over time that could change. Showing 3D films on domes has been problematic, though recently a few theaters have installed 3D in their dome theaters and are projecting on only part of the screen.

A benefit to future film production costs will be filming digitally, which is cheaper than analog film. That is reflected in the slightly lower average cost assumed for a 2D film for the future scenarios compared to the current cost.

Frankly, the field in transition and it is hard to predict how and what new factors, especially technological, that will have an impact on the field. One example of more recent entrepreneurial efforts is that filmmakers are now producing one film on multiple media platforms and in different lengths of time allowing distributors to reach a greater number of theaters and home entertainment media, not just GS theaters.

CONSIDERATIONS

The tables in this section present a framework for a business model that allows for a range of scenarios based on various assumptions that can be changed. As indicated earlier in this chapter, the three business models were based on the film production budgets of $9 million, $6 million and $3.6 million. Each of these has two funding models: 35% non-equity funding and 0% non-equity funding, resulting in six scenarios. The business model is predicated on global leases, not just leases to U.S. institutional theaters.

A key assumption driving the model is that five film releases per year are needed to sustain the global network, especially the theaters and their programming needs. That number is based on the assumption that the number of theaters in the network will not grow dramatically.

The six scenarios show that a network of as few as 144 global theaters or as many as 323 are needed to support five films, depending on the film production budget and on the funding assumptions. If the 193 current GS theaters showing STEM programming (as of May, 2010) all converted to digital, that would support three of the scenarios. With the assumption of relatively small growth in the global market of GS theaters showing STEM-related films, it is difficult to see how a steady stream of high-budget, high-quality films can be sustained. There is a wide range of film production costs depending on the film producer. The range indicated by the survey respondents for 2D films was $2 - $5 million for a “bare bones” budget and $2 - $8 million for an optimal budget. The range for 3D was $3-$6 million for a “bare-bones” budget to $4-$12 million for an optimal budget.

FINDINGS AND ASSUMPTIONS

- For a $6.0 million film, from the perspective of the producer/distributor, the future business model only works with “free money” from non-equity investors.
- Based on a $6.5 million film production budget, the current model appears to support only 4.77 films annually. (Input from DISCUSS advisors, as of November 2010, indicates that this number may now be closer to 3.5-4 films annually due to continual loss of screen time.)
- The future scenarios assume that five new film releases per year are needed to sustain the classic film industry.
- The film producers and distributors who responded to the survey and/or attended the DISCUSS Colloquium believe that the fulldome industry may have little convergence and overlap with GS and DIGSS-compliant theaters. A key factor is that fulldomes generally don’t show 3D programming. This does not preclude some fulldomes from becoming DIGSS-compliant and showing giant-screen films. One industry expert estimates that there are about 70 fulldomes that meet the GSCA size requirement for GS theaters. Recent data indicate that a few dome theaters have installed 3D and project the image on only part of the dome.
- The future scenarios assume that ancillary income (i.e. videos, books, etc.) will increase marginally, however this merits future research and analysis over the next several years due to the rapidly developing 3D home entertainment market.

- The future scenarios assume that lease fees will remain at current levels.
- The assumption was made that distribution costs may come down a little or remain at current levels, with potentially more dollars going to marketing the films.

IMPLICATIONS FOR FILM PRODUCERS AND DISTRIBUTORS

- Essentially no increase in the size of the market for classic films. The market could potentially decrease if it splinters into IMAX and non-IMAX theaters or giant and conventional size screens.
- Possibility of producing new kinds of digital films for the fulldome market.
- Some additional revenue from ancillary products.
- More competition for screen time, from DMR as well as new digital productions and live events.

IMPLICATIONS FOR THEATERS

- More options for different kinds of programming: classic, DMR, and digital.
- If theaters show too many films per year, they could reduce revenue to distributors to the extent that making new films would not be feasible. About four "A" films per year seems to be a reasonable minimum. The future model for the DIGGS digital network assumes an average of five films per year, though if the network of theaters does not grow, five films may be too many, especially as alternative digital programming grows and creates more competition for screen time.

TEMPLATE FOR A FUTURE BUSINESS MODEL FOR DIGSS-COMPLIANT DIGITAL THEATERS

Key assumptions driving the future business model scenarios appear in the following table. The current number of theaters that regularly lease classic films, 193, was obtained by subtracting all multiplexes (161) and inactive theaters (41) from the 395 global theaters that lease classic films.

The scenario allows assumptions to be changed to see the ripple effects through the model. The number of future theaters in the network is manually adjusted until the goal of approximately five films per year is achieved.

Table of Key Assumptions — Current and Future Business Models
(Theaters Regularly Showing Classic Films)

ASSUMPTIONS (in 2010 Dollars)	Analog Current Scenario	Digital - Future Scenarios					
		1a	1b	2a	2b	3a	3b
	35% non-equity funds	35% non-equity funds	0% non-equity funds	35% non-equity funds	0% non-equity funds	35% non-equity funds	0% non-equity funds
Film Productions Average Costs	$6,500,000	**$9,000,000**	**$9,000,000**	**$6,000,000**	**$6,000,000**	**$3,600,000**	**$3,600,000**
Film Format	All types	3D	3D	2D	2D	2D	2D
# of Current GS Theaters Showing STEM-Related Films	**193**						
Average number of films per year	**4.77**	**5.00**	**5.00**	**5.00**	**5.00**	**5.00**	**5.00**
Equity Financing	55.0%	55.0%	90.0%	55.0%	90.0%	55.0%	90.0%
Non-Equity Financing, i.e., "Free money"	35.0%	35.0%	0.0%	35.0%	0.0%	35.0%	0.0%
Debt Financing	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
U.S. Theaters Share of Global Theaters	40%	40% for All Scenarios					
International Theaters Share of Global Theaters	60%	60% for All Scenarios					
Relative Annual Lease Fees	Base	1.15	1.15	1.00	1.00	0.85	0.85
Average Lease Fees: U.S. Theaters	$203,000	$233,450	$233,450	$203,000	$203,000	$172,550	$172,550
AVerage Lease Fees: International Theaters	-10%	-10% for All Scenarios					
Ancillary income in Addition to Film Leases	+10%	+20% for All Scenarios					
Continuing Distribution Commission	25%	25% for All Scenarios					
Up-front Distribution Costs	$850,000	$850,000 for All Scenarios					

Table 5.24

Source: WOI: Current model derived from DISCUSS Survey of Theaters and Producers/Distributors and the DISCUSS Colloquium

Framework for Current and Future Business Models for Classic Films

	Analog Current Scenario	Digital - Future Scenarios					
		1	2	3	4	5	6
ASSUMPTIONS (in 2010 Dollars)	35% non-equity funds	35% non-equity funds	0% non-equity funds	35% non-equity funds	0% non-equity funds	35% non-equity funds	0% non-equity funds
Average number of films per year	4.77	5.00	5.00	5.00	5.00	5.00	5.00
Film Productions Costs	$6,500,000	$9,000,000	$9,000,000	$6,000,000	$6,000,000	$3,600,000	$3,600,000
Film Production Revenue Goal							
Goal for Producer's Net Revenue and Start-up Distrib. Costs per film	$6,531,000	$8,716,000	$13,063,000	$6,094,000	$8,992,000	$3,996,400	$5,735,200
Calculated Goal for Revenue per year for 5 Films		$43,580,000	$65,315,000	$30,470,000	$44,960,000	$19,982,000	$28,676,000
Annual Classic Film Lease Fees per Year / per Theater							
Assumed Increase/Decrease over Current U.S. Annual Lease Fees	Base	1.15	1.15	1.00	1.00	0.85	0.85
AVG U.S. Annual Lease Payments for Classic films / year / thtr	$203,000	$233,450	$233,450	$203,000	$203,000	$172,550	$172,550
Factor for non-US Annal Lease Payments	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%
Ratio of US / Total Global Network	40.0%	40.0%	40.0%	40.0%	40.0%	40.0%	40.0%
International AVG Annual Lease Payments for Classic Films	$190,820	$219,443	$219,443	$190,820	$190,820	$162,197	$162,197
Ancillary Revenue							
Ancillary Revenue to Distributor (as % of Film Lease Revenue)	10.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%
Attendance and Per Capita Lease Fees							
Average Annual Attendance	189,000	not assumed	not assumed	not assumed	not assumed	not assumed	not assumed
Calculated Per Capita Film Lease Fees	$1.07	not assumed	not assumed	not assumed	not assumed	not assumed	not assumed
Number of Theaters in 2010 Showing Classic Films on a Regular Basis							
Number of theaters in network that Show Classic Films	193	n/ap	n/ap	n/ap	n/ap	n/ap	n/ap

Table 5.25 (Part 1 of 3)

Source: WOI: DISCUSS Survey of Theaters and Producers/Distributors and the DISCUSS Colloquium, *LF Examiner* Databases and Industry Experts at the DISCUSS Colloquium

Framework for Current and Future Business Models for Classic Films

	Analog Current Scenario	Digital - Future Scenarios					
		1	2	3	4	5	6
ASSUMPTIONS (in 2010 Dollars)	35% non-equity funds	35% non-equity funds	0% non-equity funds	35% non-equity funds	0% non-equity funds	35% non-equity funds	0% non-equity funds
Average number of films per year	**4.77**	**5.00**	**5.00**	**5.00**	**5.00**	**5.00**	**5.00**
Film Productions Costs	**$6,500,000**	**$9,000,000**	**$9,000,000**	**$6,000,000**	**$6,000,000**	**$3,600,000**	**$3,600,000**
ASSUMPTIONS (in 2010 Dollars)							
Film Cost and Financing							
AVG Cost of film (equity total + non-equity) = budget	$6,500,000	$9,000,000	$9,000,000	$6,000,000	$6,000,000	$3,600,000	$3,600,000
Non-equity funds (sponsors, pre-leases, grants) share of budget "Free mo	**35.0%**	**35.0%**	**0.0%**	**35.0%**	**0.0%**	**35.0%**	**0.0%**
Debt and other off-the-top reimbursements	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
Equity Funds per Film	55.0%	55.0%	90.0%	55.0%	90.0%	55.0%	90.0%
Total Non-equity Funds per film	$2,275,000	$3,150,000	$0	$2,100,000	$0	$1,260,000	$0
Total Debt Financing per film	$650,000	$900,000	$900,000	$600,000	$600,000	$360,000	$360,000
Total Equity Funds per film	$3,575,000	$4,950,000	$8,100,000	$3,300,000	$5,400,000	$1,980,000	$3,240,000
Distributor							
Start-up Costs	$850,000	$850,000	$850,000	$850,000	$850,000	$850,000	$850,000
Commission / Share of Gross Revenues	**25%**	**25%**	**25%**	**25%**	**25%**	**30%**	**25%**
Timing and Payback of Financing							
Investors							
Years from mid-spending to mid-revenues	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Lost opportunity of other potential Investments as % / yr	6.0%	6.0%	6.0%	6.0%	6.0%	6.0%	6.0%
Add'l Risk margin needed to motivate investment	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%
Lost Opportunity (Equity Funds x % Lost opportunity x Years out) per film	$1,072,500	$1,485,000	$2,430,000	$990,000	$1,620,000	$594,000	$972,000
Add'l Risk margin amount	$286,000	$396,000	$648,000	$264,000	$432,000	$158,400	$259,200
Total minimum goal return to investors	$1,358,500	$1,881,000	$3,078,000	$1,254,000	$2,052,000	$752,400	$1,231,200
Plus equity funds to return to investors	$3,575,000	$4,950,000	$8,100,000	$3,300,000	$5,400,000	$1,980,000	$3,240,000
Total goal to return to investors (equity + return on investment)	**$4,933,500**	**$6,831,000**	**$11,178,000**	**$4,554,000**	**$7,452,000**	**$2,732,400**	**$4,471,200**
Debt Financing							
Percentage of Film Budget	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
Amount of Loan	$650,000	$900,000	$900,000	$600,000	$600,000	$360,000	$360,000
Rate	6.0%	6.0%	6.0%	6.0%	6.0%	6.0%	6.0%
Years out	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Interest to Pay	$97,500	$135,000	$135,000	$90,000	$90,000	$54,000	$54,000

Table 5.25 (Part 2 of 3)

Source: WOI: DISCUSS Survey of Theaters and Producers/Distributors

Investor payback and debt financing rates and terms are assumptions by White Oak and not developed from survey findings or discussions with Colloquium participants.

Framework and Scenarios for Current and Future Business Models for Classic Films

	Analog Current Scenario	Digital - Future Scenarios					
		1	2	3	4	5	6
ASSUMPTIONS (in 2010 Dollars)	35% non-equity funds	35% non-equity funds	0% non-equity funds	35% non-equity funds	0% non-equity funds	35% non-equity funds	0% non-equity funds
Average number of films per year	4.77	5.00	5.00	5.00	5.00	5.00	5.00
Film Productions Costs	$6,500,000	$9,000,000	$9,000,000	$6,000,000	$6,000,000	$3,600,000	$3,600,000
RESULTING MODELS BASED ON THE ASSUMPTIONS							
Summary of Goal for Return on Investment and Start-up Distribution Costs							
Start-up Distribution Costs per Film	$850,000	$850,000	$850,000	$850,000	$850,000	$850,000	$850,000
Debt Repayment - Principle and Interest	$747,500	$1,035,000	$1,035,000	$690,000	$690,000	$414,000	$414,000
Equity Funds to pay back	$3,575,000	$4,950,000	$8,100,000	$3,300,000	$5,400,000	$1,980,000	$3,240,000
Return on Equity to pay back investors	$1,358,500	$1,881,000	$3,078,000	$1,254,000	$2,052,000	$752,400	$1,231,200
Total Minimum Needed for Net Revenue per Film	$6,531,000	$8,716,000	$13,063,000	$6,094,000	$8,992,000	$3,996,400	$5,735,200
Calculated Annual Lease Fees and Producer's Net Revenue							
Current Model Based on Total 193 Theaters in Network Showing Classic Films on a Regular Basis							
Future Model Based on Assumption of # of Thtrs in Network, 5 Films / Year and Revenue Goal per Film							
Total U.S. annual lease payments for all Classic Films per Year	$15,671,600	$20,170,080	$30,161,740	$14,128,800	$20,787,200	$9,938,880	$13,251,840
Total International annual lease payments for all Classic Films per Year	$22,096,956	$28,439,813	$42,528,053	$19,921,608	$29,309,952	$14,013,821	$18,685,094
Total Global Annual lease payments for all Classic Films per Year	$37,768,556	$48,609,893	$72,689,793	$34,050,408	$50,097,152	$23,952,701	$31,936,934
Plus Ancillary Revenue	$3,776,856	$9,721,979	$14,537,959	$6,810,082	$10,019,430	$4,790,540	$6,387,387
Total Revenue to Distributor	$41,545,412	$58,331,871	$87,227,752	$40,860,490	$60,116,582	$28,743,241	$38,324,321
Less Distributor's share (exclusive of start-up distribution costs) 25%	$10,386,353	$14,582,968	$21,806,938	$10,215,122	$15,029,146	$8,622,972	$9,581,080
Producer's Net Revenue and Pre-Distribution Start-Up Costs	$31,159,059	$43,748,904	$65,420,814	$30,645,367	$45,087,437	$20,120,269	$28,743,241
Producer's Net Revenue and Start-up Distribution Costs per Film	$6,531,000	$8,749,781	$13,084,163	$6,129,073	$9,017,487	$4,024,054	$5,748,648
Goal for Producer's Net Revenue and Start-up Distribution Costs per Film	$6,531,000	$8,716,000	$13,063,000	$6,094,000	$8,992,000	$3,996,400	$5,735,200
Variance	$0	$33,781	$21,163	$35,073	$25,487	$27,654	$13,448
Annual # Films supported by the network	4.77						
Goal of Annual # Films Supported by the Network	n/ap	5.02	5.01	5.03	5.01	5.03	5.01
Number of Theaters Needed to Support 5 Films	n/ap	216	323	174	256	144	192
Calculated Total Network Annual Attendance	36,477,000	n/av	n/av	n/av	n/av	n/av	n/av
"Free Money" Needed / Yr (grants, sponsors, etc.) (free $ x films / yr)	$10,853,906	n/av	n/av	n/av	n/av	n/av	n/av
Cost of Impact / Visitor (free $ / total attendance)	$0.30	n/av	n/av	n/av	n/av	n/av	n/av

Table 5.25 (Part 3 of 3)

DIGSS 1.0

DISCUSS PROCEEDINGS

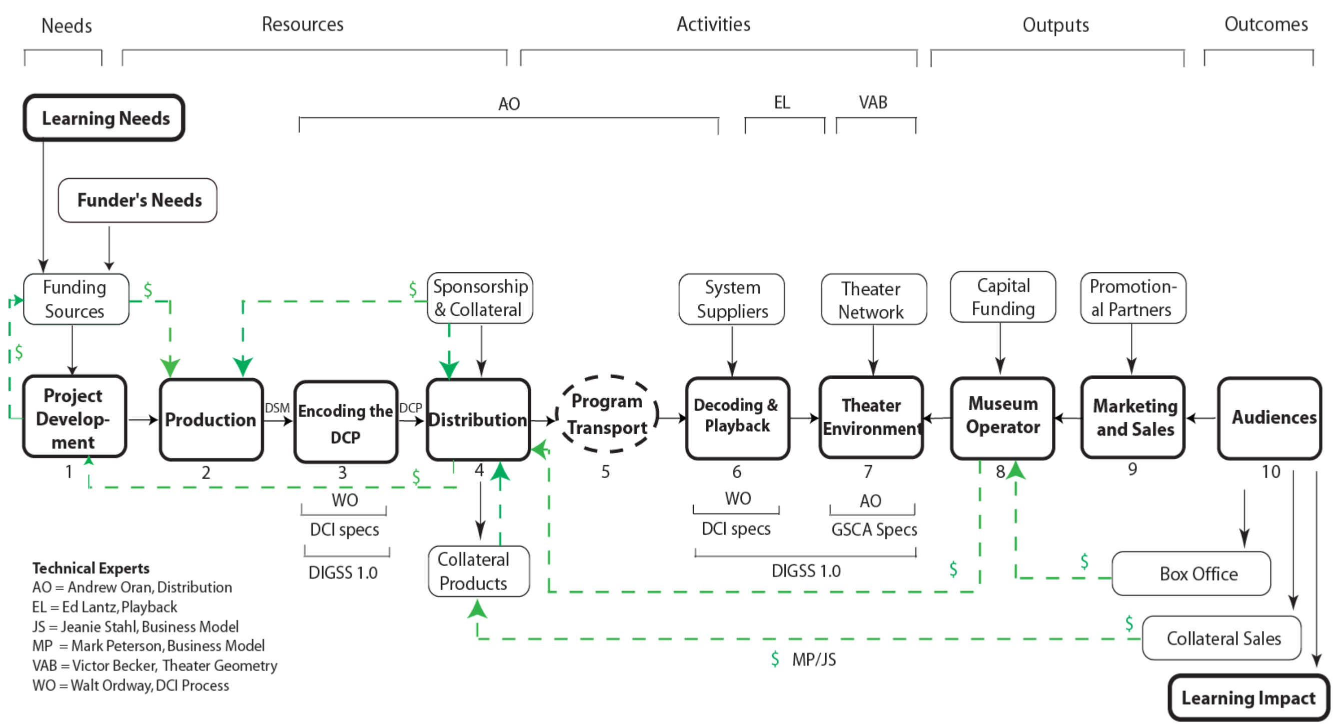
CHAPTER 6
BY AUTHORS AS LISTED

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

This chapter is also the most likely to evolve over time, as DIGSS 1.0, described in the following sections is updated to future versions. For that reason, this chapter is also available on its own as "DIGSS 1.0."

LOGIC RATIONALE

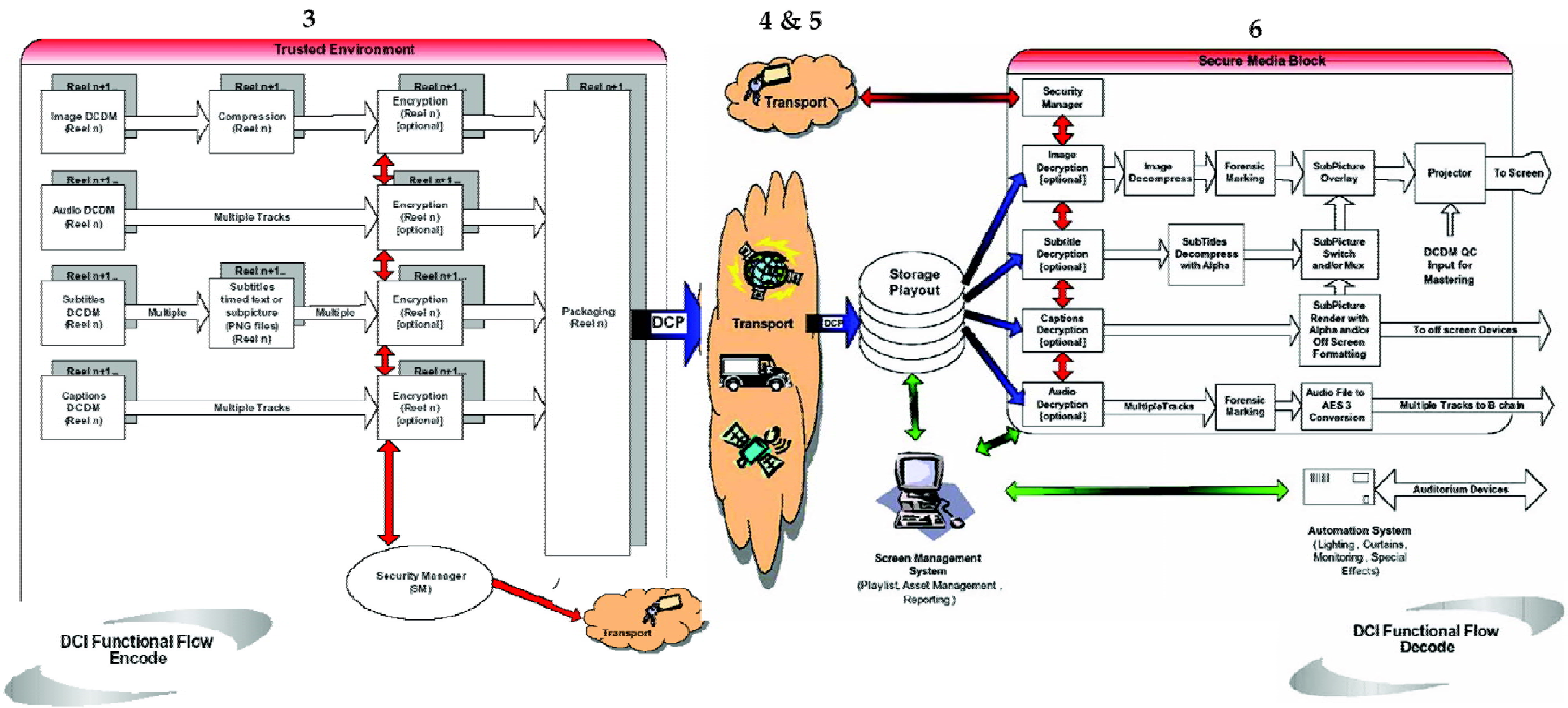
Author: John W. Jacobsen



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 3.2	Compression Frame Rate (unique frames)	JPG2000 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)*	DCI testing complete
	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. Packaging System Overview

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 Contras**t 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].

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 12º and no more than 30º. It is recommended that the tilt be 20º to 25º.
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).

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

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 45º in either direction for 2D screens and 35º 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 35º 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 130wº in the vertical field of view, with 20º of that field below the horizon line of the reference seat and 110º above it 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.
7.20	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.
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

[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.

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 180º in the horizontal plane and 120º 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 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.

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

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

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 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.

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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.

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.

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

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

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.

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.

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

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 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 20º 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.

[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.

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.

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

ATTACHMENTS

DISCUSS Proceedings

A: Glossary
B: Colloquium Agenda
C: Bibliography

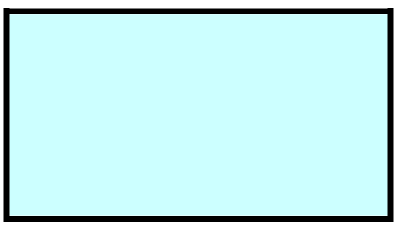
GLOSSARY

DISCUSS PROCEEDINGS

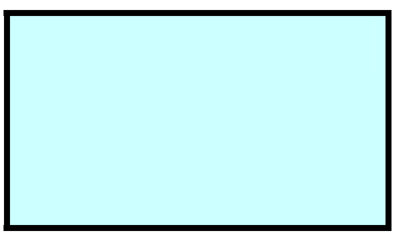
ATTACHMENT A

Aspect Ratio: An aspect ratio is a numerical way of describing a rectangular shape, like the screen. Professional cinematographers prefer a single number to describe screen shapes and refer to the 4:3 television ratio as 1.33:1, or just 1.33.

Wide Screen: sometimes available in conventional movie theaters –2.35:1



Conventional Cinema: for Hollywood movies – 1:85:1.



HD TV: The aspect ratio of HD televisions is 16:9, or 1.77:1

Giant Screens: The aspect ratio for IMAX classic films as well as of standard televisions, which before HD, were 4:3. This means that the picture is 4 "units" wide and 3 "units" high. Professional cinematographers prefer a single number to describe screen shapes and refer to the 4:3 television ratio as 1.33:1, or just 1.33.

Classic giant screen movies and screens usually seen in museums have an aspect ratio of 1.33.

The challenge for giant screens (GS) is that digital cinema projector chips have the same aspect ratio as conventional movies – 1.85. To be able to project both in a giant screen theater, there are currently two solutions: 1) use two overlapping or tiled projectors to fill a 1.33 screen, or 2) use only the middle 70% of the digital cinema projector chip when showing a movie with a 1.33 aspect ratio using a 1.85 projector. Current conventional wisdom is that there is not enough of a market to develop a 1.33 chip.

Immersive Experiences: Experiential theater works through the careful orchestration of multiple sensory inputs and through the equally important removal of reminders of the actual architecture and its machinery. The National Research Council's study on informal science learning found that "The scale and setting of a giant-screen film may result in a uniquely immersive experience compared with other screen experiences. Because of the large frame size and extremely high resolution of the film, this technology immerses viewers into the projected image, whether photographed with special cameras or computer-generated."

Experiential theaters use dimensional and surrounding media technologies and architecture to create the illusion of being inside the action/frame. In conventional movie theatres, a rectangle inside the field of view from the reference seat separates the program from the audience, just as a proscenium arch separates the actors and stage set from the audience. A GS theater is designed for immersion by minimizing this separation, and should be marketed and perceived as an extraordinary immersive experience.

Answer Print: A color-corrected film print made Print directly from the cut film negative. It is also the culmination of the creative color timing process, where final creative approval is granted before the film is duplicated for release.

Common Acronyms:

ASTC: Association of Science-Technology Centers

DCDM: Digital Cinema Distribution Master. A master set of files that have not been compressed, encrypted, or packaged for Digital Cinema distribution. The DCDM contains essentially all of the elements required to provide a Digital Cinema (DC) presentation.

DCI: Digital Cinema Initiatives, LLC, an organization formed in March 2002 by the seven major Hollywood studios (Metro-Goldwyn-Mayer, Paramount Pictures, Sony Pictures Entertainment, 20th Century Fox, Universal Studios, Walt Disney Company, Warner Bros.) to establish a specification for the architecture for digital cinema systems.

DCP: Digital Cinema Package, the set of files that are the result of the encoding, encryption and packaging process.

DIGSS: Digital Immersive Giant Screen Specifications is a process intended to help giant-screen theaters transition from film to digital projection while maintaining the superior image quality that has characterized the industry since its inception in 1970. It is an open process modeled on the Digital Cinema Initiatives that guided the commercial cinema industry through its conversion to digital projection.

DISCUSS: Digital Immersive Screen Colloquium for Unified Standards and Specifications convened giant-screen industry leaders and technical experts from June 14– 16, 2010 to develop a draft of the DIGSS.

DLP™: Digital Light Processing (a trademark of Texas instruments)

Dome Master: The program exchange protocol in the fulldome field

Fulldome: The planetarium world's term for a dome theater that uses one or more digital projectors to cover the entire dome. Contrasted with traditional analog planetariums, which used electro-mechanical star projectors and special effects projectors.

GSCA: Giant Screen Cinema Association

IPS: International Planetarium Society

JPEG: Acronym for Joint Photographic Experts Group, the international body that developed the JPEG 2000 standard.

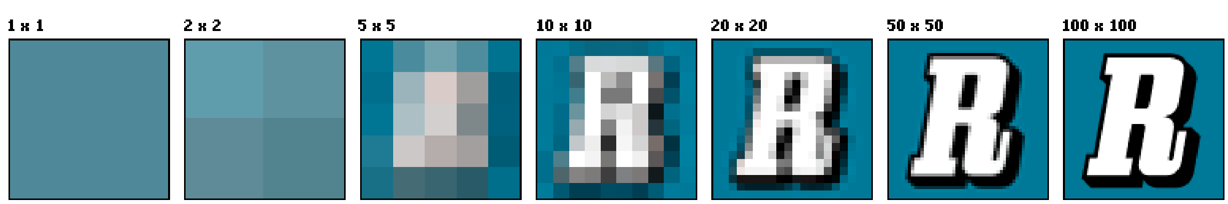
LCoS™: Liquid Crystal on Silicon (a trademark of Brillian Corporation)

Metadata: Data about data or data describing other data. Information that is considered ancillary to or otherwise directly complementary to essence. Information that is useful or of value when associated with the essence being provided.

Reference Seat: The real or imagined center seat in the center row of the seating area.

Also see the Glossary Terms from Section 10 of the DCI Digital Cinema System Specification v 1.2

Pixels: A *pixel* is a dot of light on the screen, and it is the smallest visual unit of a projector of a certain *resolution*. The more pixels on the screen (i.e. smaller pixels), the higher the resolution, as illustrated in this sequence from 1 pixel/square to 10,000 pixels/square:



Pixel illustration downloaded on 1/26/11 from http://en.wikipedia.org/wiki/File:Resolution_illustration.png

Resolution – 2K or 4K: 4K is an emerging standard for resolution in digital film and computer graphics. The name "4K" comes from its approximately 4,000 pixels of horizontal resolution (or 2,000 pixels for 2K). The terms 2K or 4K describe the horizontal resolution, as opposed to home televisions, which refer to resolutions of 720p and 1080p, which both stand for the number of vertical pixels.

Digital Projectors: There are currently two types of projectors for digital cinema: Digital Light Processing (DLP) and Liquid Crystal on Silicon (LCOS). The DCI specification for digital projectors calls for two levels of playback to be supported: 2K (2048×1080) or 2.2 million pixels at 24 or 48 frames per second, and 4K (4096×2160) or 8.85 million pixels at 24 frames per second. A 4K DLP projector will be available in early 2011; LCOS 4K's are on the market already, but are not as bright.

Three manufacturers have licensed the DLP Cinema technology developed by Texas Instruments: Christie Digital Systems, Barco, and NEC. As of 2009, there were more than 6,000 DLP-based Digital Cinema systems installed worldwide, 80% located in North America.

Early DLP projectors, which were deployed primarily in the U.S., used limited 1280×1024 resolution or the equivalent of 1.3 MP (megapixels). They are still widely used for pre-show advertising but not usually for feature presentations.

The other technology is made by Sony and is labeled "SXRD"(LCOS) technology. The projectors, SRXR220 and SRXR320, offer 4096 x 2160 (4K) resolution and produce four times the number of pixels of 2K projection.

Compatibility Standards: **DCI Compliance (exchange protocol for conventional digital movie theaters).** The Society of Motion Picture and Television Engineers began work on standards for digital cinema in 2001. Digital Cinema Initiatives (DCI) was formed in March 2002 as a joint project of many motion picture studios (Disney, Fox, MGM, Paramount, Sony Pictures Entertainment, Universal and Warner Bros. Studios) to develop a system specification for digital cinema. Giant screen theaters must have projectors that comply with the DCI standards if they want to show current Hollywood movies. DCI standards are not necessary for showing traditional museum-oriented, classic giant screen films. DCI standards are concerned with protection against piracy, calling for a standardized method of picture encoding.

DIGSS 1.0 Standards and Compliance (exchange protocol for GS museum theaters): These standards (some of which are provisional) for digital giant screen theaters emerged from a colloquium of Giant Screen professionals (DISCUSS) held in 2010 and hosted by the White Oak Institute with NSF support. DIGSS 1.0 is built on DCI, specifying additional levels of quality and size to meet museums' need for an immersive learning environment. Some DIGSS 1.0 specs are aspirational, as technologies are not yet equal to analog film.

Potential systems integrators can be asked to come as close to the DIGSS standards as they can. As this is a moving target, we want a flexible arrangement with a flexible vendor.

Giant Screen : The GSCA has adopted definitions for what theaters qualify as a GS theater that can use their Screen "Bigger, Bolder, Better" certification and marketing program:

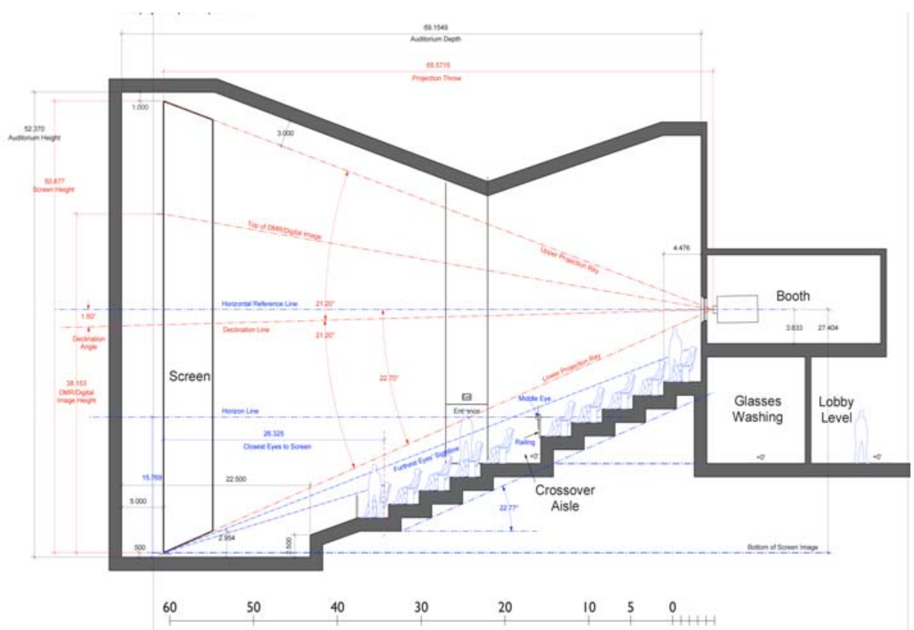
- 70 feet (21.3 meters) wide, or
- 3,100 square feet (288 square meters) in total area for flat screens, or
- 60 feet (18.3 meters) in diameter for domes, and
- Place all seating within one screen width of the screen plane

Classic and DMR® Films:

Classic: Classic films are those that a) are produced specifically for giant-screen theaters, b) run an hour or less, and c) have learning objectives, often using science, technology, engineering, or math (STEM) content.

DMR®[1]: Hollywood blockbusters re-mastered for IMAX (digitally re-mastered Hollywood studio films), such as *Avatar: The IMAX® 3D Experience*.

Theater Geometry: DIGSS Compliant



This section of the Peoria Riverfront Museum's GS theater shows the sightlines of an eye-filling immersive experience and complies with DIGSS' theater geometry specifications.

[1] DMR® and IMAX® are registered by the IMAX Corporation

Agenda: DISCUSS Colloquium

DISCUSS Proceedings

Attachment B

Monday, June 14, 2010

Start	Duration		
1:00 pm		Check-in available at the Harbor Light Inn (#2) and the BYC (#4)	
4:00		Welcome and Registration Packets	All
	5 min	Welcome and Opening Remarks	Welch
	10 min	Introductions and Acknowledgements	Stahl
	5 min	GSCA Role; Marketing Recommendations	Mensforth
4:30		Briefings:	
	10 min	1a: Evaluation Process and Front-end Findings	Fraser
	20 min	1b: Colloquium Purpose and Prior Knowledge Review	Jacobsen
	20 min	1c: Digital Cinema Initiative: A Case Study	Ordway
5:30	50 min	Questions, Group Response, and Interaction	All
6:20	5 min	Marblehead Map and Logistics	Robison
6:30		Break (Hotel check-in if not done earlier)	All
7:00		Meet for cocktails and beverages (Cash Bar)	Optional
7:45		Walk to The Landing Restaurant	
8:00		Group Dinner (Cash bar, dessert or coffee)	All

Tuesday, June 15, 2010

		B & B Breakfast	
8:45 am		Room Opens (coffee)	
9:00		Briefings:	
	12 min	2a: Research on Learning in Immersive Environments	Fraser
	7 min	2b: Theater Geometry	Becker
	15 min	2c: Digital Playback (Projection and Audio) Technologies; Fulldome and Dome Master	Lantz
9:45	45 min	Questions, Group Response, and Interaction	All
10:30	15 min	Blackberry Break – Coffee and biscotti	

10:45		Briefings:	
	12 min	3a: Digital Distribution Technologies and Security Recommendations	Oran
	16 min	3b: Digital Recording (Capture) Technologies and Analog Library Conversions	Reyna
11:15	45 min	Questions, Group Response, and Interaction	All
12:00 pm		Briefings:	
	9 min	4a: Data and Trends: GS and Fulldome Inventories	Hyder
	16 min	4b: Current and Potential Future Business Models	Stahl / Peterson
12:30	45 min	Questions, Group Response, and Interaction	All
1:15		Lunch Break and Walk to Marblehead Arts Association	
2:00	2-90 min sessions	Break-out Teams per assignment: Edit proposed standards and frame Phase 2 trial tests – 1st half	
		1. Theater geometry/Playback (JK, JF, JWJ, DC)	Becker/Lantz
		2. Recording/Distribution (DD, GM, WO, VK)	Reyna/Oran
		3. Business model (JH, DK, TM, SW, MK, TS)	Stahl/Peterson
3:30		Break	
3:45		Break-outs – 2nd half – switch to your choice	
5:15 +/-		Adjourn	
6:30		Garden Reception	All
Later		Open Dinner if you wish	On your own

<u>Wednesday, June 16, 2010</u>

		B & B Breakfast	
8:45 am		Room opens (coffee)	
9:00	10 min	Theater Geometry/Playback Team Recommendations	Team Captains
9:10	50 min	Questions, Group Response, and Interaction	All
10:00	10 min	Recording/Distribution Team Recommendations	Team Captains
10:10	50 min	Questions, Group Response, and Interaction	All
11:00	15 min	Break – coffee and biscotti	All
11:15	10 min	Business Model Team Recommendations	Team Captains
11:25	50 min	Questions, Group Response, and Interaction	All
12:30 pm	75 min	Revise the standards and questions using Online Forum	All

1:00	15 min	Working lunch served– sandwich boxes	All
1:15	45 min	Revise the standards and questions using Online Forum	All
2:00	40 min	Summarize next steps, research agenda, and process	All
2:40	10 min	Evaluation Process	Fraser
2:50	5 min	Conclusions and Thanks	Jacobsen/ Stahl
2:55	5 min	Closing Remarks	Welch
3:00		**Adjourn formal sessions**	

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