Issue 4 • March 2007

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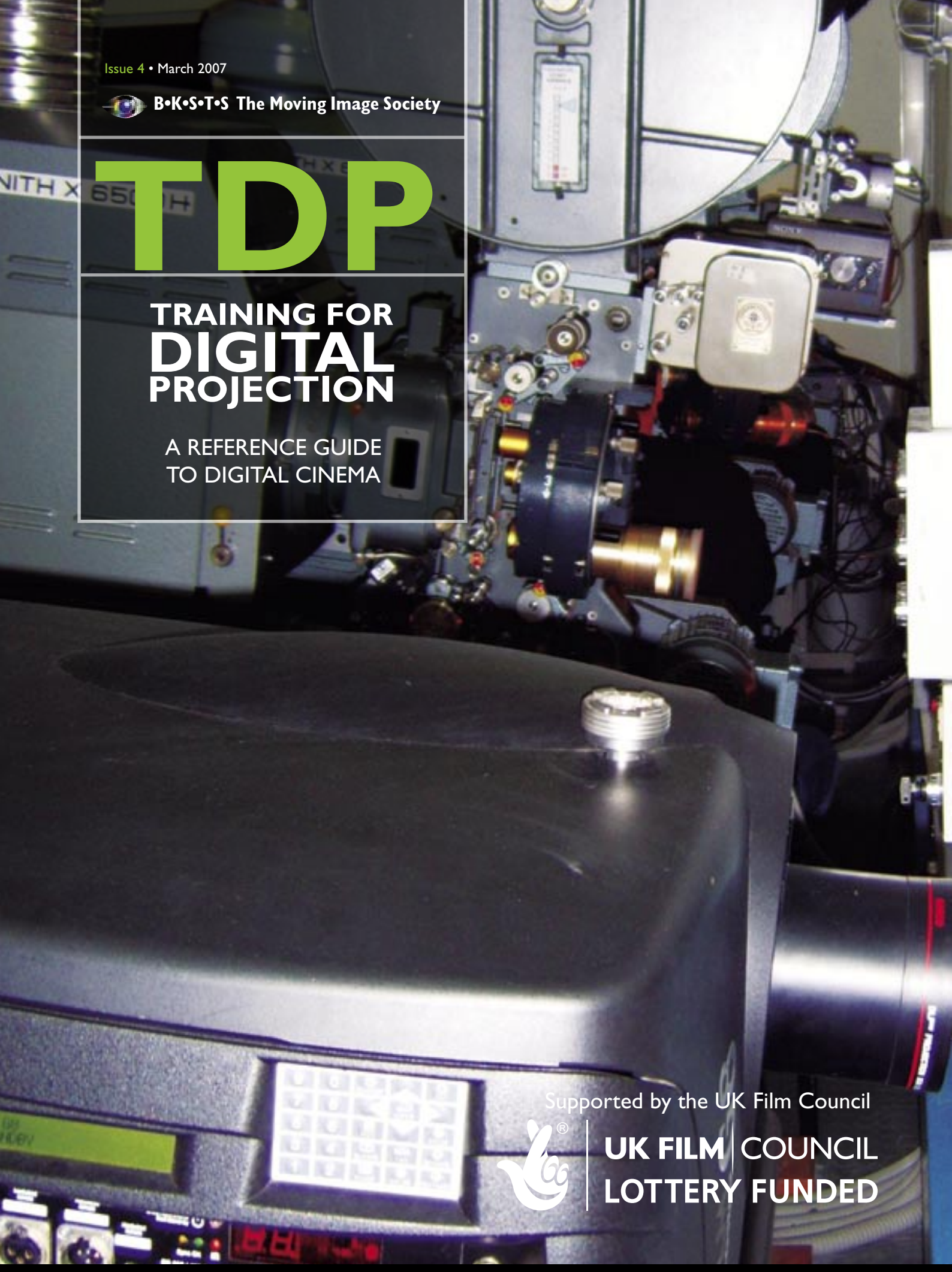
# TDP

## TRAINING FOR DIGITAL PROJECTION

A REFERENCE GUIDE TO DIGITAL CINEMA



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**A supplement to Cinema Technology**
**The leading specialist publication for cinema industry professionals**

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The Society exists to encourage, sustain, educate, train and provide a focus for all those who are creatively or technologically involved in the business of providing moving images and associated sound in any form and through any media. The BKSTS works to maintain standards and to encourage the pursuit of excellence in all aspects of moving image and associated sound technology, in the UK and throughout the world.
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## CINEMA TECHNOLOGY

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***On the cover:***
*The old (film) and the new (digital) projection equipment in the new Sala Grande at the Venice Film Festival.*
*Photo by Dion Hanson - Cineman*

# Digital newsreel...Digital newsreel...Digital newsreel...

## DOLBY OFFERS ITS DIGITAL CINEMA MASTERING SOLUTION TO THE INDUSTRY

Dolby Laboratories has decided to make its Digital Cinema Mastering solution accessible to post-production facilities, laboratories, and cinema exhibitors. The Dolby® SCC2000 Secure Content Creator is a scalable mastering solution for JPEG 2000 digital cinema compression, encoding, packaging, and encryption purposes, and offers tools that have previously only been available via the Dolby Production Services Group, which has already used it to master over 50 digital cinema titles for major Hollywood and international studios.

The Dolby SCC2000 features many of the same tools used by the Dolby Production Services Group, and the unit will be offered as part of a complete equipment rental, training, and support package. The SCC2000 has a clear and simple graphical user interface which has shown itself to provide reliable performance in real-world use at Dolby mastering facilities.

The generation of real DCI packages that can play in all digital cinemas is critical to the success of the transition to Digital Cinema, and Dolby is committed to making that a reality around the world, continuing its tradition of providing the tools to filmmakers for producing the highest quality content for cinema playback.

The Dolby SCC2000's suite of software offers a complete set of tools needed to take a Digital Cinema Distribution Master (DCDM) and quickly produce final digital cinema distribution files, known as Digital Cinema Packages (DCPs), for easy distribution to cinemas.

As studios release more digital content in the JPEG 2000 format, postproduction and digital intermediate (DI) facilities need to be equipped with the proper mastering resources to create digital movie files for distribution to cinemas, and the Dolby SCC2000 addresses the emerging industry standards, including the JPEG 2000 image format. Dolby is also committed to support studios and exhibitors with the appropriate playback systems in accordance with the Digital Cinema Initiatives (DCI) specifications. The company is currently deploying JPEG 2000 upgrades to its more than 250 sites worldwide.

A scalable solution for all digital cinema content, the Dolby SCC2000 is designed to work as a stand-alone unit or integrated into current postproduction and DI systems, enabling efficient 2K and 4K JPEG 2000 encoding.

The option for generating secure keys offers key delivery message (KDM) creation and management via the Cosmos digital cinema database, operated by Dolby content-protection subsidiary Cinea.

## DTS TEAMS UP WITH DCL FOR DIGITAL CINEMA UPGRADE IN IRELAND

DCL is an Irish company which makes the bold claim that it aims to provide the world's first countrywide digital movie and advertising distribution network. DCL is supported by a team of technicians based in Thurles, Co. Tipperary, and works in collaboration with major Hollywood and European distribution companies and Irish cinema owners to deliver new digital movie releases to the cinema going public all over Ireland. DTS has announced that it has reached agreement with DCL to upgrade the first phase of DCL's Irish D-Cinema installation, and for both parties to work together to facilitate the wider rollout of Digital Cinema in Ireland.

DTS will upgrade DCL's existing network to ensure compliance with the latest studio requirements for release of Digital Cinema movie content. This will require meeting the JPEG2000 file format compatibility and security features defined in the DCI standard specification. DTS will also bring additional functionality to the network by introducing its management software toolset. This suite of tools is designed to make distribution and playback of D-Cinema movie content a simple and reliable process for both studios and exhibitors.

This critical upgrade will bring DCI to a level of compliance with the DCI specifications that is essential for the receipt and playback of D-Cinema movie content today, and puts the company on track to maintain the compliance levels that will be needed in the future.

DTS will work together with DCL to manage the upgrade, expansion and operation of the network, and both will work with local film distributors to acquire, prepare and deliver content to the screens.

The announcement reflects DTS' recent moves to develop its business as a specialist provider of solutions for digital cinema by separating its business into two autonomous divisions. DTS' European cinema business is developing flexible solutions to meet the needs of content owners and exhibitors in the transition to Digital Cinema.

DTS stress that they continue to support the needs of their existing DTS Digital Sound™ audio coding business, having demonstrated a commitment to the movie business over the years that will continue into the future.

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*DCL: www.digitalcinema.ie*

## TEN YEARS ON FOR DIGITAL PROJECTION

Incredible though it may seem, it was in 1997, ten years ago, that projector manufacturer Digital Projection began shipping what was claimed to be the very first high brightness 3-DLP projector, the POWER 4DV. The SVGA resolution unit was officially launched that April, at NAB, and produced 3,500 ANSI lumens, at a list price of $86,000. It won a Tommy Award for Technical Achievement, and set the wheels in motion for the coming of digital cinema projection.

Since then the company has gone from strength to strength, winning an Emmy® Award on the way. Digital Projection International (DPI) has just announced an agreement with UFO Moviez (part of the Apollo Group) to provide an additional 750 custom-designed DLP-based projection systems for cinema installations worldwide, the majority in India.

Expanding from an original projection order to equip 500 Screens, the partnership between DPI and UFO Moviez continues to strengthen and grow. The success story of UFO Moviez is unprecedented, and today, their deployment of D-cinema systems in India remains unrivalled. The cinema rollout has been so successful that UFO Moviez is expanding the model into new international markets with a number of very exciting projects starting up outside of their home country.

During the last 12 months while the first 500 systems were being deployed, the joint learning experience has been rapid and extensive. UFO Moviez has redesigned the Indian Cinema experience, supported and assisted throughout the process by DPI. Application understanding, system reliability, outstanding hardware and collaborative partnership have been at the core of the network's expansion, but ultimately it is the audience that dictates whether the digital revolution is a success. After more than 100,000 shows, 100% delivered by satellite, the audience reaction has been unanimously positive thus propelling this second stage of investment.

DPI receive daily feedback from the local distributor - Image Engineering, from the Indian audiences, and from their extensive training programs conducted country-wide. This feedback has provided a very good idea of what is required for success and has helped to further refine

the products to fully support the business model. The result of this collaboration has been a custom built and designed projector, 100% geared for UFO Moviez and the requirements of the market. Specifically, this experience gave rise to the new Morpheus 7000 HDi projector. This new DLP projector has been very well received locally, and has exceeded all expectations in blind viewings. Digital Projection has very high aspirations for this unit both in India and other countries world-wide. UFO Moviez and DPI together are committed to remain at the forefront of the digital cinema rollout.

Digital Projection equipment was recently chosen for a purpose-built theatre at Arizona State University, where a virtual space has been created, featuring a 260 degree immersive video screen system with 5.1 surround sound audio, and multiple shared resources. Seven Digital Projection HIGHlightPro SXGA+ projectors provide back-projected images.

AV integration firm Technology Providers Inc. (TPI) managed the project, with strategic partner Fakespace, an advanced visualization solutions provider and integrator. TPI dealt with power and structural issues, while Fakespace handled the projector and screen installations and system calibration.

The installation includes seven screens, and uses five-conductor coax, high-resolution RGB cable for all of the cable runs, situated under the theatre's raised floor system. Each projector has its own 20-amp power circuit.

A total of seven 100-foot-wide by 75-foot-tall VE Series Stewart Filmscreen projection screens provide the 260 degree viewing experience from the seven Digital Projection HIGHlightPro SXGA+ projectors, which have a short 15-foot throw. Digital Projection provided the special 1:1 short-throw lenses, which were made for 4:3 aspect ratio images.

The somewhat cramped conditions between the structural pillars of the building meant that the projectors had less than 6 inches of clearance, so special custom fan arrangements had to be built to ensure proper ventilation.

The projection system runs high-resolution graphics and video using an eight-node Dell PC cluster running on a Linux OS. A single PC is used for each projector, plus one master PC that serves as the main user interface. All of the PCs run into an Extron CrossPoint Plus 32x16 HVA matrix switcher that enables users to send signals from three MediaSonic media servers housing custom content.

Each Digital Projection HIGHlightPro projector provides 1400x1050 pixels, giving a total of nearly 10,000,000 pixels across the seven projection screens. The DLP projectors are stereo-ready, being capable of the higher 96 Hz refresh rate required for active stereo viewing, where a single projector can show both the right and left eye images. A StereoGraphics Projection ZScreen is mounted over the projector lens, and acts like a liquid crystal modulating panel that allows theatre users to view in stereo mode. Edge matching - the graphical adjustment of two images that appear as one when matched - is added between the screens to complete the experience. The system can also use an Intersense system to track the user's movement. Strips of overhead sensors allow the user to be tracked when wearing a head tracking device or holding a wand, so the user can apparently move within a presentation.

JBL Control 26C ceiling speakers powered by QSC CX254 amplifiers are used to provide quality audio for the presentations.

*Details: Enquiries@digitalprojection.co.uk*

## DIGITAL IN EVERY SCREEN - ODEON TRIALS MARK THE START OF THE NEXT PHASE IN DIGITAL CINEMA ROLLOUT

Well over 200 of the UK's 3300 screens have gone digital in the last couple of years, generally to the approval of all concerned. Distributors and operators of the majority of digital cinemas, which have only a single digital screen, have discovered that they can't make the best business use of the new technology, because when the time comes for a successful film to be moved from the digital screen in order to make room for the latest release, the cinema then has to ask for a 35mm copy so that the movie, which is still making money, can be shown in its other screens. This negates many of the business / commercial advantages of having had the original 'print' in digital form, and for some time now there has been a growing feeling that if digital cinema is to spread its wings to gain the maximum advantage, there will be the need to equip several screens per cinema with the currently very expensive digital projection equipment.

It is good to see, therefore, that the UKs largest cinema operator, Odeon, has decided to take the brave step of equipping every screen in two of its largest multiplexes, at Surrey Quays in East London and at Hatfield, Hertfordshire, with digital projection equipment. Distributors are fully involved with the trials, providing films in digital form from Lionsgate UK, Paramount, Pathe, Releasing International, Sony, Twentieth Century Fox, and Universal.

The financing arrangements haven't been made clear, but Odeon has announced what it calls 'six-month trials' which will involve all nine screens in each of the multiplexes being 'completely digital', as the announcement states, but I gather that the existing 35mm projection kit will remain, of course. Although one finds it hard to imagine that after such a huge investment in time and equipment for the trials the digital equipment might afterwards disappear, it is significant that these are genuine trials, with the two sites using different projectors, different servers, and different installers and service providers. The 'trials' status was confirmed again when visiting the Arts Alliance Operations Centre - they told me that they have to store all the equipment packaging materials for the period of the trials. Wouldn't it be interesting to know who is paying for what in these trials?

Bell Theatre Services will run the trials at the nine-screen Odeon Hatfield.

At the Hatfield site, NEC 2500 projectors and Kodak servers are used, and all screens at both sites will be DCI-compliant as far as is possible. The Kodak Digital Cinema content player and its new Theatre Management System (TMS) will be at the heart of the digital cinema solution being installed at Hatfield. The TMS will enable Odeon to find new ways to automate content handling, improve their workflow, and develop new operational efficiencies. Kodak will be working with Odeon to help them more fully realize the promise of digital cinema.

Odeon will be using both test sites to prove the reliability and support of the different theatre management systems under the demanding conditions of a busy, working theatre. The Kodak Digital Cinema system handles 2D or 3D movies and automatically recognizes the compression format used – JPEG or MPEG – and employs that for playback (It will

normally be JPEG 2000 for new movies, of course). It's designed to be used as a standalone unit for a single screen – or, as at the Odeon site, in fully networked configurations on many screens, to take full advantage of the capability, flexibility, efficiency, and power of the Kodak Theatre Management System controlling the network. The technology should make it very easy for projectionists to use, providing all the capability their demanding job requires.

BKSTS Cinema Technology Committee member Max Bell, who is Managing Director of Bell Theatre Services, responsible for the Hatfield installations, said that everyone is still learning, and that there is no substitute to learning under actual market conditions, with paying customers – and their expectations for a flawless performance – sitting in the seats. The Hatfield trials, in collaboration with Kodak, will enable a great many business lessons to be learned.

All the Odeon projectionists were trained on the new digital systems by BTS at their fully-equipped 35 seat training facility in Borehamwood, to prepare them for the launch of this digital multiplex. A full working system was prepared with identical equipment to that on site for this training. A fully networked system, with the same equipment at Hatfield, was tested at Bell Theatre Services' projection room (picture above), before delivery was made. This involved checking network operations with the new Strong e-CNA-200 Automation, designed to make the running of film and digital operate in the same way as multiplexes currently do with film only.

The first digital screening in the newly-equipped Hatfield multiplex was "Dreamgirls", on February 2, and everything went well.

Arts Alliance Media are providing all the necessary services to the nine-screen Odeon Surrey Quays complex. These screens use Cineeccanica digital projectors and Doremi servers. The work was completed in a remarkably short period of time, and it is thought that this multiplex can claim to be Europe's first to go completely digital with all of its nine screens. The equipment for Surrey Quays was received at AAM's Operations Centre in Byfleet, where it was pre-built and tested before being shipped out to the East London site. As described elsewhere in this issue of Cinema Technology, the AAM Operations Centre, which is used for the DSN rollout, combines a 7000 sq ft warehouse, full pre-build and testing facilities and a training room equipped to mimic an actual DC installation.

Arts Alliance Media will also be providing remote support and maintenance for the equipment during the trial. All systems are continuously monitored, and emails are generated when faults arise, allowing for early warning of imminent problems. Remote access to the equipment from AAM's head office in London will allow the vast majority of faults to be resolved without engineers having to attend the site.

Until now, the major cinema advertising agencies have seemed reluctant, for obvious financial reasons, to duplicate all their advertising material in digital form, which has meant that at virtually all digital cinema sites the pre-show material is shown from 35mm even when the main feature is digital. So it is another interesting step forward to be able to report that Arts Alliance Media has agreed to encode and deliver digital adverts from Carlton Screen Advertising to all screens at the Surrey Quays site. The first digital film at Odeon Surrey Quays was shown in February.

These trials represent an important step for the UK cinema industry - it is the first time we've seen whole cinemas going digital on this scale anywhere in Europe. This is an invaluable step if we are to make digital a reality for all our cinemas and deliver the economic benefits – something that Odeon say they aim to get right and to implement fully over the next few years.

## AUSTRALIAN DSN?

The Australian Film Commission (AFC), has announced plans for a digital cinema network in regional Australia. Eight independently-owned regional cinemas - one in each state and two in New South Wales - will receive digital equipment on loan and in exchange will be required to screen a range of Australian content, old and new, for patrons and schools. Up to $51,000 (A$65,000) per cinema will be spent on installing the 1.47K set-up so that the cinemas can receive a live satellite feed of the 16 short film finalists from Tropfest, the one-day festival established by filmmaker John Polson. The event happens in Sydney and is already shown in all other Australian capital cities. Satellite delivery is the eventual aim of the network but most of the content will arrive by courier on digital files at this stage. In most cases, the AFC will meet the cost of digitising these films. The way ticket sale revenue is split will depend on the nature of what is being shown.

The AFC has begun lobbying the Federal Government for $5.9m (A$7.5m) over three years to work with another 40 cinemas. The point of the network is to give country people more access to Australian films at the same time as their city cousins. It may also mean that more specialist films end up being shown in the bush as, unlike the US studios, the distributors of these films regard the standard of this equipment as adequate. The equipment may be upgraded in future, however.

## 2000 INSTALLATIONS FOR CHRISTIE/AIX

In February Christie/AIX, a wholly owned subsidiary of Access Integrated Technologies, Inc. installed and commissioned the company's 2,000th networked digital cinema system.

The systems, which serve cinemas in 29 states, feature Christie 2K DLP Cinema® projectors, JPEG-2000 media players, a central server running AccessIT's unique Theatre Command Center software, two-way satellite connectivity, and some of the more robust security elements of the DCI Technical Specification including Cine-Link2 and video watermarking.

This represents the half-way point towards the company's initial 4,000 screen deployment goal. Supported by all of Hollywood's major studios and major independent distributors, Christie/AIX provides exhibitors with fully-integrated and networked digital cinema systems designed to conform to technical specifications set by DCI.

# JPEG 2000 Rate Control for Digital Cinema

by Michael D. Smith and John Villasenor

*Traditionally, it has been the 'Technology' part of Cinema Technology's title that makes our journal different. The following article gives one of the best explanations that I have ever seen of some of the most important parts of the digital cinema system. It is unashamedly technical, but will repay the time spent on it by providing a better understanding of some of the factors that will affect all of our futures in this industry. I know my readers, and thought long and hard before deciding to present this article (formulae and all!) to many who are more used to understanding the intricacies of electromechanical systems. I would ask you to 'give it a try', if necessary skipping over the bits you can't readily understand at first, including any formulae that prove puzzling, and I am prepared to bet that you will come to the end with a much better understanding of a complex subject. - Ed.*

Recent industry developments have made it clear that although digital cinema signals are image sequences, they will almost certainly be compressed using an intra-frame image compression method such as JPEG-2000 that operates on one frame at a time. This is in contrast to traditional inter-frame video standards such as MPEG that operate on multiple frames at once. Furthermore, recent research has shown that the coding efficiency advantages of inter-frame coding are significantly reduced for 4k digitized film content at the data rates and quality levels associated with digital cinema. This raises a number of important issues related to rate control methods, which have the goal of maximizing quality while also ensuring that the overall post-compression bit rate maintains average and peak values within the limits of the delivery and decoding systems.

While rate control in general has received significant attention in the academic and commercial communities, with a few notable exceptions there has been almost no formal research aimed at addressing the problem when a still image coding method such as JPEG-2000 is applied to successive frames in an image sequence. A new framework is introduced for rate control that enables a JPEG-2000 encoder to achieve a user-specified quality and therefore makes it possible to produce constant quality from frame to frame. The new method makes direct use of the same JPEG-2000 coding pass data as the traditional approaches and thus can easily be adopted at the back end of JPEG-2000 encoding engines. The proposed method is compared with two other common rate-control techniques for JPEG-2000.

## Introduction

JPEG-2000 is the most advanced still-image compression standard and has the potential to affect still image coding over a wide range of commercial applications. The standard is very flexible and, when applied to a single image frame, offers a wide range of rate-distortion choices and enables substantially improved compression efficiency over the older DCT-based JPEG standard, particularly at low bit rates. JPEG-2000 represents the end product of very significant research and standardization efforts on the part of the participating institutions and the image processing community in general and, as a result, offers rate-distortion performance that is unlikely to be surpassed in the foreseeable future, particularly if reasonable constraints on complexity are imposed.

While new opportunities to derive improved frameworks for still image compression are quite limited, the issue of how JPEG-2000 can best be used for frame-by-frame video compression remains open. At first glance, the application of JPEG-2000 to video may seem inappropriate, particularly in light of the availability of advanced video coding algorithms such as MPEG-4 and H.264 that specifically exploit the inter-frame redundancy found in video sequences. However, for very high-rate, high-quality encoding, the benefits of exploiting this redundancy are lower. In the limit of high coding rate, the bandwidth costs of coding motion compensated prediction error can approach the costs of simply directly representing the desired image content without any predictive coding.[2] In addition, when compared with still image coding, video coding of course involves significant additional computational complexity and memory associated with generating and utilizing prediction data. These factors and others have led the cinema industry to choose frame-by-frame JPEG-2000 compression as the basis for digital cinema distribution. Substantial commercial efforts are already under way to prepare for the inevitable transition to digital cinema, and algorithmic methods that can lead to lower cost, higher efficiency solutions thus will have high importance.

There is a long history of work on rate control for traditional video encoders; however, almost no attention has been paid to the issue of how to manage rate control on a video sequence in which each frame is compressed independently but where consistent post-encoding quality is desired. Similarly, while there have been extensive efforts to develop rate distortion optimal approaches to wavelet still image coding, many of which have led to specific techniques in JPEG-2000, those efforts have by definition been aimed at coding of standalone images.

## About the authors

***Michael D. Smith*** *(above) is a consultant in the area of digital imaging and signal processing, with recent work for organizations including Digital Cinema Initiatives (DCI), Warner Brothers Technical Operations, Dolby Laboratories, Cinea Inc., Path1 Networks, PhatNoise Inc., and various law firms. He is a member of SMPTE and AES. Smith received BS and MS degrees in electrical engineering from UCLA in 2001 and 2004, respectively (miksmith@attglobal.net).*

***John Villasenor*** *(below) received a BS degree in 1985 from the University of Virginia, a MS degree in 1986 from Stanford University, and a PhD degree in 1989 from Stanford, all in electrical engineering. From 1990 to 1992, he was with the Radar Science and Engineering section of the Jet Propulsion Laboratory in Pasadena, CA, where he developed methods for imaging the earth from space. Villasenor joined the Electrical Engineering Dept. at the University of California, Los Angeles (UCLA), in 1992 and is currently a professor. He served as vice-chair of the department from 1996 to 2002. At UCLA, his research efforts lie in communications, computing, imaging and video compression, and networking. Villasenor is a senior member of the IEEE (villa@icsl.ucla.edu)*

Even in the standalone image case, methods for targeting a specific post-compression quality have not been a focus of attention. Thus, from a coding standpoint, the combination of JPEG-2000 and digital cinema creates a unique opportunity. When bandwidth is not at a premium, satisfactory visual quality can be obtained using very simple fixed- or variable-rate coding schemes. For example, a fixed-rate scheme with a high per-frame bit allocation or a variable-rate approach that targets very small residual distortions will ensure very high visual quality. However, approaches such as this tend to use far more bits than are necessary. It is therefore desirable to have a scheme that enables constant high quality and simultaneously makes economical use of bits subject to the quality constraint.

## Rate Control for JPEG-2000

Currently available JPEG-2000 encoders usually implement either "rate-based" or "efficiency-based" rate-control algorithms. This section provides an overview of some key building blocks of a JPEG-2000 code stream and briefly reviews these common rate control methods.

The fundamental unit of data in the JPEG-2000 compression standard is the code-block. A code-block is simply a spatial grouping of wavelet coefficients, which have size 32 x 32 for digital cinema applications. Each code-block is further decomposed into "fractional bit-planes." As the term implies, this decomposition is related to the bit planes in the binary representation of the quantized wavelet coefficients. There are typically three fractional bit-planes for each bit-plane in a code-block. The fractional bit-planes are compressed with a context adaptive arithmetic coder. Compressed fractional bit-planes are often called "coding-passes," and contain the actual bits that comprise a JPEG-2000 code stream. For a 4096 x 2160 3-color 12-bit digital cinema image, decomposed using a 5-level discrete wavelet transform (DWT), there are approximately (4096/32)*(2160/32)*3 ≈128*68*3 = 26112 code-blocks. The number of coding passes per code block is a function of various factors, including the quantization precision used. For example, in a case in which there are on average 45 coding passes per code block, this means there are approximately 26112*45 = 1175040 coding passes that result from the 4k digital cinema image. If all the coding passes are retained in the output code stream, lossless or nearly lossless compression will result (depending on the DWT filters used). In contrast to a lossless compressor, a typical lossy compressor will discard a large number of coding passes. It is the lossy compressor's rate-control algorithm that specifically determines which of the many coding passes to include in the final output code stream and which to discard.

A rate-distortion optimized compressor typically calculates an efficiency measure for each coding pass of each code-block. This efficiency measure is sometimes called "distortion-length slope."[3] Each coding pass has a certain size, ΔL, measured in bits or bytes. The inclusion of each coding pass reduces the resulting image distortion by an amount ΔD. The quantities ΔL and ΔD are used to calculate the distortion-length slope of the coding pass, S = ΔD/ΔL. The distortion-length slope is essentially a measure of the efficiency of the bits in that particular coding pass in reducing distortion. The distortion-length slope is calculated for each coding pass of each code-block. JPEG-2000 places some restrictions on the order in which coding passes can be included, ensuring, for example, that the least significant bits of a wavelet coefficient are not placed in the code stream before the most significant bits.[4,5]

Given this framework, the two traditional methods for rate control are often referred to as efficiency-based and rate-based. A rate-based rate-control algorithm specifies a target size for the output code stream, L. The coding passes with the steepest distortion-length slopes are included before including other coding passes with lower distortion-length slope. Coding passes are included in this manner until the target size, L, is met. This results in an output code stream that meets specific length goals. A thorough explanation of this commonly used rate-based rate-control algorithm is available. [4]

An efficiency-based rate-control algorithm specifies a certain distortion-length slope threshold, $S_{threshold}$, and all coding passes with a steeper slope than $S_{threshold}$ are included in the output code stream. The task of determining the appropriate $S_{threshold}$ was addressed for image sequences subject to buffer constraints.[6] This approach ensures that all coding passes that have efficiency greater than the threshold are included.

## Constant Quality Rate-Control for JPEG-2000

The traditional approaches have sound motivations and achieve results that in many environments are quite satisfactory. However, the distortion-length slope is a highly local measure that pertains to individual coding blocks. By contrast, what is of interest in many applications, including digital cinema, is the ability to obtain one or more images having a specific desired peak signal-to-noise ratio (PSNR) after encoding. In such constant distortion environments, the goal is to have the same residual overall distortion in the images obtained after considering data from all the code-blocks and taking the inverse wavelet transform. The residual distortion in a coded image is most directly related to the distortion reductions from the code-blocks that were not included in the code stream, not the distortion associated with the code-blocks that were included. Thus, it is more intuitive, as the results below show, and more accurate, to utilize an approach that specifically accounts for distortion that will not be mitigated by the data in the coding passes that are used.

We propose a new constant-quality rate-control algorithm, which delivers a specified target distortion for the output code stream, $D_{Target}$. The coding passes with the steepest distortion-length slopes are included before the coding passes with the lower slopes. In contrast with the earlier approaches, the cutoff is based on a global measure of total distortion, $D_{Target}$, as opposed to local measures based on the distortion-length slopes of individual code blocks. The total amount of distortion reduction possible for a code-block for which there are a total of N coding passes available is the summation of all N distortion reductions corresponding to each coding pass.

$$D_{CBTotal} = \sum_{i=0}^{N-1} \Delta D_i$$

If M coding passes from a given code-block are included in the output code stream, then the remaining distortion in the code-block, $D_{CBRemain}$, is calculated as:

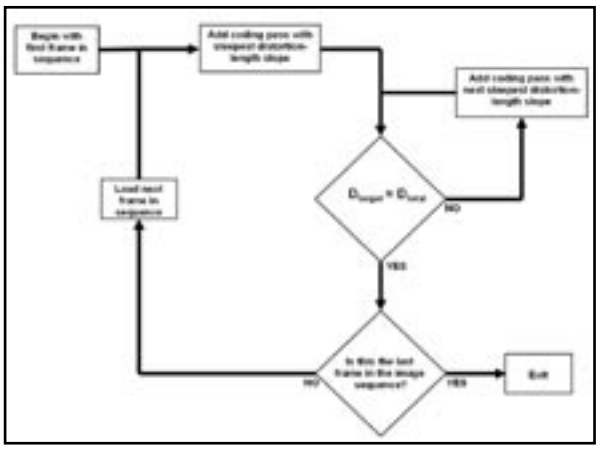
$$D_{CBRemain} = D_{CBTotal} - \sum_{i=0}^{M-1} \Delta D_i$$

The total remaining distortion in the image is the summation of the remaining distortion of each code-block; in other words, it represents a measure of the distortion that can be expected in the image due to the coding passes not included in the encoder output.

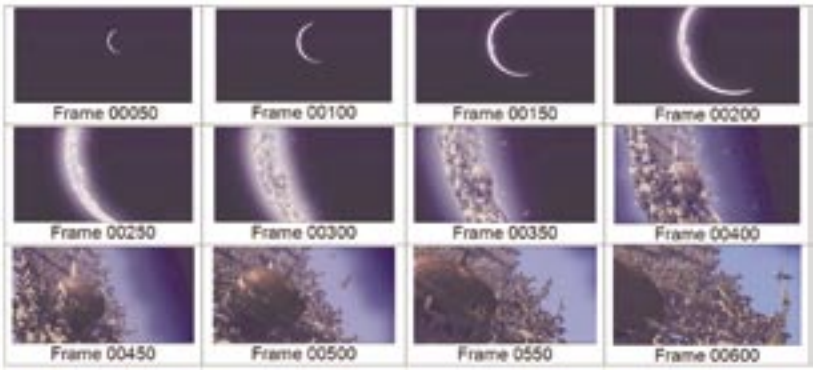
If there are B code-blocks in the image (B is approximately 26,112 for the example 4k image with a 5-level DWT considered earlier), then the total remaining distortion, $D_{Total}$, can be expressed as follows:

$$D_{Total} = \sum_{b=0}^{B-1} D_{CBRemain}(b)$$

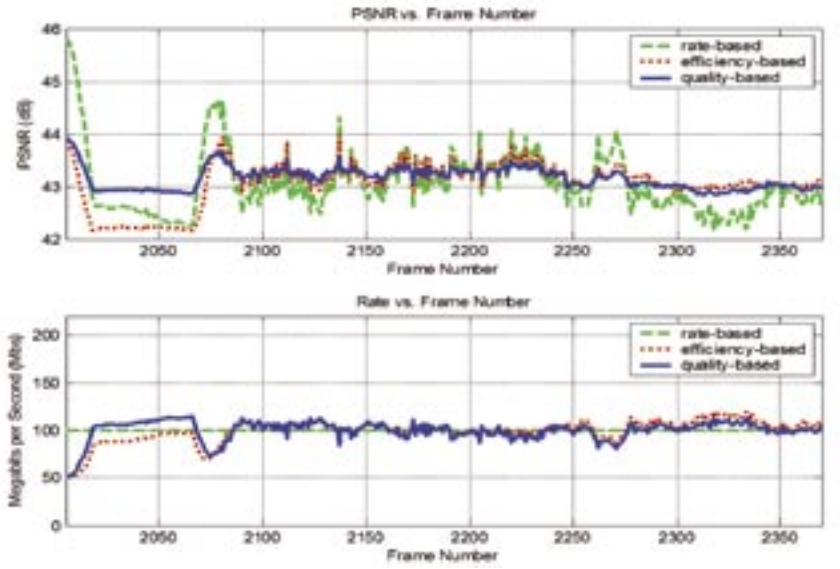
where $D_{CBRemain}(b)$ represents the remaining distortion in code-block b. Coding passes are added until the total remaining distortion, $D_{Total}$, equals the target distortion, $D_{Target}$. If the same target distortion, $D_{Target}$, is applied to all the images in an image sequence, the result is a constant-quality per frame across the whole image sequence. A flow chart illustrating the implementation of the constant-quality approach is given below.



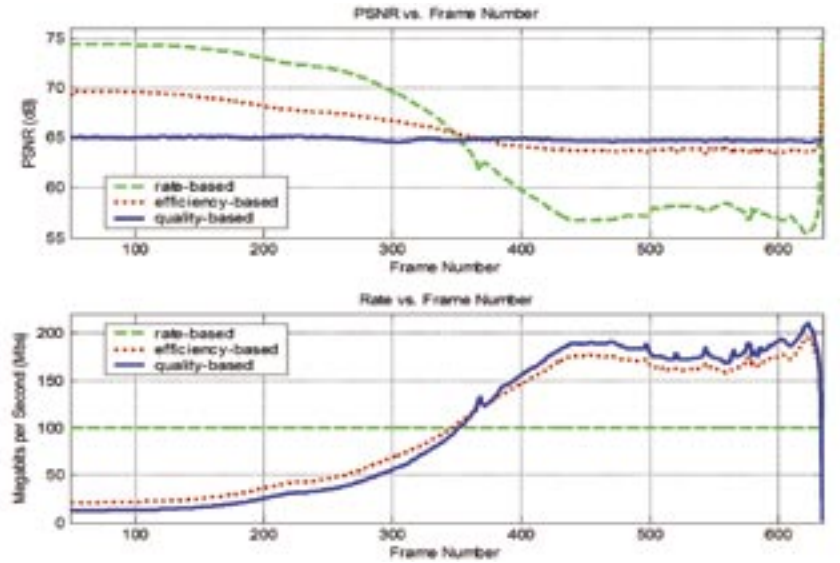

*1. Frames from the DCI StEM sequence*




*2. Frames from the Treasure Planet sequence*




*3. Rate distortion plots for DCI StEM content*




*4. Rate distortion plots for Treasure Planet content*

## Implementation and Results

Two 4k clips were used to demonstrate the proposed quality-based rate-control method. The first clip (shown 1 left), contains 366 frames from the DCI StEM content; this sequence was referred to as "Clip 2" during the DCI compression tests. The second clip, (shown 2 left), contains 586 frames from Disney's "Treasure Planet" content; this sequence was referred to as "Clip 6" during the DCI compression tests. Both clips are 4:4:4 12-bit 4k content, the DCI StEM content has dimensions 4096 x 1714 and the Treasure Planet content has dimensions 4096 x 2160. The PSNR (Peak Signal to Noise Ratio) metric is used for the quality comparisons in units of decibels (dB). For 12-bit content, PSNR is calculated as PSNR=10*log10 (4095*4095/MSE), where MSE is the mean square error between the original and decompressed image. Megabits per second (Mbs) is used for the rate comparisons. Rate results are often presented in units of bits per pixel (bpp) in the image compression literature and kilobits per second (Kbs) or megabits per second (Mbs) in the video compression literature. In these experiments, 100 Mbits/sec corresponds to approximately 0.594 bpp for the DCI StEM content and 0.471 bpp for the Treasure Planet content.

The compression experiments were performed using the luma (Y') color channel. To make fair comparisons between the three rate-control methods, the average bit rate was kept at 100 Mbits/sec for each sequence. The compression software used for these tests is C++ based. The quality-based method has also been implemented in Java software, and the method is currently being ported into a hardware implementation.

The compression results for the three rate control methods are shown in 3 and 4 left. Note that the proposed quality-based approach has the smallest variation in PSNR of the three methods. The PSNR results are also described statistically in Tables 1 and 2 (opposite page top).

The small residual variations in PSNR for the "quality-based" curves shown in Figs. 4 and 5 are due in part to the non-orthogonality of the discrete wavelet transform (DWT) and thus the fact that energy correlations between the DWT and image domains are approximate but not exact. The experiments that were performed minimize the mean square error between the original and decompressed image. It is well known that mean square error is not the best perceptual quality metric, but it is used here for simplicity and comparison purposes. It is reasonably straightforward to adapt the JPEG-2000 rate-control framework to use other perceptually-based quality metrics such as those based on the contrast sensitivity function (CSF) or visual masking.[7]

Both the rate-based and the proposed quality-based rate-control methods require

only a single frame to be buffered at a time. The efficiency-based method introduced in[6] requires a number of frames to be buffered so the appropriate distortion-length slope can be determined. The number of frames in the rate-control buffer has a direct effect on memory usage as well as the degree of parallelism that can be exploited by the encoder. The rate-based and proposed quality-based methods achieve frame-level parallelism, (meaning each frame can be independently encoded). The efficiency-based method[6] requires access to the rate-distortion statistics of all the frames in the sequence. From an implementation point of view, the rate-based and proposed quality-based methods are much easier to parallelize than the efficiency-based approach.

**Table 1—PSNR Statistics for DCI StEM Clip**

| | PSNR Std. Dev. | PSNR Minimum | PSNR Maximum |
|---|---|---|---|
| Rate-Based | 0.60 dB | 42.2 dB | 45.8 dB |
| Efficiency-Based | 0.41 dB | 42.2 dB | 44.0 dB |
| Quality-Based | 0.20 dB | 42.8 dB | 43.9 dB |

**Table 2—PSNR Statistics for Treasure Planet Clip**

| | PSNR Std. Dev. | PSNR Minimum | PSNR Maximum |
|---|---|---|---|
| Rate-Based | 7.32 dB | 55.4 dB | 75.3 dB |
| Efficiency-Based | 2.32 dB | 63.3 dB | 73.4 dB |
| Quality-Based | 0.16 dB | 64.5 dB | 65.2 dB |

## JPEG-2000 Profiles for Digital Cinema

Two special digital cinema distribution profiles have been created by the JPEG committee in collaboration with SMPTE. Profile-3 is for 2k content and Profile-4 is for 4k content. The profiles have very specific constraints related to the organization and structure of the JPEG-2000 code-stream. The main attributes of the Profiles for Digital Cinema are as follows:

- Code-blocks have size 32 x 32.
- Precincts are size 256 x 256, except those at the lowest resolution level, which are 128 x 128.
- The irreversible 9/7 wavelet filters are required.
- A single tile is used for the whole image.
- The progression order is CPRL.
- The tile-part lengths, main header (TLM) marker must be included.
- For 24 frame/sec content, each code stream may not exceed 1,302,2083 bytes, which corresponds to 250 Mbits/sec.
- For 4k content, the 2k portion of the image must precede the 4k data in the code stream.

Further details of the Digital Cinema profiles are available.[8]

## Conclusion

An encoding method has been described that enables JPEG-2000 encoding to achieve a user-specified quality on an encoded image. When the same distortion constraint is applied to all the frames in an image sequence, the result is a sequence of images with nearly constant quality. The algorithm can be implemented on one frame at a time, so no multiframe buffering is necessary. Experimental results confirm that the new method has much less PSNR variation than earlier rate- and efficiency-based methods when applied to successive frames in an image sequence. Thus, it has strong potential for application in digital cinema where it can guarantee consistent image quality levels while also making efficient use of bits.

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*Presented at the*

*SMPTE and VidTrans Joint Conference, Hollywood, CA*

*Jan. 29-Feb. 1, 2006,*

# Advantages of Variable Bit Rate JPEG Encoding used in DTS Digital Cinema Encoder™

by Dr. Michael Marcellin and presented at IBC 2006, Amsterdam, Netherlands

## Introduction

This paper is a summary of the advantages of the variable bit rate (VBR) JPEG 2000 encoding for digital cinema images that is used in the DTS Digital Cinema Encoder. The content is based on an IBC paper submitted by M.W. Marcellin and A. Bilgin.

## Background

In July, 2005 Digital Cinema Initiatives (DCI) published specifications for distribution of the digital cinema content and chose JPEG 2000 as the standard for image compression. JPEG 2000 provides state of the art compression performance with advanced features, such as the ability to extract multiple resolution images from a single code stream.

This makes it possible to display a 2K image (2048 x 1080) or a 4K image (4096 x 2160) from a single 4K compressed code stream. The DCI specifications for digital cinema encoding also place strict limits on the file size of each image in a sequence. In particular, no compressed image shall exceed 1,302,083 bytes in length.

Additionally, no compressed color component of a 2K image shall exceed 1,041,666 bytes in length. The 2K portion of a 4K image must also satisfy the latter constraint. In total, the maximum data rate can be no larger than 250 Mbit/s.

Although JPEG 2000 can employ fixed or variable bit rate encoding for motion pictures, DTS has chosen JPEG 2000 variable bit rate encoding for its Digital Cinema Encoder, which produces images with higher constant quality than fixed bit rate encoding.

### Summary of JPEG 2000 Image Compression Methods

- First, a JPEG 2000 encoder performs a component transform on each pixel of the three color components of the image, known as X′, Y′ Z′, for the purpose of obtaining three new transformed color components. No sub-sampling is allowed.
- A wavelet transform is applied independently to each new color component to produce transform coefficients, which are divided into a number of subbands. The transform coefficients of each subband are then divided into 32 x 32 blocks, referred to as codeblocks. Each codeblock is then encoded independently.
- Encoding begins by quantizing (the process of converting an analog signal into discrete or digital values) the wavelet coefficients from each codeblock to obtain quantization indices or digital values, represented by an array of signed integers.
- The codeblock encoder produces a number of compressed coding passes for each codeblock. It also computes the amount of distortion reduction provided by each coding pass together with the length of the coding pass. This makes it possible to compute a distortion-rate slope for each coding pass. The distortion-rate slope of a coding pass is the amount of distortion reduction per byte provided by the coding pass. A coding pass with a larger distortion-rate slope can be considered more important than one with a smaller distortion-rate slope. See Figure 1 above.

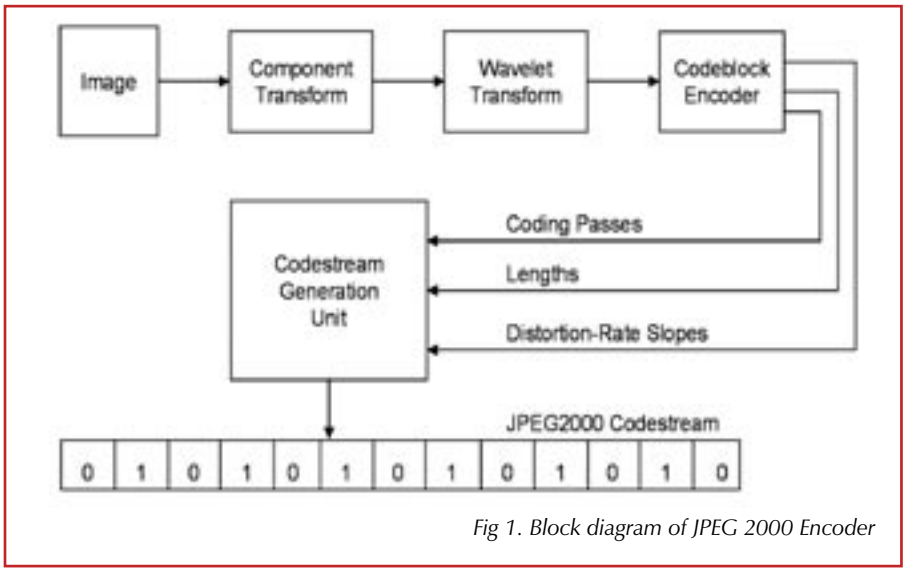


*Fig 1. Block diagram of JPEG 2000 Encoder*

## JPEG 2000 Encoding for Digital Cinema Applications

The JPEG 2000 still image compression summary above describes how a single image is encoded and is provided as background. JPEG 2000 technology is designed for encoding a single image or an image sequence such as a motion picture. When encoding a motion picture it is possible to select a fixed or variable data rate (number of bytes in each image). While a fixed data rate is simple and allows easy implementation, it yields inadequate performance in some applications and the characteristics of the images can vary significantly. DTS developed a JPEG 2000 variable bit rate (VBR) encoding method that maximizes image quality and satisfies all of the required DCI constraints.

### Summary of JPEG 2000 Variable Bit Rate Encoding Methods for Motion Pictures

- Compressed size limits are placed on each transformed component as well as the entire image, as dictated by the DCI specification.
- The coding passes having the largest distortion-rate slopes are selected that also satisfy the size limits.
- This process is repeated for each image in the sequence. If fixed data rate encoding is desired, the process ends here and the images will be encoded at 250Mbit/s, the maximum allowed. However, additional rate control measures can be performed over the entire sequence of images to further reduce the overall file size while maintaining image quality in an optimal fashion.

Specifically, DTS variable bit rate (VBR) encoding further selects only coding passes having the highest distortion-rate slopes. Simply stated,

DTS variable bit rate JPEG 2000 encoding results in a motion picture with maximum average quality for any given bitrate.

The following diagrams show results obtained using the DTS Digital Cinema Encoder™. Figure 2 depicts bit rate over elapsed time for one reel of digital cinema content. The bit rate ranges from a low of 25 Mbit/s to a high of 250 Mbit/s. Near the center of the graph are three arrows indicating sustained periods of low bit rates, which are areas that are "easy" to compress. Near the left and right of the graph are arrows that indicate high bit rates corresponding to areas that are more "difficult" to compress. In effect, the algorithm takes bits from the easy frames and gives them to the more difficult frames, thus maintaining more constant image quality as well as a higher average image quality than fixed bit rate encoding. The average bit rate in the example is 195 Mbit/s. Nevertheless, many frames are encoded at the maximum allowed value of 250 Mbit/s.

Figure 3 shows the peak signal-to-noise ratio (PNSR) for the same digital content using the bit rate allocation shown in Figure 2 and the arrows correspond to the arrows in Figure 2. It is important to note that the highest signal to noise ratios occur when the bit rate is the lowest. This indicates that although bits are taken from the easy frames to boost the quality of the difficult frames, the resulting image quality is still very high for the easy frames.

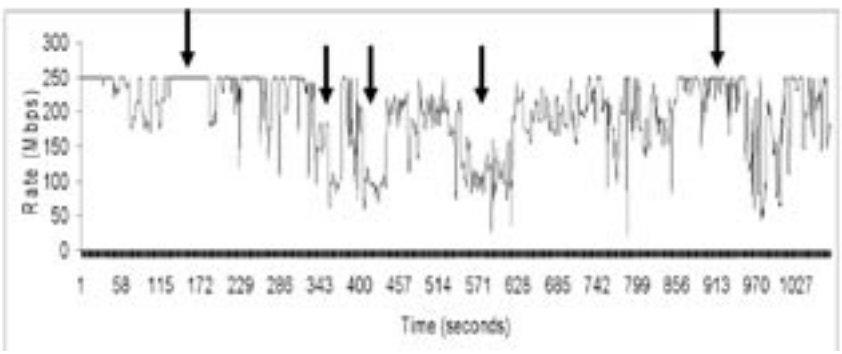


*Figure 2: Bit rate vs time for a typical reel of digital cinema content*

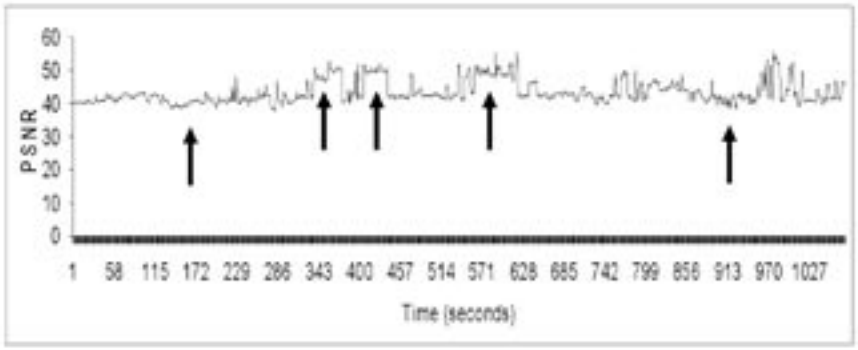


*Figure 3: Peak signal to noise ratio vs time for a typical reel of digital cinema content*

## Summary

This paper presents a summary of the advantages of a variable bit rate allocation for JPEG2000 encoding of digital cinema image content. The encoder assigns more bits to difficult images and fewer bits to easy images. It does so in a way that maximizes the image quality over an entire motion picture. At the same time, all bit rate constraints as specified in the DCI specifications are guaranteed to be satisfied. For these reasons, variable bit rate JPEG 2000 encoding has been selected for the DTS Digital Cinema Encoder.

*For more information visit www.dts.com/cinema.*

**PROJECTIONIST TRAINING...PROJECTIONIST TRAINING...PROJECTIONIST TRAINING...**

# EARLY WARNING! BKSTS DIGITAL CINEMA AWARENESS DAY

**The BKSTS Cinema Technology Committee is currently arranging a digital cinema seminar specifically targeted at projectionists. The aim will be to raise 'digital awareness', to provide 'real' information to balance some of the rumour with which our industry is rife, and to provide an opportunity for those projectionists who haven't yet done so to see for themselves just how good Digital Cinema pictures and sound can be.**

The venue will be:

**Cineworld, Birmingham Broad Street (Formerly UGC), 181 Broad Street, Birmingham, B15 1DA**

The date will be:

**April 17th • 2007 Registration and coffee 10.30am • Start 10.30 • Finish approx 1.30pm**

*Top speakers - including* Paul Schofield, Technical Manager of Odeon UCI Cinemas, Steffan Laugharne of Bell Theatre Services and Marc John of City Screen/Doremi - *currently working to drive the rollout of the Digital Cinema business will make presentations and take part in question and answer and discussion sessions.*

The provisional programme includes:

*• Welcome - Introduction - The reality of what's happening now • Demonstration of JPEG2000 Digital Cinema content • Digital Projector Technology • Understanding digital jargon and terminology • Alternative Content - opening up a cinemas 'event' capabilities • Digital Advertising • Questions & Answers*

*The course will be sponsored by the David Lean Foundation and presented by the BKSTS Cinema Technology Committee. The David Lean Foundation sponsorship makes it possible to for the course to be made available free of charge to projectionists and cinema technologists. Our grateful thanks to Cineworld for providing the venue and Bell Theatre Services the refreshments.*

**To confirm details and to make a booking contact : Wendy@bksts.com Tel: 01753 656656** *cinematech@btinternet.com*

# Everything you always wanted to know about digital cinema players, but were afraid to ask

*François Helt, Technical Manager for Digital Cinema at Doremi, lets Cinema Technology readers into the secrets*

The rollout of digital cinema in Europe and the UK is gathering pace. Already in 2007 Doremi Cinema has been contracted to supply up to 240 of its DCP-2000 players for Arts Alliance Media in the UK. With worldwide sales well over 2,000 these players are becoming widely used, so it may be useful to know a bit more about exactly what they are.

## A little background

Doremi Cinema is a subsidiary of Doremi Labs, Burbank, California, who have for many years been producing high performance video disk stores and servers for the television market at relatively low prices. The V1 series of video servers, contained in a 3RU chassis, developed from standard definition (SD) to high definition (HD) television capability and at IBC2004 was shown replaying a JPEG2000 encoded version of the ASC StEM test footage at 2K resolution on the big screen at the RAI's Auditorium in Amsterdam. This was all in the same 'V1' 3RU-sized box which developed into the DCP-2000 player of today, and, for most of the audience, was the first time they had seen JPEG2000 images at all, let alone on a big screen. A few got very excited.

The StEM footage, widely hailed as an MPEG-breaker, looked perfect using the JPEG2000 compression and running at 250 Mb/s – a vindication of DCI's choice of codec and maximum bit rate. To put this into perspective, at that time many of the audience thought that the data rate was too high (they believed it meant a big expensive box) and all other JPEG2000 decoders where hot racks in the lab – nowhere near commercial implementation. Doremi has since scored many more industry firsts as it has built on this lead to develop the fully-fledged DCP-2000 of today.

## Inside the box

The small 3RU size gives little indication of the complexity and power of what goes on inside. The DCP-2000 is based around a PC that runs on Linux, drives a very powerful card and is equipped with storage for hours of movies. The card is the heart of the server and delivers the performance required by the latest digital cinema technology with stability comparable, or even superior to, the ubiquitous 35 mm projector. At the same time it has all the flexibility you can expect from a modern computer. It even comes with an internal touch screen and a virtual keyboard all within the rack-mount box. It is, of course, possible to connect external screen and keyboard for comfort.

## DCI essential

There are a number of vital features that must be met for the player to be of long-term use. Part of the success of motion picture film has been that it is a worldwide standard and can be played in any cinema. For compatibility in digital cinema the DCI has created a set of recommendations that all prospective digital cinema equipment suppliers would be wise to meet. The DCP-2000 is built to fulfil the following requirements:

- Conforming to the DCI recommendations including the most stringent in terms of security
- Offering easy operation
- Keeping the movie securely for long periods.

In terms of security, the powerful card does the whole job. It is possible to open the box for maintenance work, such as cleaning the fans, without breaking the integrity of the system. Surprisingly this is not the case for other systems.

The storage for the movie files currently has a standard capacity of 1000 Gigabytes and an option for 1500 Gigabytes. This is provided by three 500 Gigabyte drives arranged in a RAID-5 configuration so that if any fails the show can still go on without any quality change using the remaining two. When time permits, a replacement disk can be fitted and the missing data rebuilt and recorded to it. A typical 90-minute movie with 20 minutes of pre-show material all running at 250 Mb/s and uncompressed 16-channel 24-bit AES audio would require about 230 Gigabytes. Thus several movies can be securely held in the standard store.

The system disk, the one used by the Linux operating system, is not a disk at all but on solid-state EEPROM memory so it is impossible for the average user to write to it by accident. This helps to make the system foolproof and, as a consequence, after a power failure the system reboots gracefully and quickly. Further steps are made to ensure the server keeps running – including providing dual redundant power supplies.

## What goes in

A typical simple single-screen installation is likely to receive a movie on a USB disk, which does not require separate computer equipment to play it into the server. The server is designed so that it can continue replaying to the projector while loading new movie material. If there is danger of a conflict in the server, the USB operation has to wait as reply has top priority. Material can also be delivered over a DSL line. Soon a satellite link capability will be added with support for an incoming ASI stream to provide an alternative HDTV content playback to the main theatre screen.

The server, being a computer, can execute most common computer functions, but it is also tuned to deliver its best performance as a DCI server. So some operators prefer to leave the server doing this and devote the other computer tasks, like DSL connections, to a more ordinary PC nearby.

As soon as there is more than one screen, the typical installation will need a specific Network Operation Centre (NOC). This is a computer with plenty of disk space, a DSL connection and a Gigabit Ethernet connection to each server in the multiplex. Dedicated software, often called a Theatre Management Centre, is able to manage the various tasks at hand that include:

- Ingesting incoming movies
- Distributing the data onto the targeted screen servers
- Composing play lists
- Monitoring server activity.

The server is primarily designed to play any conforming Digital Cinema Package (DCP) files. The user, projectionist or screen manager should not have to make any further adjustments – just cue-up and play. The movie should just play perfectly every time. For backward interoperability, the DCP-2000 server can also play old MPEG-2 MXF Interop packages.

There are usually no requirements to sync other equipment but, just in case, the DCP-2000 can output an optional LTC timecode signal. This may be useful in locations such as motion ride theatres, and has already been used in some installations.

## What goes out

The connections between the server and the projector include transactions for projector settings, automation cues and everything required to run the projection smoothly. The main connections are two HD-SDI SMPTE 292M links that together carry 3Gb/s with physical encryption – as specified by the DCI. A dedicated Gigabit Ethernet connection between the projector head and the server is required to use the Cinelink subtitling system.

Security of the DCM movie is vital. The server is fitted with a variety of devices and technologies to avoid and discourage

copying the material. The system is ready for the next level of security as embodied in CineLink II Strong Link Encryption.

There are two sets of audio outputs. The digital output is 16-channel AES/EBU and there are 8-channels of analogue.

Other connections include a number of GPIs as well as automation inputs and outputs that are provided at the rear of the rack.

## Day-to-day management

The standard procedures are kept simple and are limited to two operations:

- Ingesting new content
- Preparing show play lists.

As mentioned, the ingest operation is done simply by plugging the USB disk to one of the system's four USB inputs. This automatically starts the ingest software. Then it is only a matter of selecting the content and the appropriate security keys to initiate ingest and that's it.

It is then necessary to prepare the show play list. This comprises a succession of:

- Events – dim the room lights, open and close the dowser, open and close the curtains, etc.
- Content – for example, advertisements, trailers, movie and further trailers.

The show play list is started within a pre-programmed schedule prepared with the same user interface. A manual start may be inserted to allow for direct control through a GPI.

These operations may be done once a week or at whichever period needed to replace the movies to be played to the screen. Nothing else is needed and days may pass without requiring any attention to the server. It is always possible, of course, to modify a show play list or a schedule at any moment.

## Stereo (3D) replay

Displaying 3D digital movies with the DCP-2000 is hugely simplified and gives far better and more reliable results than with film – it comes almost free and only one player and projector is needed. The system has stereo playing capacity as standard. It can play at 48 frames-per-second thus 24 for the left eye and 24 for the right. These left and right frames are automatically sequenced in the replay and then, using just one projector – not two – the left and right images are sequenced onto the screen. Note that this avoids the old nightmare of the near-impossible task of aligning two projectors onto the screen as well as running two players in sync. Thus the operation is greatly simplified and opens the door to the much wider use of much better 3D – not just at showcase venues but at any digital theatre. The only piece of additional equipment is a drive to switch between left and right eye images for the audience. There are currently two different methods available that use passive or active glasses. With passive glasses which are polarized (left and right), there is a polarization system in front of the projector lens to ensure the left eye sees only the left frame, etc. With active glasses, infrared emitters drive the switching that then occurs in each pair of glasses.

## What's next?

The current player offers 2K-native playback with real-time 2K extraction from 4K DCP master files. A 4K module will be available in March to upgrade any existing field-installed DCP-2000 to 4K native playback. Validation tests have already been run successfully using Sony SXRD 4K projectors (below).

*The digital cinema scene has moved on hugely since that IBC2004 demonstration. With DCI recommendations for movie media and its security in place, and the equipment available to meet them, cinema owners have been able to invest in the new technology. Now the initial targets of better-looking movies, much reduced distribution costs and greater flexibility are being met. At the same time there is scope to do much more…*

As the Digital Cinema rollout slowly gathers momentum, Jim Slater reports on a visit to the Arts Alliance Media Digital Cinema Operations Centre at West Byfleet, where he had some fascinating talks with the Operations Manager and his staff, and then sat in on one of the regular projectionists' training courses to get a feel for just how those at the sharp end of the digital revolution are likely to take to some of the wholly different technologies involved.

# It's systems and scalability that will determine the future of Digital, say Arts Alliance

## Pride in the job

One of first things that strikes you when talking with Operations Manager Ian Strang (below) and his team at the AAM Digital Cinema Operations Centre is that they are all proud of the jobs they are doing and very pleased, perhaps even privileged, to be in at the start of what they know will become a major new industry. That 'pride in the job' is exemplified by the way I was shown the smartly-liveried service van fleet parked outside, and by learning of Ian's insistence that his service engineers are smartly turned out and wear an AAM branded sweater so that customers can be sure that they are dealing with good people from a top-rank company.

Ian himself has a logistics background, and although he has learned a great deal about the cinema industry in the last year, he is convinced that AAM's operational team, organisation and systems set-up, allied with the unrivalled Technical Operations team that Rich Phillips (a member of the BKSTS Cinema Technology Committee) runs, is a key selling point that will make Arts Alliance Media a major force in the Digital Cinema Business.

Ian showed me around the spacious 7000 sq ft of the AAM warehouse and logistics centre, and he was just as proud to show the fully racked, tracked and inventoried parts room and storage areas as of the high-tech areas where the digital projectors were being assembled (pre-built) and soak-tested.

The West Byfleet centre is within easy reach of all the major southern motorways, although I have to confess that it took me half an hour to travel the five miles or so from the M25, thanks to a whole series of roadworks! The security of all aspects of Digital Cinema is vital to its long-lasting success, and security has been given major attention, with the centre being covered by 24hr monitored CCTV, an access control system, and BT Redcare response out of working hours.

There are only three people permanently based at the centre, the logistics manager and two engineers to pre-build the equipment, but on a typical day there will be several other engineers on site to help with the pre-builds and to carry out other technical tasks. The field service engineers who are located in the South of England also tend to come in frequently. At the current state of the rollout there are typically two projectionist training courses a week being held at the centre, often involving the service engineers from the regions where the installations are due to be done.

As well as the four main areas, the pre-build room, the parts room the warehouse and storage area, and the training room, the centre provides the base office for VIZUMI, AAM's own Video on Demand network, which delivers video content and more



Darren Briggs


Charles Rayne-Davies


Nigel Priest

from all the major studios, including Warner Bros., in the form of download services. The numbers are growing - and fast!

Some of the facts and figures are astonishing. AAM's engineers have worked with digital cinema (DC) equipment since 2003, and AAM have so far performed well over 150 DC installations in multiple countries. AAM's engineers have trained over 300 cinema projectionists in the operation of digital cinema equipment.

The engineers are experienced with a wide range of equipment, including Christie, NEC, Barco, Cinemeccanica, Doremi, and QuVIS.

Ian was proud to explain how AAM's engineers had recently installed and integrated Europe's first fully digital 9 screen multiplex at The Odeon, Surrey Quays (mentioned elsewhere in this issue of CT). The job necessitated the inclusion of a centralised content ingest system and integration with the existing Theatre Management System (TMS).

An idea of the heady pace of the installations and the workload can be understood from the fact that the equipment for all nine digital screens was received at West Byfleet on the Friday, was unpacked, assembled and soak-tested over the weekend, and then taken to Surrey Quays and installed on the Monday. Incredibly, the whole nine screens were operational by the Monday evening, thanks to the sterling efforts of the five AAM installation engineers.

In parallel with the technical work, all the projectionists from Surrey Quays came to West Byfleet for two separate training course days (half of them one day, half another - somebody had to keep the cinema running!)

## The 35mm inheritance - or not?

I was interested to hear Ian say that although there are many good things to be learned from traditional 35mm service provision, he considers that one of the strengths of the way Arts Alliance tackles the installation of digital cinema equipment and provides its training is that it has had the chance to build its support systems completely from scratch. Since it wasn't building on an existing 35mm projector system support base it wasn't constrained by any existing designs and didn't inherit a whole raft of 'this is how we have always done it' attitudes from the 35mm projector installation business. I was somewhat relieved, as will be many CT readers, to discover that this seemingly rather fierce attitude is in practice more than tempered with a modicum of practicability - Ian told me that the majority of their cinema engineers do have a background in 35mm film projection, and this is extremely important when it comes to integrating digital cinema with existing equipment, as is necessary on nearly all current sites. The 'lots of 35mm experience' tag certainly applied to the three people - pictured above - who were acting as instructors on the training course during my visit.

Darren Briggs is National Field Manager for AAM, and is already well-known to CT readers from his time with City Screen York and his involvement with the annual Bradford Widescreen Weekend where his enthusiasm for 70mm as well as 35mm is undoubted.

Charles Rayne-Davies is Scottish regional engineer for AAM, and brings an in-depth understanding of the traditional film projection business to the company, as does

Nigel Priest, AAM's newest recruit, is the Midlands regional engineer.

It is always nice when you come across BKSTS Members working in the industry, and it was good to talk with Russell Smith MBKS, (below)

*Below - 1. Checking the Doremi servers as they undergo soak-testing 2. Christie projectors in the pre-build area awaiting final commisioning 3. Specially built heavy-duty base units for the NEC projectors and 4. Projectors mounted on the base units 5. The fully equipped mechanical workshop area 6. Southampton Solent University graduate Russell Smith*


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who graduated from Southampton Solent University, and who spoke warmly of the training received from Roger Lownsborough and from BKSTS Education and Training Committee Chairman Martin Uren - always up to date and relevant. Ian Strang mentioned that AAM have so far taken on two graduates from the Solent Courses (these courses were amongst the first to gain BKSTS accreditation) and said that they were so impressed by the practical nature of the training that the graduates had obtained that AAM were about to open a dialogue with the university to see if they could perhaps cooperate more closely.

### DSN Rollout - finished in April

I took the chance to ask Ian about progress with the DSN rollout, saying that I gained the impression that things had slowed down over recent months - numbers of installations shown on the DSN website are no larger now than they were three months ago. He said that there had been a pause for breath, whilst the decision to change the servers from QuVIS to Doremi had been considered, but that progress had now restarted, with typically 40 installs a month, and in February a phenomenal 18 sites are week are being installed, so that the long-term target of 240 screens will have been achieved by the end of April.

### Why change servers?

I asked about the interesting decision to change from QuVIS to Doremi servers.

AAM wanted to upgrade the network to the current industry standard, so that its cinemas have the best possible technology providing access to the widest possible range of digital content. The decision making started from the premise that all the existing QuVIS servers would eventually need to be upgraded to support emerging standards from the SMPTE DC28 Digital Cinema working committees, and to work towards DCI compliance. Whilst it would have been perfectly possible to modify the existing QuVIS units, significant hardware changes to the internal circuitry would have been required, and this meant that the complete replacement of the servers was a viable alternative.

An important factor was the need to be able to take an HD video tape and encode it into JPEG2000. This is a fairly recent technical development, and until this was achieved, QuVIS had been the best option for showing specialised digital content from a variety of source formats. AAM have now developed a JPEG2000 encoding workflow, based around a new encoding technology that offers cost effective and time efficient JPEG2000 encoding from HD video tape.

AAM have had a working relationship with Doremi since 2003, and when it came to considering the economics of modifying several hundred systems, taking into account the need for instant changeovers in the existing digital screens, were able to reach an agreement with Doremi allowing the upgrade to be made cost-effectively. The adoption of the Doremi servers also brings extra benefits to cinemas, in that they will be provided with 3D facilities at no extra charge, and the units support Thomson watermarking protection, Cinelink II encryption, the loading of content via a USB2 interface and a guaranteed upgrade to FIPS-140 level 2 compliance.

Feedback so far has indicated that the new equipment is easier to use for projectionists. I later learned from the training course (there are always knock-on benefits of these visits!) that the one feature that some users would miss from the QuVIS server is its incredible ability to show a clear moving image on its display screen even when being 'fast-forwarded' at a hundred times normal speed!

### Operational aims

Ian told me that AAM's operations have been set up with the purpose of becoming the 'Gold Standard' in digital cinema service. With digital technology finally reaching cinemas, AAM believe that it is time to move cinema service forward from its current ad hoc, paper based nature and provide the level of customer service and information technology that other industries already expect as standard. AAM's operational structure, IT systems and support have been designed specifically to meet and exceed the needs of digital cinema. The service structure reflects AAM's belief that digital cinema uptime is best served by having all components of cinema service, from installation to maintenance, provided by the same entity.

### Installation

Installations are managed by a dedicated Project Coordinator based in Kensington.

They are tracked on a database which has been custom designed for cinema installations. Reporting is easily available on individual or overall screen progress.

AAM's Engineers carry out detailed site surveys and produce integration reports. These reports contain schematics and also recommendations on alterations to accommodate digital cinema equipment.

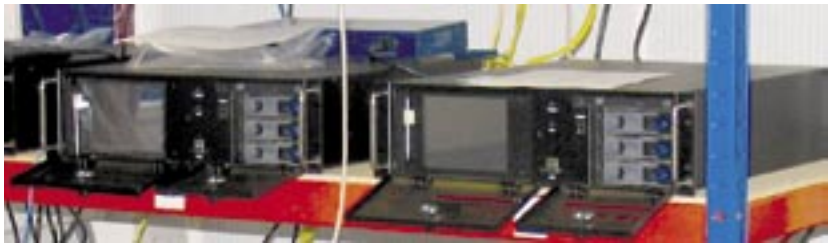
Equipment recommendations can be made or alternatively AAM's Engineers can work on the basis of pre-agreed equipment being installed - the company is completely flexible.

Every system undergoes a comprehensive pre-build and test before it is shipped for final installation. Critical system components are soak tested for several days to catch early life failures. The integrated systems are built up to a standard configuration using strict procedures, ensuring high and consistent quality between installations. The finished system then has to pass a comprehensive test schedule which tests all aspects of operation before it is released for installation. Onsite installation is thus reduced to a single day with one engineer, reducing screen downtime to a minimum.

Physical delivery and movement into place of the equipment occurs either on the day, or on the day before the installation. The equipment is installed and commissioned by an AAM engineer in a single day. After the pre-built system is reassembled, it is connected through an AAM designed interface box which simplifies connection to existing cinema systems. Commissioning is comprehensive, and includes full projector alignment and a rigorous test schedule.

### Support

AAM's Customer Helpline is open 24 hours a day, 365 days a year for fault reporting. During office hours, 2nd line technical support is provided by AAM technicians based in Kensington, and out of hours support is provided by on-call AAM Engineers. All customer contact can be tracked and logged in AAM's IT systems. The Network Operation Centre monitors all systems continuously, and is able to generate automated email alerts when certain fault conditions arise. It provides early warning of imminent problems, enabling maintenance to be scheduled before a fault develops. All equipment can be administered and controlled through the NOC, allowing 90% of issues to be resolved remotely,

and software to be kept up to date between maintenance visits.

I asked about the most common problems requiring help, and Ian quickly called up the log of the past couple of days, which included 'missing encryption keys' as the most common incident , 'projectionist having trouble with script-writing' (I know we are all in the movie business but what do we expect from the guys in the box?!) and 'QuVIS freezing', all of which were simply and quickly solved remotely.

### Service Management

All equipment is tracked and managed on AAM's systems, equipment fault history is captured and trends can be analysed. Field visits are scheduled and instructions dispatched to AAM's Engineers' hand-held units via GPRS. Customers can report faults via a web interface into the AAM software, and detailed and customised reporting is available. AAM's Engineers are based all around the country and are responsible for the performance of their own geographic area. Their whereabouts are always known via GPS, so that faults can be allocated to the closest engineer. Hand-held units allow them to have detailed customer and equipment history available to assist them. All this with the team of highly skilled and experienced digital cinema engineers providing seamless service from installation, through monitoring, to repair and customer care, all built around systems designed specifically to service digital cinema, goes a long way to match Ian's proud boast that AAM provide The 'Gold Standard' of cinema operations.

### Training is Vital

AAM put significant focus on training and believe it is a key factor in maintaining uptime. Courses are run by AAM Engineers, preferably local to the attendees' cinemas, often from Byfleet, with the course generally lasting 1.5 days. It combines tutorial, group exercises, hands-on equipment training and concludes with a test. After the initial course the responsible AAM Engineer then provides further on-site training to the projectionists. To date more than 275 projectionists have been trained as part of the DSN scheme, with numerous others, including the recent Odeon Surrey Quays staff.

I was fortunate enough to be invited to sit in on one of these courses, which actually turned out to be a unique 'one-off' course with specialist training for both QuVIS and Doremi servers being provided simultaneously! Half of the projectionists involved were having equipment installed in their cinemas this very week, so needed to know about the Doremi servers currently being fitted, whilst the other half were the second projectionists to attend from their already digitally equipped sites, and they needed to know about operating the existing QuVIS servers. Ian explained that after April all existing QuVIS servers will be replaced with Doremis, a process that will only take about half an hour per screen, plus the time needed to update the projectionists on site.

The training room is huge, with a large screen taking up the whole of the end wall - an extra screen had been installed for the Powerpoint presentations - and I cannot believe there is another similar one containing Christie, NEC and Cinemeccanica digital projectors, the latter having been specially imported as part of the Odeon Surrey Quays trials.

Initially the group of about 15 (most of them surprisingly young) projectionists sat around the tables with Darren providing an overview of the DSN project and the different pieces of equipment involved. He explained the basic theory of DLP® projection systems, and the differences between the different projectors. The Christie needs three-phase power, whilst the NEC can work from a 16 amp commercial single-phase socket. I watched with interest as we were shown how to power up the Christie and NEC projectors, with Darren emphasising what to look for on the projectors' control panels. We learned that the one switch turns off the lamp and the projector in the case of the NEC (a bit like a domestic video projector) whereas the Christie has separate switching for the higher - powered lamp. We were shown that the Christie needs a special air extraction unit, whereas the NEC merely vents its air out of slots in the side. It was recommended that the projection equipment should be permanently connected to the mains, via the Uninterruptable Power Supply, since this would allow the remote monitoring engineer

to get into the system to provide an encryption key, for example. Darren recognised that some cinema chains have strict 'all power off when you leave the box' rules, which would make it difficult to comply with this request.

Loading the different sized hard drive units into the different servers was demonstrated, with lots of advice on careful handling of the drive units, even though there have been very few mechanical failures of the hundreds of drives now regularly in transit. The QuVIS unit was the simplest to load, needing the projectionist to merely post the drive into a slot. The Doremi drives currently need to be connected to a power supply and a USB cable, which is less convenient, but Darren explained that AAM have designed an interface drive-loading bay panel to be fitted along with the Doremi server, which will save the need to deliver leads and power supplies with the hard drives, so this is only a short-term problem. The Doremi units can currently hold 1.5 Terabytes of data, slightly more than the QuVIS.

The projectionists then split into two groups, with Darren explaining about the Doremi unit, and Charles going through all the different functions of the QuVIS server. The advantages of having a sizeable training room became clear, as both lecturers were able to operate side by side, speaking quietly, but perfectly audible to the groups concerned.

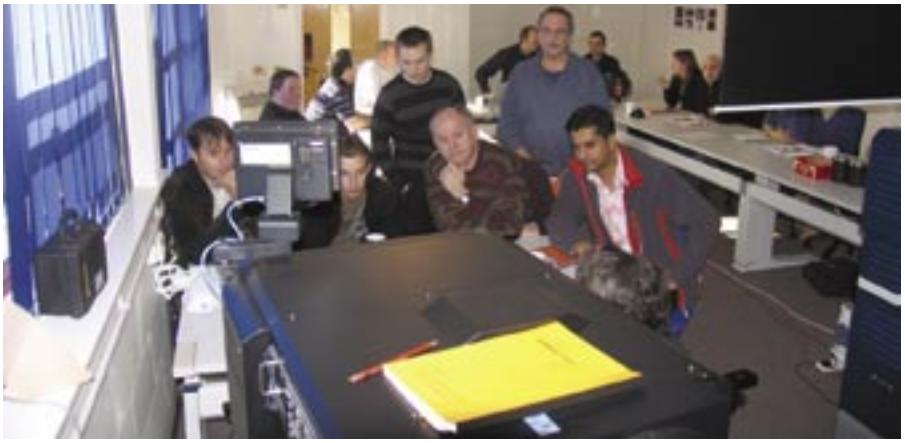
The lecturers pointed to the different pages in the servers' menus, highlighting the most important features. They showed how to connect different types of 'video' and 'alternative content' to the projectors using the AAM adapter box, and showed how to electronically select the different inputs.

It was great to see how much unsolicited feedback there was from the projectionists, which kept the lecturers on their toes, although they had heard it all before and could cope quite readily, of course!

Darren agreed with one suggestion that it could be possible to use a laptop display with mouse to make manipulating the smaller built-in touchscreen menus easier. He explained that the Doremi is effectively a very high-spec PC which uses the LINUX operating system, and a 'Windows-like' Graphical User interface. Other questions were about connecting the projectors to existing automation systems - the AAM system can accept cue pulses from all the main automation systems. The servers both provide so much built in automation control, however, that some thought may be needed as to how best to achieve particular effects by the best combination of server and pulse control.

Keys that fail to arrive as scheduled can be provided via email onto a USB memory stick, and I was fascinated to learn that you can't alter the system clocks on the projectors because if you could it would completely defeat the idea of having keys that only allow you to show movies at specific times. Obvious when you think about it, but I hadn't!

We were taken through the basics of script building, with an in-depth hands-on session due for the afternoon, including show-building, ingestion, and collecting data together for the drives, but I learned about 'elements' - any individual item of content or an action - and saw that it was very straightforward to build a simple play list. As always, there can be a huge difference between those who can simply show a movie and those who can really 'put on a show'.



It was good to see that all three lecturers were present throughout, and although Nigel was quiet during my short session, I know that he was due to give the projectionists a substantial session on maintenance on the following day. It was pointed out that maintenance and regular scheduled servicing are important. Although lamps are expensive, it could be false economy to delay a scheduled lamp change if a subsequent explosion destroyed a mirror costing thousands of pounds.

The whole atmosphere of the training course was friendly and professional, and the projectionists joined in whenever asked, and were always ready with another question. It takes something special to build a rapid 'rapport' amongst a group of people from all around the country, and the three lecturers I saw certainly had 'that certain something'.

Projectionists aren't let out of their boxes anything like often enough, and I left with the impression that the experiences and knowledge gained from their Arts Alliance digital training course will remain with them for many years to come.

*Thanks to all the Arts Alliance staff who arranged my visit and 'put up with me' during the training course - it is much appreciated.*

*Jim Slater*

# Protecting Movies Against Piracy: Why Encryption Isn't The Whole Story

*by Jason Power, Dolby*

**Piracy is very obviously a hot issue in the film business today. In the transition to digital cinema, there are many new opportunities to prevent theft, as well as a few new piracy risks to consider. To ensure a flow of quality content in the future, cinema operators need to consider the anti-piracy measures of the digital cinema equipment that they wish to install very carefully.**

In digital cinema, a movie is no longer distributed to cinemas on 35mm film, but is sent electronically as digital data, usually on some form of portable hard disk. One of the significant advantages of this digital technology is that, once the distributor has created the master digital file package, it can be copied or transferred any number of times without causing any degradation in quality. So endless perfect digital prints can be created onto small transportable hard disks, or even bounced off digital satellites, offering significant potential savings over the costs of making and distributing 35mm prints, and realising consistent presentation quality in cinemas.

But this portability also presents a major challenge: if the digital data falls into the hands of a pirate, quality copies can be made and transferred around the world easily and quickly. Fortunately, the data can be protected using very strong techniques, such as encryption, which mean that the data is valueless unless decoded with a mathematical code or "key". In digital cinema, the master movie file package can be encrypted before distribution, and only unlocked (or "decrypted") during cinema playback.

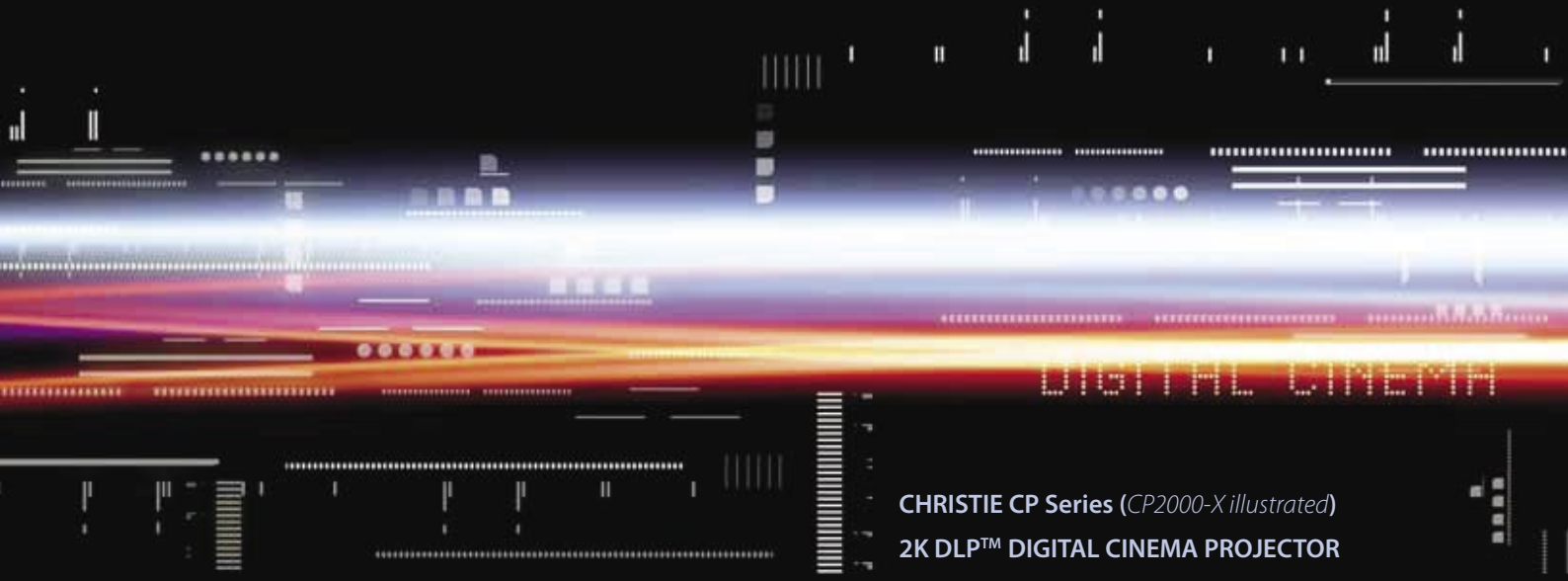
Today's encryption schemes provide very, very strong protection, so it is extremely unlikely that any pirate would be able to decrypt a file without using the key. So the real protection challenges in digital cinema are to protect movies in the stages of the distribution and playback chain where they are not encrypted, and to ensure that keys fall only into the right hands – the cinemas that booked the movie.

Tackling these challenges requires significant effort in the design of the digital cinema server. Inside the system, it is necessary to decrypt the movie during playback before the image decoding can be processed. This means that, inside the system, valuable movie data is passing around unencrypted, so some other protection is needed to eliminate the risk of a pirate lifting the lid and intercepting the circuit to steal the data. This can be achieved by a combination of physical protection measures such as secure silicon processors, specialised circuit board design with 'buried' connections, and tamperproof enclosures.

As it's very difficult to guess at what, if any, physical protection measures have been taken inside a server, the DCI specification calls for the main decryption and decoding module to be certified as meeting a formal security standard called FIPS140-2 Level 3. [Federal Information Processing Standard]. Level 3 calls for an advanced level of anti-tampering measures – having a locked or tamper-evident enclosure alone is not sufficient. FIPS certification is awarded after a military-grade analysis of security integrity controlled by the US National Institute of Standards and Technology, which can take many months to complete. Dolby has already started this process and expects to be one of the first digital cinema server manufacturers to be awarded certification. Preparation for this process has involved significant investment in specialised circuit design and manufacturing. For example, we've had to develop completely new ways of testing circuits as conventional test jig and test point approaches cannot be used.

In fact, the DCI requirement for FIPS Level 3 certification is perhaps the toughest part of all 176 pages of specification for server manufacturers to meet. Until the Fraunhofer Institute has completed its work to create an overall DCI Compliance test, cinema owners will need to trust that their equipment provider will deliver whatever is needed to bring them to full "DCI-compliance" once the testing programme is underway.

# It's About Choice

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