# SMPTE Technology Committee on Digital Cinema—DC28: A Status Report

**By R. M. Rast**

*During the past year, a new SMPTE technology committee has been active, DC28, the Technology Committee on Digital Cinema. This report discusses its work and progress.*

*Most conclude digital cinema is the future of the consumer movie theater experience. Indeed, numerous press reports claim its imminence, and D-Cinema projection can be seen in several dozen theaters in the U.S. and abroad. However, what has been in the theaters has been in the nature of demonstrations of partial systems. DC28's activity applies to an overall end-to-end system for theatrical release of motion pictures, replacing the existing 35mm distribution model. The entire system must be defined, designed, proven in, and standardized. The work needed extends well beyond that which any one organization, including SMPTE, can provide. However, SMPTE's standards work is essential, and it is now well underway.*

## Background and Charter

DC28 started as the Task Force on Digital Cinema in the fall of 1999. A brief meeting of the task force was held at ShowEast in October. A charter was adopted, eight working parties agreed, and Curt Behlmer appointed chairman. Bob Rast and Mark Hyman were later appointed vice-chairman and secretary, respectively.

Subsequently it was decided that the task force should instead be a technology committee and that the working parties should be study groups. Thus DC28 is a due process committee, but the work is currently being undertaken in the non-due process study groups. As specific standards and practices needs are identified, the work will be assigned to due process working groups that will be formed if not already existing.

A first, joint meeting of the new committee and its study groups was held January 13, 2000 at the Universal Hilton in Los Angeles. With that organizing meeting, DC28 was up and running. The study groups have been active since, meeting approximately monthly. That is an aggressive schedule for SMPTE study groups! The meetings are usually held in the Los Angeles area and tend to cluster into what has become known as the monthly "SMPTE Week."

DC28 allows technologists from across the motion picture industry, i.e., production, post-production, distribution, exhibition, and equipment manufacturers, to come together in "neutral territory" to identify and address technical issues in the development of digital cinema. While the goal of the activity is to ultimately identify and write appropriate standards and recommended practices, the initial effort has been to assess the situation and determine how to proceed.

The DC28 charter is to:

1. Provide an industry technical forum for digital cinema (D-Cinema).
2. Identify key systems and technology issues.
3. Develop a recommended approach to D-Cinema standards.
4. Identify, establish and coordinate necessary study/working groups to achieve overall D-Cinema objectives.
5. Ensure, through the resulting standards and recommendations, interoperability, compatibility, performance and support for future innovation.

## Scope of Work

For the purpose of simplifying a still very complicated task, DC28 focuses on standards and practices for digital cinema distribution and exhibition; that is, production and post-production are not included. What remains is still the Himalayas, even though Mount Everest may not be included. The input to the digital cinema system, from post-production, is a set of master signals in digital form, video, audio, and associated and accompanying data. The output of the system, at the movie theater, is the presentation to the consumer.

## Work Approach

The work has been initially divided among eight study groups:

DC28.1 Steering and Systems
Curt Behlmer, chair
Bob Rast, vice-chair and secretary

| | | |
|---|---|---|
| DC28.2 | Mastering | Jerry Pierce, chair<br>Howard Lukk, vice-chair<br>Bill Hogan, secretary |
| DC28.3 | Compression | Matt Cowan, chair<br>Mike Tinker, vice-chair<br>John Ratzel, secretary |
| DC28.4 | Conditional Access | Chuck Harrison, co-chair<br>Bill McMannis, co-chair<br>Phil Lelyveld, secretary |
| DC28.5 | Transport and Delivery | Steve Storozum, co-chair<br>Chuck Garsha, co-chair<br>Ira Lichtman, secretary |
| DC28.6 | Audio | Garry Margolis, chair<br>David Gray, vice-chair<br>Jim Ketcham, secretary |
| DC28.7 | Theater Systems | John Wolski, chair<br>Michael Karagosian, vice-chair<br>Kevin Wines, secretary |
| DC28.8 | Projection | Al Barton, co-chair<br>Dave Lund, co-chair<br>Dave Schnuelle, secretary |

Part of the thinking in creating the groups related to a desire to define the overall system as a series of system elements. Open standards facilitate a selection of suppliers for different system elements and allow a choice of suppliers for any given system element, while maintaining interoperability. In support of that, the study groups need to define exactly what needs to be standardized. For example, is it sufficient to only standardize the interfaces between elements? Also, the system elements ultimately standardized may not conform precisely to the groups as defined. Further, since the standards are voluntary, any particular vendor may provide products in which more than one system element is integrated, with the interface between those elements being non-conforming and buried inside the implementation.

Two ad hoc groups have subsequently been created. The first is the Colorimetry Ad Hoc Group, chaired by Fred Van Roessel, jointly created by the Mastering and Projection Study Groups. In the tradition of ad hoc groups, we'd like to think the colorimetry group will complete its task and disband.

More recently a Packaging Ad Hoc Group, chaired by Chuck Garsha, was created to acknowledge the importance of the package of signals that is transported, but realizing that the details of the package go beyond the responsibilities of any one group. Part of the task of the group is to help us determine its future, i.e., become a study group, a working group, or disband.

We have endeavored to achieve a broad participation of technologists across the industry and from key industry associations and believe we have done so. In some cases technologists outside the industry have been asked to participate to help with technologies that will be introduced with digital cinema, e.g., digital signal security. There are over 200 people registered for DC28. Attendance at study group meetings can vary significantly, from as few as 5 to as many as 100.

Recognizing that the broad industry needs to be included and kept informed of where D-Cinema is heading, there is a significant outreach effort. DC28 presentations are made at many industry conferences, including, IBC, InfoComm, ITEA, ITS, ShowEast, ShoWest, SMPTE, etc. Meetings have also been held with members of the creative community, e.g., ASC and DGA, to inform and to listen to needs. We are attempting to ensure an inclusive process.

## Progress of Study Groups

Digital cinema is a complex system with substantial interaction between its subsystems. A simplified view of D-Cinema video signal flow in the context the study groups is shown in Fig. 1. Direct connection of the Mastering output to the Display input should be possible, bypassing the intermediate elements. While functionally the audio signal flow is the same, audio mastering, compression and display/performance are managed within the Audio Study Group.

## DC28.1—Steering and Systems Study Group

Figure 2 is a simplified functional block diagram generated in DC28.1. DC28.1 deals with systems, coordination and administrative issues, and is comprised of the chairs and vice chairs of DC28 and its study groups. The box colors indicate study group responsibility. From the diagram it is clear that the conditional access subsystem interacts with almost all of the other subsystems.

The work of the study groups has been documented in

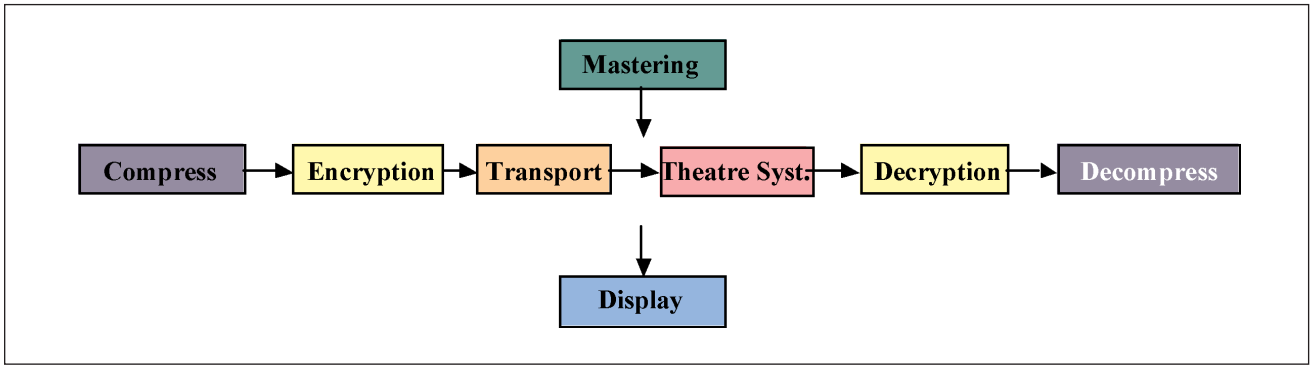



*Figure 1. Overall D-Cinema video flow (simplified).*

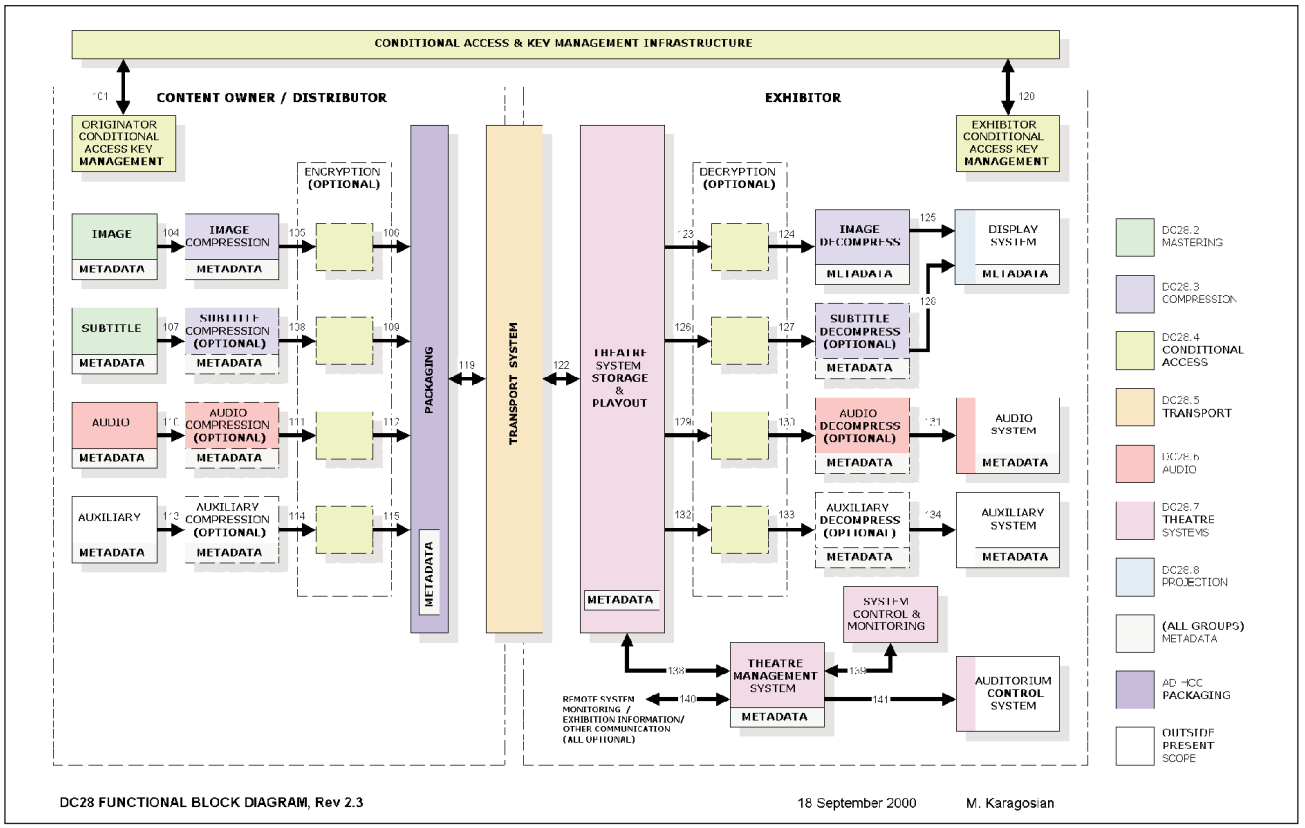



*Figure 2. Overall system architecture.*

interim reports prepared by each of the groups. What follows in this section briefly summarizes some of the results. Readers are also reminded that study group findings are preliminary. Any resulting standards, and underlying assumptions, will be vetted in due process working groups.

## DC28.2 —Mastering Study Group

The start of the imaging process is mastering. DC28.2 deals with the visual image. The goal set by Mastering is that digital cinema picture quality available to the consumer in his local theater should meet or exceed answer print presentation quality now achieved in the controlled environment of a studio.

"Film Centric" and "Data Centric" processes have been defined. Film Centric assumes traditional cut negative procedures for the assembly of feature films, while Data Centric for all-digital assembly of features. In either case, the starting point for the D-Cinema process is a Digital Source Master (DSM). In a Film Centric case, conversion to digital is necessary to obtain a DSM. The DSM is described as two layers: the digital negative which is the exact captured file, and a correction layer that indicates changes for color correction, cropping, gamma, and lift. All necessary distribution formats, i.e., film, video (NTSC, PAL, and HDTV), and digital cinema, are derived from the DSM. Recommended practices for the DSM may be appropriate to facilitate exchange in production and post-production.

The Digital Cinema Distribution Master (DCDM) is derived from the DSM. Figure 3 illustrates the flow. The DCDM is the file that is distributed to the theaters for display. It is the most important product of the DC28.2 committee. This file format must be a worldwide standard with acceptance equivalent to 35mm film.

The specification of DCDM will be a layered set of standards. Specifications include color space, bit depth, pixel format, frame rate, transport protocol, and the physical interface to the projector/compression engine. The layers differ as to pixel format for higher resolution images. The study group proposes:

- Color space: A new set of primaries has been defined that includes all the human-visible color space. (This color space will also apply to the DSM.)
- Bit depth: Each color is described by a 12-bit "log" number. The conversion from linear to "log" is defined.

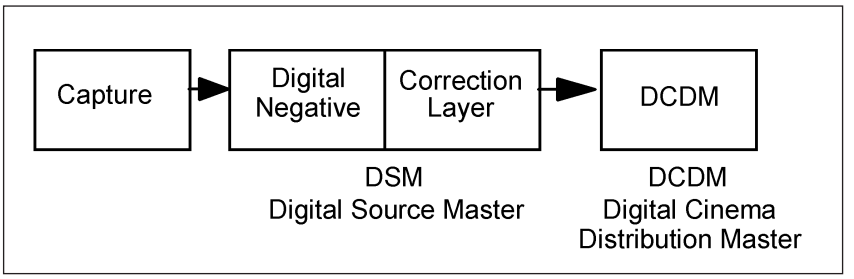



*Figure 3. New architecture.*

• Full bandwidth color: Each pixel is described as three color values (RGB) without color subsampling.

• Frame rate: Must include 24 frames/sec. Other frame rates (12, 16, 25, 30, 48, 50, 60, 72) may be part of some of the profiles. The key frame rates for D-Cinema applications are 24 and 48.

• File protocol is based on a file-based format with streaming capabilities. The DPX format will be used for all profiles.

• Pixel format: A difficult and controversial topic, with consensus not achieved. A set of profiles has been defined. The number of the profile conveys the number of Megapixels in a single frame of the format. For instance, profile DCDM 5.5D would be 1536 x 3680, with approximately 5.5 Megapixels. The discussion continues.

## DC28.3—Compression Study Group

DC28.3 has identified the following key requirements for a D-Cinema video compression subsystem:

• Visually lossless - the original uncompressed image is indistinguishable from the compressed/uncompressed image

• Scalability - will support higher and lower resolution images (resolution in spatial and bits per pixel).

• Transport compatibility - compatible with all envisioned transport mechanisms.

• Downward compatibility - compression evolution must support previously installed decompression hardware to avoid hardware obsolescence or multiple inventories at the distributor to support one title.

• Compression and decompression of live events is outside the scope of the digital cinema compression study group.

The Compression group recommends that its study group transition into a working group, with the following mandate:

• Write specific standards for the data formats and physical interfaces to the encoder (compression) and decoder (decompression).

• Develop the test procedure that would be used to evaluate potential compression approaches.

• While it may not lead directly to standards, the working group should continue to look at algorithm requirements and quality measurements for compression.

• Maintain a liaison with MPEG's digital cinema working group. A liaison has been formed and a co-chair of the MPEG group participates actively with DC-28.3.

## DC28.4 —Conditional Access (CA) Study Group

The conditional access subsystem allows access to the content by legitimate exhibitors, in accordance with contractual requirements, while preventing access or misuse by unauthorized parties. Having considered the available methods for protecting content, i.e., physical control of access, encryption of digital media, and legal recourse, the CA Study Group has focused on encryption, with some consideration of methods of detection of authorized access.

The CA group recommends that the following standards be adopted by SMPTE, adopting by reference where feasible:

• Cryptographic packaging convention.

• Key management protocols (distribution).

• Encryption algorithms.

• Signature algorithms for key management and authentication.

• Public key infrastructure.

• Conditional access protocols.

The CA group additionally recommends that SMPTE adopt the following engineering guidelines and recommended practices:

• Intra-theater content protection.

• Key management protocols (intra-theater).

• Auditing practices.

• Response to system compromises.

The CA group has identified watermarking and fingerprinting as requiring further study. Organizationally, it recommends creation of a Conditional Access and Content Protection Working Group and the convening of a Security Experts' Group.

## DC28.5 —Transport and Delivery Study Group

DC28.5 has evaluated the processes involved in delivering digital cinema information from the content owner or distributor to the theater from a "transport-agnostic" point of view. That is, the same processes should be workable whether the digital cinema distribution master is delivered across terrestrial data communication networks, over satellite distribution systems, or even by the same means that today's prints are delivered via courier services. Figure 4 illustrates this concept, showing some suggested protocols.

There is a commonality to the processes involved in all of these delivery methods, each following the same sequence :

• Transaction Phase

• Initiation Phase

• Transfer Phase

• Termination Phase

In the Transaction Phase, a contract is established between the sender and recipient, specifying the terms of the transactions and credit information. The Initiation Phase establishes the means of delivery, requiring exchange of transport system resource management information to set up the transfer. The Transfer Phase results in delivery of the digital cinema distribution master plus any additional information required at the theater. Delivery time and content quality guarantees must be met during the Transfer Phase. Finally, the Termination Phase checks the content integrity, provides a delivery receipt, and terminates the interaction between sender and recipient. The whole process needs to be designed to deliver large quantities of data to multiple destinations with the time urgency of feature distribution.

There are two different communication channels in play within a digital cinema transport system, namely, the content channel and the management channel. Content will be transmitted in one direction over a relatively high-bandwidth channel and may be sent to a single destination or simultaneously to multiple destinations. Management information will travel over a lower bandwidth channel and will be a two-way interaction between the content

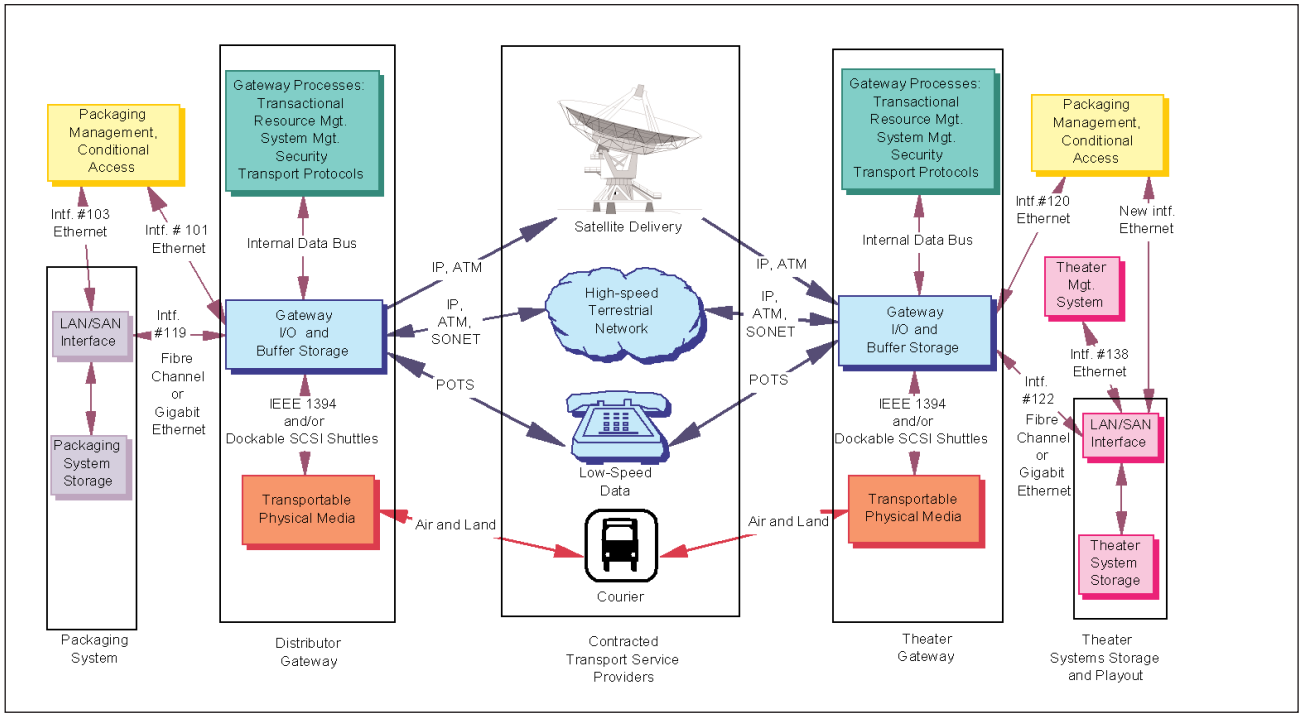



*Figure 4. Transport system functional diagram.*

owner or distributor and the theater. This channel may be open before, during, and after the content transfer to permit ongoing information exchange to enable changes in screen/auditorium, length of engagement, and number of showings per day, for example.

Transport has exposed a number of issues that will require further work by SMPTE. The most significant of these was the realization that information destined for transfer must be packaged at the source in some fashion that is consistent with the needs at the receive end of the transport system. For example, it may be acceptable if some pieces of information precede others in arrival at the theater, or it may be required that all information arrives at the same time. Also, the process that describes how all of the relevant information is gathered and combined into a common package must be established. Consequently, it was recommended that an ad hoc group on packaging be established to study the issues involving grouping data together for transport.

Other recommendations by the Transport group include:

- Promote interoperability by using OSI Model to guide future work.
- Continue the study group to examine operational and performance requirements, management systems, and application layer protocols.
- Transition to a working group to draft standards for the interfaces between digital cinema packaging transport and theater subsystems.
- Establish a dialogue with the professional groups such as Video Services Forum, SCTE, SBE, ANSI, and EBU working in these disciplines with the intent of sharing knowledge.

More specifically, the Transport group suggested that the following items should be evaluated during the standardization process to determine if recommended practices are appropriate for documenting methods for achieving interoperability and required functionality:

- File formats suitable for content transfer.
- SMPTE wrapper and container for physical and network content transport (content mapping).
- Transport protocols suited to digital cinema requirements for content transfer.
- Management of a variety of digital cinema transport gateway functions, including:
  - Configuration
  - Error/fault detection and correction
  - Flow control
  - Performance assurance
  - Security
  - Account tracking
- File systems and file management pertinent to the transport gateway.

## DC28.6—Audio Study Group

The scope of the Audio Study Group covers all tasks related to audio in the digital cinema process. The study group's purview begins after the completion of traditional postproduction editing and mixing tasks (now largely digital) and extends to the delivery of audio to the theater playback system. Audio tracks produced on the traditional mixing or dubbing stage are the input to this system element. The audio Digital Source Master (DSM/A), i.e. "the mix," after appropriate mastering, becomes the audio Digital Cinema Distribution Master (DCDM/A). The DCDM/A may then be compressed, encrypted, packaged for transport, moved to the storage in the theater, unpacked, decrypted, decompressed as necessary, and reconstituted as a transparent copy of the DCDM/A ready for reproduction in the theater, as allowed by the condi-

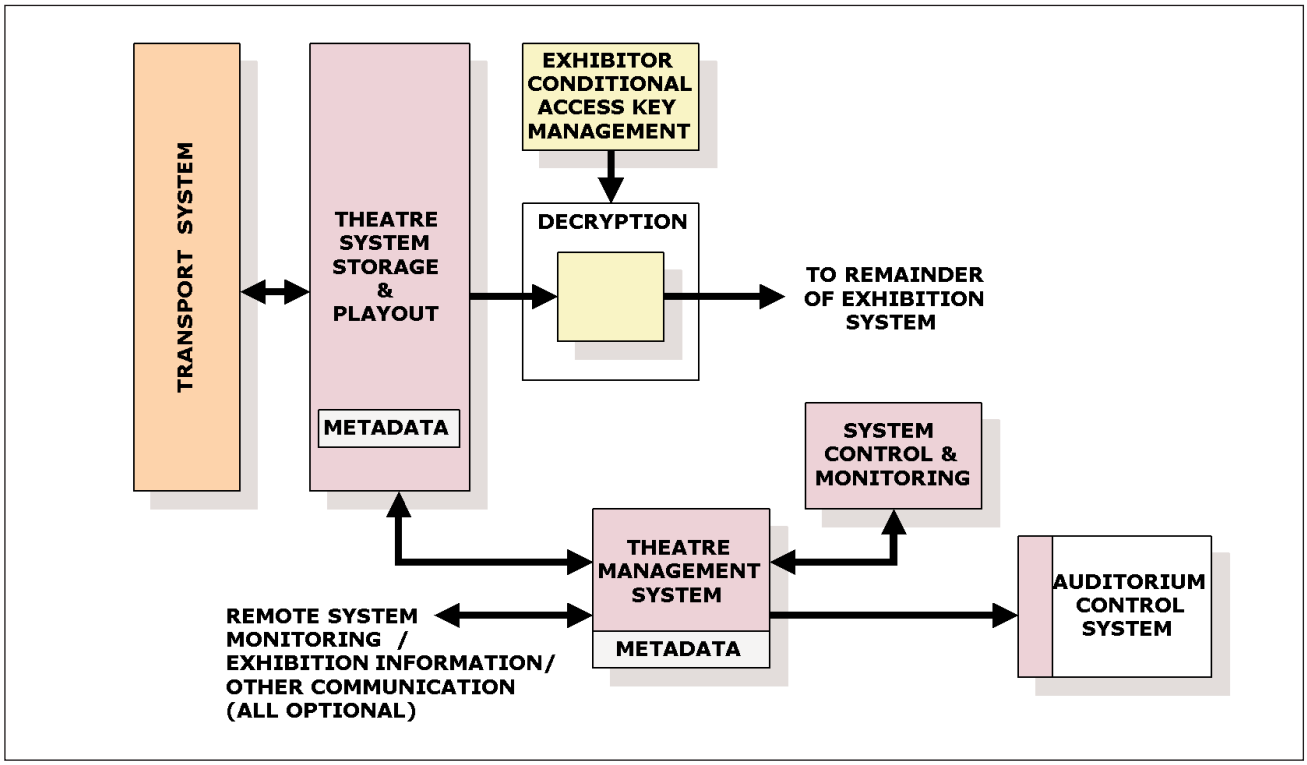



*Figure 5. Theater system functional block diagram.*

tional access keys provided by the content owner.

The Audio group has identified a need for the following standards and recommended practices:

- Input interface(s) to the processes which create the DCDM.
- File formats of the DCDM essence and metadata.
- Contents and format of metadata within the DCDM.
- Output interface(s) of the processes which create the DCDM.
- Packaging of the DCDM and metadata for delivery.
- Splice granularity required and potential need for alignment with image splice granularity.
- The means by which audio, image, text, metadata and other files are sequenced and synchronized within the DCDM, whether distributed in whole or parts.
- The means by which audio, image, text, metadata and other files are sequenced and synchronized when played back in the theater.
- Mapping of audio channels to theater loudspeakers.
- Physical interfaces to theater playback systems.
- Tolerance for bit errors from DCDM to playout.
- Tolerance for sound quality changes during post-authoring processes.

## DC28.7—Theater Systems Study Group

The Theater Systems Study Group is researching the requirements, from a systems perspective, for the operation and maintenance of a digital motion picture theater, along with those issues that relate to interoperability and extensibility of system elements. Figure 5 is a functional block diagram of the theater system.

The group set out by identifying key elements of a present day cinema operation. Among the elements, four were described as strategically significant and a subcommittee for each was formed:

- Automation
- Metadata
- Playlist
- Monitoring

The DC28.7 Theater System Study Group acknowledges that digital cinema technology should not negatively impact current theater business and operational practices. The group recommends several functional issues for which standards should be established:

- Supervisory monitoring and control method.
- Networks for transporting data within the theater.
- Metadata.
- Electronic communications between content distributors and theater systems.
- Transmission of data between system components.

Theater Systems further recommends that the following working groups be formed.

- Application Protocols Working Group to address interoperability concerns at the application protocol level for digital cinema, including standards and recommended practices related to SNMP and other possible control and monitoring methods; control-related elements such as "playlist" protocols; and the application of protocols for electronic delivery of content and electronic communication between distributor and exhibition system.
- Networks Working Group to address standards and recommended practices concerning network applications within the digital cinema exhibition system. The group will handle the lower layers of the networks as opposed to the Applications Protocols Working Group, which will handle the upper communication protocols.

• Metadata Working Group to address and coordinate metadata standards and recommended practices for digital cinema, including those of production, distribution, and exhibition.

• Packaging Working Group. This group, among other tasks attributed to it by other DC28 study groups, will address standards and recommended practices for physical media associated with digital cinema exhibition, as well as the form for electronic storage of content for playback by the exhibition system.

## DC28.8—Projection Study Group

The Projection Study Group has covered issues including the physical projector, physical interfaces to mastering and theater systems, security of the projector and content it is displaying, and the display attributes that will be seen on the screen.

The study group recommends that it evolve into a working group to create standards in these areas:

1. Physical interface to the theater system.

2. Minimum display characteristics of the display device, e.g.:

• Have a display device with a minimum of 1K pixels vertically and 2K pixels horizontally.

• Accept content at a frame rate of 24 Hz.

These minimums do not preclude higher pixel counts or additional frame rates.

3. Minimum display attributes for the screen. The display attributes are the most critical aspects of the projection system. The goal is to provide electronic theatrical presentation that exceeds that of 35mm film exhibition. Some of these key attributes include:

• Minimum brightness of 12 fL.

• Sharpness.

• Uniformity (luminance and color).

• Geometry.

Definition of the whote point temperature needs more study.

## Outlook

As discussed above, DC28 is creating working groups to write standards for D-Cinema in those areas where the need is clear. The standards will be useful to companies wishing to make D-Cinema products. While doing so, DC28 will continue to examine the issues through study groups and ad hoc groups.

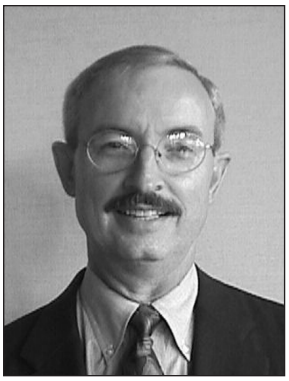
In a broader sense, when it comes to successfully developing and implementing D-Cinema, DC28 is necessary but not sufficient. There is a need for marketplace and laboratory testing, which will occur and help to further shape the standards needs. Finally, there are numerous business issues that must necessarily be resolved outside of SMPTE. Those business results will reflect back into the technology, and affect the industry standards.


## Acknowledgments

• To the participants in DC28 and its study groups who, through their efforts, have led to the progress reported here.

• The members of DC28.1 for assistance on this article, particularly Jerry Pierce, Steve Storozum, and Michael Karagosian for their extra efforts.

• Walt Ordway, Dick Stumpf, and Tom Scott for contributions as past, founding chairs of study groups.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Rast is vice-president of business development at Dolby Laboratories, San Francisco. He joined Dolby in September 1998 to lead the company's efforts in digital cinema. Development projects include digital cinema (D-Cinema), music delivery, and expanding usage of Dolby technology in computers and games.

Previously, Rast was vice-president, technical business development, for General Instrument, where he focused on HDTV and coordinated GI's participation in digital television standards setting. Following GI's historic proposal for an all-digital HDTV system, in 1990, Rast led the effort to make it the U.S. broadcast standard. When the remaining four competing systems merged into the Digital HDTV Grand Alliance in 1993, he became one of its leaders. The Grand Alliance system is the basis for the DTV broadcast system now being deployed in the U.S. and other countries.

Rast holds 13 patents. He was a co-recipient, in 1980, of the RCA David Sarnoff Team Award for Outstanding Technical Achievement. In 1997, he accepted, on behalf of GI, an engineering Emmy awarded to the Grand Alliance member companies for contributions to the broadcast DTV standard. His contributions to HDTV and the Grand Alliance are described in Joel Brinkley's 1997 book, *Defining Vision.*

Rast holds a BSEE from the University of Maryland and attended graduate school at the University of Pennsylvania.