Development and Implementation of Digital Versatile Disc (DVD) for the Storage of Digital Photolog Images In Connecticut

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16. Abstract
This study addresses all aspects of the application of digital versatile disc (DVD) and related digital imaging technologies as they apply to the storage and retrieval of Photolog images. Additionally, this study outlines the implementation of DVD-based workstations and network-based Photolog servers to replace the analog optical laser videodiscs, which had been the primary Photolog image storage media in Connecticut.

I.

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List of Abbreviations and Acronym

ARAN	Automatic Roadway Analyzer
AGP	Accelerated Graphics Port
ATAPI	ATA Packet Interface
AV	Audio/Video
AVI	Audio-Video-Interleave
BMP	Bitmap File Extension
CAV	Constant Angular Velocity
CJL	Compressed JPEG Library
CD-R	Recordable Compact Disc
CD-ROM	Compact Disc Read Only Media
ConnDOT	Connecticut Department of Transportation
DAT	Digital Audio Tape
DDP	Digital Disc Protocol
DDIP	Disc Description Protocol
DLT	Digital Linear Tape
Department	Connecticut Department of Transportation
DVD	Digital Versatile Disc
DVD-R	Recordable Digital Versatile Disc
DVD-RAM	DVD – Random Access memory
DVD-ROM	Digital Versatile Disc Read Only Media
DVD-RW	Recordable and Rewritable Digital Versatile Disc
EPS	Encapsulated Postscript File Extension
fps	Frames per Second
GB	Gigabyte
GOP	Group of Pictures
EIDE	Enhanced Integrated Drive Electronics
IP	Internet Protocol
JFIF	JPEG File Interchange Format
JPG	File Extension for JPEG File
JPEG	Joint Photographic Experts Group
K	Kilobyte
KOMP	CJL Creation and Compression Program
LAN	Local Area Network
Lbs.	Pounds
LVD	Low Voltage Differential
M	Meter
MB	Megabyte
MHZ	Megahertz
M-JPEG	Motion-JPEG
mm	Millimeter
MPEG	Moving-Picture-Experts-Group
NTSC	National Television System Committee
PLV	Photolog Laser Videodisc
PC	Personal Computer
PCI	Personal Computer Interface
PVD	Perception Digital Video File Extension
PVR	Perception Video Recorder
QXD	Quarkxpress Formatted Design File Extension
RAID	Redundant Array of Independent Drives
RAM	Random Access Memory
RPM	Revolutions per Minute
SCSI	Small Computer Systems Interface
TCP	Transmission Control Protocol
TIF	Tagged Image Format File
WAN	Wide Area Network

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Development and Implementation of Digital Versatile Disc (DVD) for Photolog

Background and Significance

During the 1970's and early 1980's, the Connecticut Department of Transportation (ConnDOT) had three 35-mm film-based, Photolog-image retrieval stations located in various offices and buildings within the Department. These stations provided a drivers-eye-view of the roadway for purposes of review, measurement, confirmation and documentation. Utilization of these images resulted in substantial cost savings by reducing the need for field trips and length of time spent in the field.

The use of 35-mm reel-to-reel film analyzers provided excellent image quality; however, this linear access medium was time-consuming to both produce and review. Typical annual highway-network storage requirements for the 670 one-hundred-foot film reels were substantial. Research and Photolog Staff developed and implemented a PC-based laser-videodisc image-retrieval system in the period 1983 through early 1985, to meet the expanding needs of a growing user base. This Photolog laser videodisc workstation system, commonly referred to as the PLV, provided dense image storage, low image replication cost and enhanced user utility by virtue of on-disc random-access image retrieval. During the initial implementation, eleven PLV systems running the VideoHIWAY application software were strategically located within the Department at a cost of $40,000 per station.

During the 1980's and early 1990's, personnel from additional operational areas within ConnDOT expressed interest in acquiring PLV

stations, but the cost of the system was prohibitive. Rapidly evolving microcomputer technology offered opportunities to effectively respond to these needs. The cost and size of each station was dramatically reduced from its original 1985 configuration by eliminating some components and upgrading the PC (personal computer) operating system and software. As a result, the "Mini-PLV" became available to the Department in 1995, at a cost of under $11,000 per station. Demand for Mini-PLV stations markedly increased as a direct result of the lowered cost and ease of use and grew to approximately 30 workstations.

Also in 1995, ConnDOT took delivery of two state-of-the-art automatic roadway analyzer vehicles (ARAN)™. These vehicles were equipped with ConnDOT's 35-MM. motion picture film cameras. These were preferred to the standard interlaced-video cameras provided by the ARAN manufacturer.

In 1997, a camera system upgrade was undertaken. This consisted of installing progressive scan color video cameras; digital tape decks and PC-based digital video capture boards. 1997 was also the last year that ConnDOT utilized the Philips™ format laser videodisc for storage and retrieval of Photolog images.

At this time, high-density digital storage media were emerging and becoming popular. Recordable compact discs (CD-R) were less than $3.00 per copy and the Digital Versatile Disc (DVD) was making inroads into the digital-imaging market. By 1998, the analog optical storage media used by ConnDOT, i.e., the Photolog laser videodisc (PLV), was considered a "mature" product by the imaging industry, and was likely to be discontinued soon. This perception, coupled with the proven reliability of DVD, provided the

impetus for developing a lower cost state-of-the-art solution for the storage and retrieval of Photolog images.

Problem Statement

Given the impending obsolescence of the analog optical videodisc, the need exists to develop a digital-image based Photolog retrieval system that delivers comparable image quality and system functionality at a lower cost than the current laser videodisc based systems.

Study Objectives

The following research objectives were developed:

1) Design a digital-image based Photolog retrieval system, operating under Microsoft Windows NT 4.0™ operating system;

2) Examine state-of-the-art DVD formats and production issues and determine its suitability for the storage and retrieval of Photolog images by providing access to non-network users;

3) Provide Department access to network-based Photolog images, using client/server architecture, allowing for LAN/WAN (Local Area Network/Wide Area Network) retrieval of state maintained roadway images and data. This will be accomplished in concert with the Departments' Division of Graphic Information Systems; and,

4) Investigate the feasibility of Internet Photolog-image retrieval as time and resources permit.

Expected Benefits

Benefits realized from a successful study would include:

1) Reduced station-hardware cost;
2) Smaller equipment footprint;
3) Increased image resolution;
4) Reduced cost for media production and replication; and,
5) Department-wide availability via DVD or network.

Roadway Imaging and Acquisition

The emergence of progressive scan color video cameras provided the avenue by which an entirely new digital-imaging system could be designed and implemented. By virtue of this non-interlaced technology, image vertical-resolution was effectively doubled, when compared to conventional interlaced video cameras. The roadway digital-image capture interval is user-configurable. ConnDOT's Photolog vehicles acquire images at an interval of 10-meters or 100 images for each kilometer traversed. ConnDOT's progressive scan color video camera is shown in Photo 1.

Photo 1. Progressive Scan Color Video Camera

A continuous real-time roadway inventory is simultaneously recorded using a digital recording deck and videotape. Each forward-facing and side-facing camera provides image resolution of 640 X 480 pixels.

PVD Digital Video Format

A digital "frame grabber" provides the engine for in-the-field digital-image acquisition, in-the-office non-linear-editing and compressed-image formatting. This board produces a proprietary digital-video format that is a "flavor" of the motion JPEG format. It is referred to as a PVD (Perception Digital Video File Extension) file and is comprised of a sequence of roadway images. Digitization of the images occurs upon triggering by a distance-based measurement device. Each 720 X 480 pixel resolution frame contained within any PVD requires approximately 150 kilobytes of hard drive space. Proprietary hardware and software are

required for review and editing of all PVD video files and for referencing the corresponding BMP, TIF and JPG image formats.

Minimal additional PC components were envisioned to configure new lower cost digital-image based Photolog workstations. It was anticipated that only an internal DVD-ROM drive would be required. Unfortunately, utilizing the native PVD digital-video format requires the installation of hardware and software costing $2,000 for each Photolog workstation. Therefore, a hardware independent digital-image file format needed to be utilized.

Evaluating Digital Image Formats for Use With Photolog Pictures

Assessing the quality of various digital image formats was conducted in a subjective manner, where a consensus of both Photolog Staff and end-users determined which formats provided the most true-to-life reproduction of the roadway environment. All formats had to substantially reduce the overall storage requirements by virtue of file compression. PC hardware and performance could not be adversely affected when accessing files and displaying images.

JPEG Image Format: The JPEG/JFIF image format offers user-scalable compression for varying the image quality, file-size and its impact on overall storage requirements. In order to evaluate JPEG images, they first need to be created from their associated PVD files by exporting them, using the proprietary player software. The resulting JPEG images produced

had acceptable overall image-quality with an average file size of 70,000 bytes per frame.

The entire State-maintained roadway network is represented by more than two million images annually. Individual JPEG images would create large on-disc file directories that would drastically slow-down both hard-disc and DVD-ROM access. Additionally, final inventory and distribution of this enormous image collection would be extremely cumbersome. Due to these issues, use of discrete JPEG images was not undertaken.

Other Motion-JPEG Formats (M-JPEG): Other proprietary formats were identified that also required the use of a PC-hardware encoder and decoder board. No further investigation was undertaken as ConnDOT's ARAN Photolog vehicle currently utilizes motion-JPEG, based on one particular company's frame grabber and specifications.

AVI Digital Video Formats: AVI (Audio-video-interleave) format utilizes various software compression and de-compression strategies. The major disadvantage of AVI was found to be the inability to accurately point to a particular frame within the image sequence. Being able to bi-directionally navigate to one specific image and roadway location remains paramount for Photolog retrieval.

MPEG-1 and MPEG-2 Formats: MPEG was evaluated for encoding both continuous as well as the 10-m distance interval roadway images. The most obvious differences between MPEG-1 and MPEG-2 are their pixel size and

maximum bit rate. MPEG-1 uses lower bit rates and provides a resolution of (352 x 240) pixels. MPEG-2 was field tested instead of MPEG-1, because it encodes at a higher bit rate and provides for a better resolution of (720 x 480) pixels.

Two professional-quality real-time MPEG encoder boards were used for the test. Technical support engineers demonstrated their respective boards by providing the expertise in optimizing for image quality-versus-size. They utilized ConnDOT source material at the maximum usable bit rate and used both constant as well as variable bit rate encoding. Various Photolog image-sampling rates were used. Pictures were captured continuously (30 fps) and once every 1-, 3- and 10-m interval. Analysis of the MPEG images showed that the faster the image sampling rate, the fewer the observed artifacts.

An additional limitation with using MPEG-2 compression was that currently available DVD-VIDEO hardware players did not support true, frame-accurate, bi-directional navigation. This was due to DVD-VIDEO's unique group of pictures (GOP) structure, typically comprised of bi-direction and interpretive frames.

In summary, MPEG-2 can provide excellent results when used for encoding continuous video source material. However, as Photolog images are acquired and ultimately distributed at a 10-m sampled distance interval, the use of MPEG-2 was not prudent at this juncture.

Compressed JPEG Library Format (CJL): The compressed JPEG library (CJL) file format was created for ConnDOT by an independent

software developer. This method utilizes standard JPEG compression on individual images coupled with an image "table of contents" file header. The collection of sequential images is organized into a library of images within a single PC file. This technique provides quick access to specified images without needing to read the entire file. Running under NT 4.0, even the longest of Connecticut's highways can easily be accommodated within the structure of a single CJL file. In fact, 18,900 individual images comprise this 189-kilometer route, requiring less than one gigabyte of storage space. A "mild" JPEG compression ratio was selected for optimizing image quality and file size. Negligible artifacts were encountered using this setting.

As anticipated, the new CJL image-format can be utilized on all Department PC's. These files can be accessed from hard drives, optical storage medium such as CD-ROM and DVD-ROM and over the Department's network. Based on this performance, it was concluded that the new compressed JPEG library format would fulfill all of ConnDOT's new Photolog image requirements.

Creating CJL Files from PVD Video Files

Photologging is accomplished for all State maintained roadways bi-directionally, where applicable. This yields two digital-video PVD files from the forward and side video cameras and their associated hardware, as depicted in Photo 2, for each direction.

Photo 2. Forward Camera View with Corresponding Side Camera Image

The digital frame grabber card performs the majority of the image processing and compression on-board, so having a computer-processor faster than 400 MHZ did not noticeably increase image-processing speed. AVI-compliant SCSI hard drives are used for storage of the source PVD digital-video files and are interfaced via the on-board SCSI controller. The digital tape deck provides the added utility of being able to build a new PVD digital video file from images of a different sampling rate, if required for special projects. This is accomplished by using the continuous roadway videotape, video reference data files and custom software.

A software program was developed that automatically creates CJL files from PVD video files by exporting their corresponding JPEG images. This PC-based process requires that the same frame grabber board be installed. Once initialized, the CJL creation and compression program called KOMP, references a user-generated batch file, which contains the path to the PVD video source material, as

well as other information. The PVD file is created by digitizing the progressive scan, color video camera's 640 X 480 pixel output. This is done with the frame grabber and its' 720 X 480 native pixel size. Post processing of the data removes the extraneous black bands located within the 720 X 480 image. This band is inadvertently created by the disparity between camera output and frame grabber input and is negated by the KOMP program by stripping off the leading and trailing black bands. The geometric perspective within each image must remain unaltered from the original 640 X 480 pixel aspect ratio because virtual measurement tools will be used with these images.

As the program builds the CJL file, KOMP determines the total amount of picture frames within the PVD video file. A header is created for prefacing all of the newly created JPEG images. This will be used to quickly find and load specified images from each CJL file.

Lastly, 640 X 480 pixel JPEG images are exported from the PVD files, at a rate of 1/2 second each. In order to produce CJL files for all State maintained routes, two dedicated 400 MHZ PC-workstations ran continuously for four weeks. The PC-based hardware used to create CJL files is shown in Photo 3 and listed in Table 1.

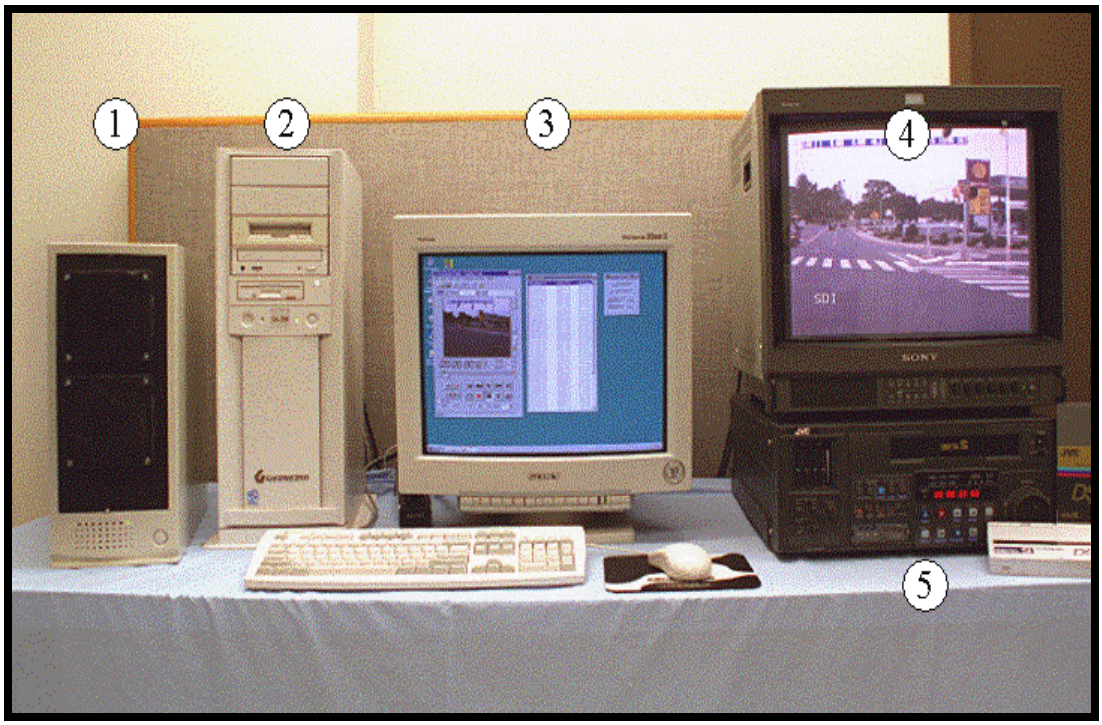

Photo 3. Digital Video Editing Workstation

Item	Hardware	Cost
1	External SCSI Hard drive enclosure/7 Seagate 9 GB drives	$4,000
2	PC Pentium 3/128 MB	$2,000
3	21" PC monitor	$1,000
4	Studio quality video monitor/YUV/SDI inputs	$800
5	Digital tape playback deck	$9,000
See Photo 3	PC Digital video frame grabber board	$2,500

Table 1. Hardware for Digital Video Editing

Procurement of all of the hardware listed in Table-1 can be done using the generic specifications, which are provided in the appendix.

Viewing CJL Files Using Roadpeek-Lite

A simple Photolog viewer called Roadpeek-lite was initially created for assisting in the evaluation of both frame refresh rate and image quality.

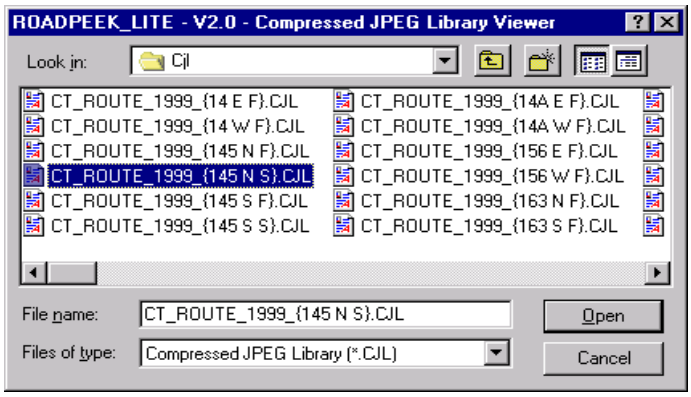

Photo 4. Roadpeek-Lite CJL-Selector Screen

Multiple instances of the software can be started for displaying all available camera-views simultaneously. The images can be manually synchronized via their common frame number. Clicking on the desired file name (see Photo 4) launches the image window and navigation tool bar.

Photo 5. Typical Forward Camera Image with Navigation Tool Bar

The navigation bar (see Photo 5) provides for bi-directional single frame stepping as well as multi-frame scanning at about 10 fps. Additionally, the user can scroll to a specific image frame number or enter it manually. Clicking on the file-details button provides an in-depth look into the internal header portion of each CJL file, as depicted in Photo 6. The appendix provides additional information on this topic.

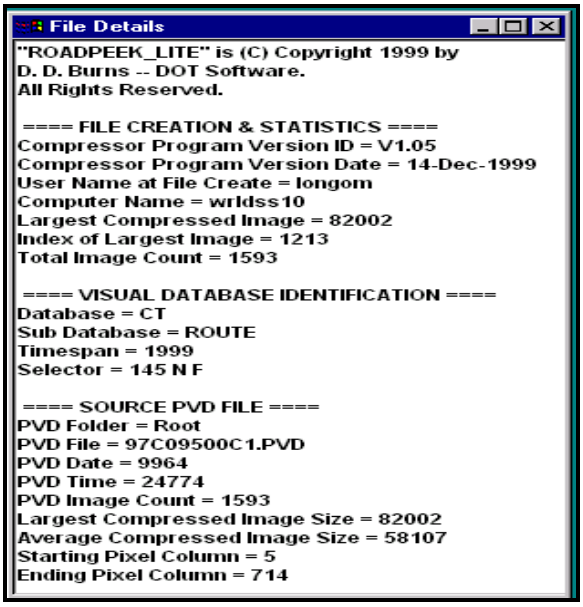

Photo 6. Screen Capture of Roadpeek-Lite Header Contents

The DVD Formats

Digital videodisc, also referred to as digital versatile disc (DVD), provided the means to efficiently store and distribute ConnDOT's digital Photolog library. This digital storage technology is available in a variety of sizes and formats. A single sided, dual layer DVD-9 DVD-ROM can provide as much as thirteen times the data storage capacity of CD-ROM. DVD

has swept into the home entertainment, computer and business information markets. It is well represented by major electronics and computer hardware companies, as well as most movie and music studios.

It is important to understand the difference between the *physical formats* (such as DVD-ROM or DVD-R) and the *application formats* (such as DVD-Video or DVD-Audio). DVD-ROM is the base format that holds data. DVD-Video defines how video programs are stored on disc and played in a DVD-Video player or a DVD-based computer. DVD-ROM includes recordable variations DVD-R, DVD-RAM, and DVD-RW. The application formats include DVD-Video and DVD-Audio. There are special application formats as well. While DVD-Video was the first of the DVD formats to be developed and has received more widespread attention, DVD-ROM was chosen for use in this project because it can provide massive amounts of file storage, significant when CD-ROM capacity is inadequate. Additionally, unfavorable Photolog-image test results using MPEG-2 meant that the DVD-Video format would not be appropriate. All DVD-based CJL libraries will be mastered onto a DVD-ROM.

DVD and Photolog

When ultimately choosing a DVD disc-format, the ability to access a Photolog forward-camera image along with its corresponding side-facing image was of prime consideration, Calculations indicated that 4 GB (gigabytes) of DVD space would be required to store all four CJL files for the longest state maintained route. While evaluating the various available types of DVD media, these key points were considered.

- Must be able to store the longest state maintained route on one side of a DVD, by providing greater than 4 GB of storage per DVD side.

- Should minimize the incidence of changing or flipping DVDs while viewing.

- Should provide clear and concise labeling for each year's discs.

- Should provide the smallest possible physical quantity of DVD discs per library.

Selection of the DVD-9 Disc Format

Table 2 provides a description of currently available industry supported DVD media formats that were considered for use in this project.

NAME	CAPACITY (GB)	LAYERS	SIDES	COMMENTS
DVD-5	4.7	1	1	Read from one side only
DVD-9	8.54	2	1	Read from one side only
DVD-10	9.4	1	2	Read from both sides
DVD-18	17.08	2	2	Read from both sides
DVD-R	4.7	1	1 or 2	Recordable DVD

Table 2. DVD-Disc Formats and Descriptions

All of the DVD-disc formats listed in Table 2 met the minimum storage capacity requirement of 4-GB per disc side. Specific issues are:

- DVD-5 was disqualified because of the excessive quantity of discs required and subsequent higher production costs.

- DVD-18 was not readily available in 1998 and is not currently offered by all DVD production facilities. Rim-art is utilized along the central hub margin of the DVD and is typically found on double sided media. It was determined to be less desirable than the full size artwork found on single sided media.

- DVD-R was not considered to be feasible, based on the sheer number of individually burned copies required, the associated high unit cost of the media and mean-time-between-failure of using replication hardware in this manner.

- DVD-10 was considered but because it is a double-sided disc format, product labeling for end-user disc identification would consist of rim-art. Rim-art on double sided media was found to be harder to read, due to the smaller font size. On the other hand, the full size label artwork typically found on any single-sided media such as DVD-9 offers the advantage of being less confusing to read and identify. Therefore, DVD-10 was not given any further consideration.

- DVD-9, a single-sided disc is comprised of two data layers (see Photo 7). Referred to as layer-0 and layer-1, they are both read from the bottom side of the disc. Layer-1 is considered the top or second layer and may be read in either

parallel track path or opposite track path modes. Parallel track path requires that the player head skip back to the inner radius in order to read layer-1. Opposite track path mode reads layer-1 in the opposite direction to the first data layer, that being layer-0. To provide for acceptable disc replication process margins, all dual layer masters are produced with approximately 10 percent longer pits than a single layer master. This accounts for the 10 percent reduction in DVD-9's data capacity of 8.5 GB, compared to the 9.4-GB capacity of a DVD-10 single-layer double-sided disc.

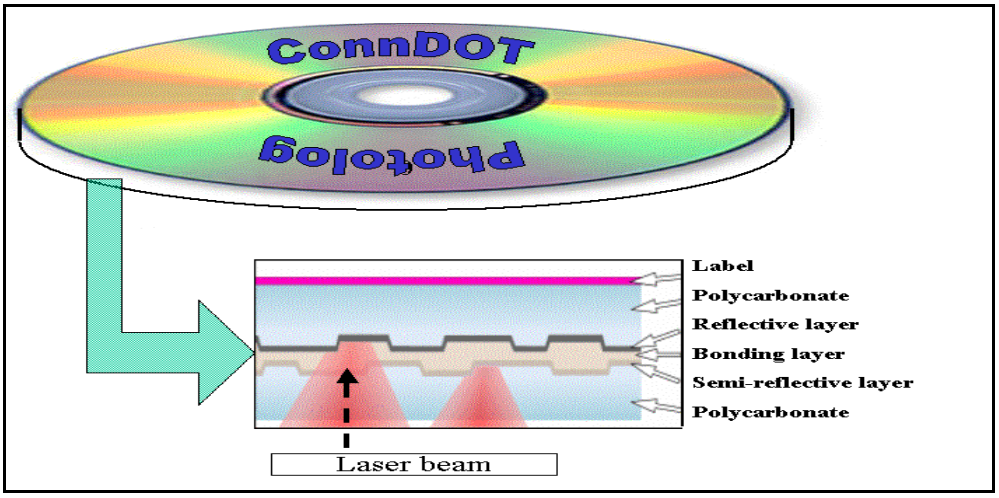

Photo 7. Cross-Sectional View of a DVD-9's Composition

Upon reviewing and evaluating the available DVD-disc formats, it was determined that DVD-9 provided the best overall solution, by virtue of its' 8.5 GB density, full size artwork and labeling capability, at a cost effective price. Therefore, DVD-9 was selected as the media, on which Photolog images would be stored and distributed.

Typical DVD-ROM Production Costs

Table 3 provides the quantities and prices for mastering and replication of the 17 Photolog DVD-9 disc titles that were produced for the 1999 Photolog season. Comparable prices and quantities for DVD-5, DVD-10 and DVD-R are provided. Costs were based on 150 replicates for each master/title. A complete ConnDOT DVD-9 library typically consists of over 900 CJL files, comprised of 140 GB of data.

Type of DVD	**Total master discs required**	**Unit cost per each master, less DVD image build**	**DVD Image build fee is $500 per side/layer**	**One title with 149 replicates, less DVD image build**	**Pre master fee is based on $200.00 per Gigabyte of data**	**Annual library pricing, less pre-mastering**
DVD-5	30 DVDs	$9.36	$500.00	$1,404.00	$28,000.00	$57,120.00
DVD-9	17 DVDs	$11.03	$1,000.00	1,654.50	$28,000.00	$45,126.50
DVD-10	15 DVDs	$10.36	$1,000.00	1,554.00	$28,000.00	$38,310.00
DVD-18	9 DVDs	N/A	N/A	N/A	N/A	N/A
DVD-R	38 DVDs	$31.00 each	N/A	$4,650.00	N/A	$176,700.00

Table 3. DVD Media Cost Comparison in Photolog DVD Year 1999

Pre-Mastering for ConnDOT's DVD-9 Check-Disc

Before a DVD production facility can master a DVD-9 title/disc, ConnDOT's data must be provided on two digital linear tapes (DLT). The pre-mastering process creates these two tapes, containing a total of five different files. These files are:

- **DDPID** Standing for Disc Description Protocol, this file provides a description of the data to be mastered onto a DVD-ROM. This standard was developed by Doug Carson and Associates and later adopted as an ANSI standard.

- **CONTROL.DAT** This file provides manufacturing information.
- **MAIN.DAT** This is the main program file.
- **LAYER-0 IMAGE FILE** Provides all of the customer's data for use in the 1st layer of the DVD-9 disc.
- **LAYER-1 IMAGE FILE** This file supplies all of the customer's data for use in the 2nd layer of the DVD-9 disc.

The two DLT tapes containing these five properly formatted files are then submitted to the production facility, to be used by their glass-mastering machine's laser burner. The "glass master" is used to make injection-molding dies for disc pressing. The DLT pre-master tapes contain the disc contents in their correct physical sequence, including volume and directory information.

Production facilities typically provide a fee-based pre-mastering service. It became clear that ConnDOT's DVD pre-mastering costs could be as much as $28,000 each and every year. In the hope of reducing this annually incurred expense, third party software product called ForDVD™ was identified. It had the potential to be used for in-house pre-mastering by Photolog staff, and at a cost of under $1,000.00 for materials.

In order to work out all of the DVD production-related concerns, and to be fiscally prudent, ConnDOT decided to have a check disc made. Check discs provide the same storage density and functionality as a normal DVD-9 title, but do not include artwork. They typical cost about $500.00 each to have made.

Three DVD-manufacturing vendors were solicited for creating ConnDOT's first check disc in April of 1999. Each company was asked to perform all pre-mastering using the ForDVD™ third party software.

The solicited bids from various vendors were:

- Vendor #1 $2,800
- Vendor #2 $4,800
- Vendor #3 $9,000

ConnDOT used Windows NT-backup™ software in order to create one DLT source tape for use by the low bidder. This tape contained less than 8.5 GB of CJL-image files, DVD-project information and various demonstration digital-video files. This assemblage of files was then organized into directories. The low bidder used NT-Restore and then provided pre-mastering using the ForDVD™ software. The check disc was then produced by the DVD production facility.

Upon receipt of the check-disc and four replicates, ConnDOT staff used Roadpeek-lite for testing the DVD-9's ability to access and retrieve CJL-image files. An internal 3X speed or better DVD player provided good frame

rates with no hesitation. The Roadpeek-lite software had an acceptable image frame display rate of 9 pictures per second.

The test disc evaluation results were so favorable that the development team decided to produce 450 copies with on-disc artwork. They were then distributed to attendees of the 1999 Transportation Research Board Meeting. This same product later became disc number one of the 1999 Photolog DVD production season.

In-House Pre-mastering Hardware and Software Requirements

In order to perform in-house pre-mastering, the following hardware and software have been successfully utilized:

- Intel™-based 400 MHZ or better PC with 128 megabytes RAM, 10+ GB primary hard drive, SCSI PCI controller, DVD-105S internal player, LS120 superdisc.
- 19” or better PC monitor
- 20+ GB secondary hard drive, 7200 RPM or faster AV qualified, SCSI interface.
- Digital Linear Tape (DLT), 1.5 MB/second SCSI interface
- Type III or type IV DLT tape media. Two tapes are required for each title. Capacity of 20/40 GB native format.
- ForDVD™ pre-mastering software used for creating two DLT tapes with the digital disc protocol referred to as **DDP 2.0.**
- The PC should be running Microsoft NT 4.0 Workstation™, service pack 6.0.

The DLT tape format is the current standard for DVD Production. A DLT-drive must have a minimum native data-transfer rate of 1.5 MB/second and a native capacity of 20 gigabytes. DLT tapes submitted to the manufacturing plant for DVD production must be Type III 10/20-megabyte tape written in the DDP 2.0 format. Some companies will accept the higher capacity Type IV DLT tapes as well. A separate tape is needed for each layer of a DVD-9 disc. The ForDVD™ software determines where each layer begins and ends and prompts the user when it is time to swap tapes. Using the above-mentioned hardware, each tape requires approximately 45 minutes of read/write time to prepare the two-tape pre-mastering DLT set.

Selection of Hardware for DVD-Based Photolog Viewing

The DVD-based Photolog-viewing-system-hardware requirements are more memory intensive and demanding of the processor than previous laser-disc based applications. Accordingly, twenty-four laser videodisc based viewing stations with 166 MHZ Pentium 2 PC's were replaced with the following specifications in order to support DVD-based image retrieval.

- Intel™-based 400 MHZ or better PC with 128 MB RAM, 10+ GB primary IDE hard drive, 32 MB AGP Video card, DVD-105S internal player IDE interface, LS120 super-disc.
- 19" or better PC monitor, less than .28-mm dot pitch.
- 10 GB secondary hard-drive used for geometric data storage.
- NT 4.0 Workstation™, service pack 6.0.

In 1999, ConnDOT experienced difficulty in obtaining PC's with both internal DVD-drive and preloaded Microsoft-NT™ software. This was due to

the fact that NT-drivers did not exist for DVD-Video. As a result, some of the major PC manufacturers would not provide a product configured in this manner. This was unfortunate and deemed to be an unnecessary restriction, as ConnDOT was not planning to view DVD-Video content. In fact, since the desired DVD drives were of the IDE-controller type, no additional drivers were required. The generic ATAPI drivers typically resident on most PCs would have sufficed. ConnDOT resolved this issue by purchasing slot-loading internal DVD-ROM drives and installing them into NT-Workstation™ PCs. This illustrated the common misconception that was held by both salespeople and the end users at that time in regard to DVD-ROM and DVD-Video. Specifically, what hardware and software are required when using a DVD-ROM for data storage versus when using a DVD-Video for playing movies?

Software Development and Modification to Support DVD

Utilizing the Philips-format 12-inch laser videodisc for Photolog image retrieval required the presence of a NTSC video capture and overlay board in each workstation for displaying the pictures. Individual roadway images were "burned" to a specific frame location of this randomly accessible analog-optical media. A total of 54,000 frames were available on each side of the disc. The external laser videodisc players were capable of providing real-time video frame rates (30 fps) in both forward as well as reverse scanning modes.

Laser videodisc based application tools were being developed on an on-going basis, for use in assisting Department staff for performing various highway-engineering related tasks. With the need to find a suitable medium for replacing the "mature" laser videodisc technology, the DVD-project

investigators were continually concerned with preserving the functionality and "feel" of the existing Photolog software. Therefore, it was decided that software development would consist of creating a new "engine" for powering digital-image file-retrieval. The laser videodisc version of the virtual measurement tool, which provides for "on-screen" object distance and height calculations, as well as other companion tools needed to be modified in order to work with digital images.

This new all-digital Photolog software was renamed DigitalHIWAY. Completely new software modules that were exclusively created for use with DigitalHIWAY were:

- VideoHIWAY NetCompressor – this module initially creates the Compressed JPEG Library" (CJL) files.
- VideoHIWAY NetClient – this module provides end-user display of both DVD-based as well as network-served images.
- VideoHIWAY NetServer – this module provides, extracts and delivers digital Photolog images to one or more VideoHIWAY NetClient users, via a TCP/IP network connection.

An installation CD was created and provided users with both the DigitalHIWAY application as well as the geometric roadway data. Corresponding geometric roadway data for each Photolog image is required before the geometric data tools can be utilized. The current installation practice consists of loading the annual data set for an entire year and locally storing it on each users PC's hard drive. In the future, updating the new season's data set will be accomplished via a network download or ODBC database connection.

Limited Network Access for Distribution of Digital Photolog Images

A network-based Photolog image retrieval system using client/server architecture via a TCP/IP network connection was developed in concert with both ConnDOT's network administrators and Graphic Information Systems. The following hardware and software configurations have been successfully tested and approved for serving Photolog images to selected key-operational areas:

- Intel™-based 800 MHZ+ PC with 384 MB RAM.
  - 20+ GB primary hard drive.
  - DVD-ROM 4X internal player.
  - LS120 120 MB floppy superdisc.

- 15" PC monitor.

- 140+ GB of secondary hard drive space.
  - 7200 RPM or faster AV qualified, LVD or Ultra160 SCSI.

- Microsoft NT-4.0 Workstation, service pack 6.0

- DigitalHIWAY Server version 1.09

This configuration performed flawlessly during in-house testing by providing 20 simultaneous TCP/IP connections to various office PCs that were running the DigitalHIWAY version 1.99 client software. Each client PC accessed both exclusive as well as shared server-based CJL roadway image-files at a continuous rate of about one-to-two images per second. The NT 4.0 Performance Monitor utility was used to assess server PC performance criteria during the testing. CPU utilization peaked-out at less than 50-

percent, while other parameters remained nominal. Additionally, no adverse impact to the client-PCs was encountered. Upon concluding the test, the network administrator reported that no noticeable impact to the 100-megabit-per-second network had occurred.

In order to preserve network bandwidth, in the event a user clicks the scan ahead or scan backwards button and leaves the workstation unattended, the client software will terminate the request for images after 120 frames have been accessed.

The DigitalHIWAY client software purportedly employed an integral governor, which was designed to limit each client workstation to a maximum frame rate of two images per second, when retrieving network-based images. This was intended to minimize any adverse impact to network bandwidth. It was discovered during testing that by quickly rotating the mouse's center wheel, images are pulled off the network at up to five frames per second. The actual frame rate is dependent on the overall processor speed of the client workstation PC. [It is unlikely that a typical user would utilize the mouse in this fashion.] This software problem was reported to the software developer and should be remedied in future versions of the DigitalHIWAY client software.

Feasibility of Department-Wide Network-Access for Photolog

In the near future, Network based Photolog viewing for the entire Department could be realized if implementation of additional servers is properly undertaken. The administrators of ConnDOT's network were asked to provide their vision in regard to future Photolog servers for the

Administrative Headquarters building. Nodes would be created, each consisting of approximately 50 Photolog users. Each node would be organized by their physical location within the Main building and would be serviced by one Photolog server, located at the Department's Data Center. Network switches would be strategically placed so as to contain the Photolog related network traffic within that node. Photo 8 illustrates one possible scenario for future implementation.

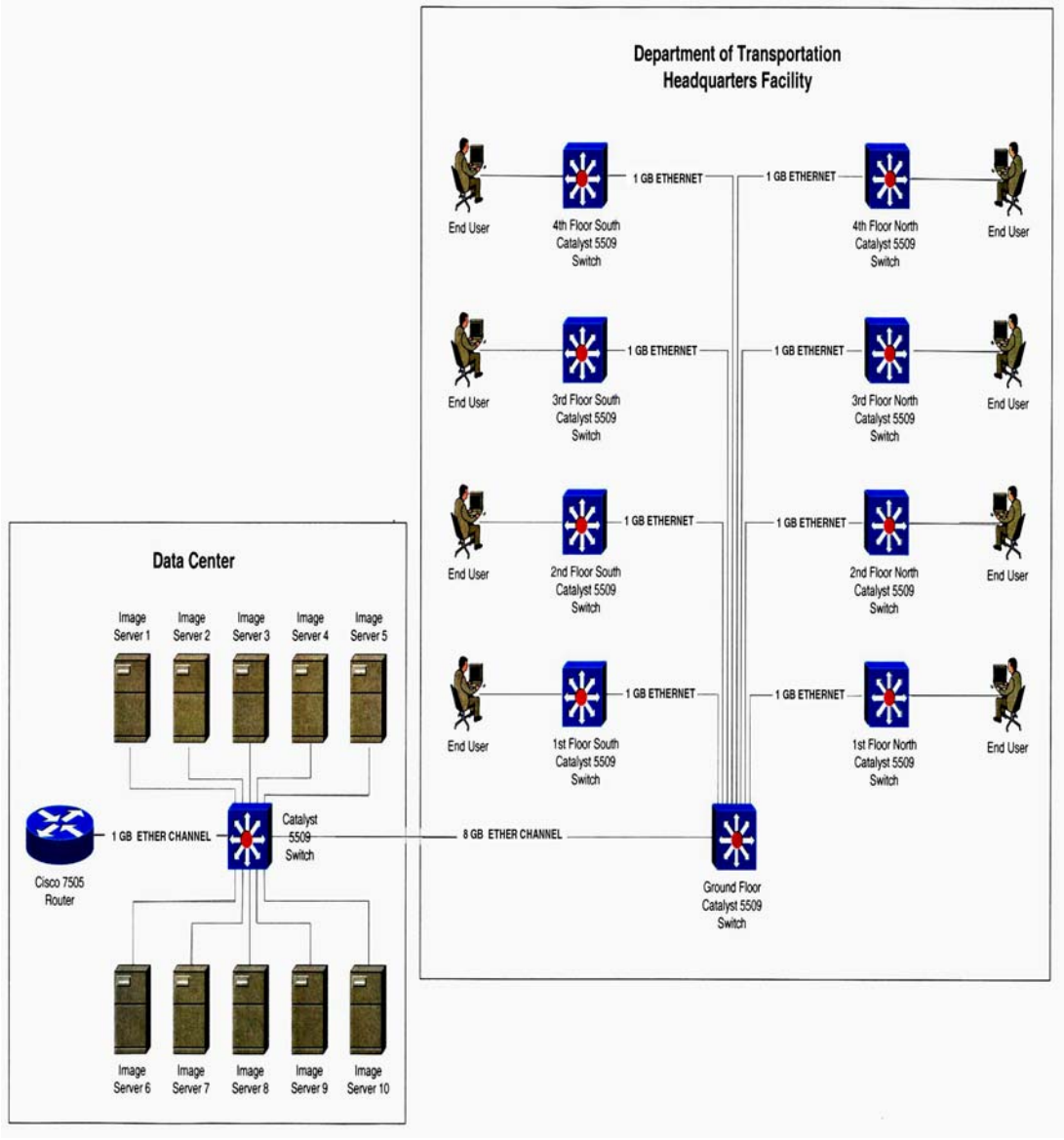

Photo 8. Department-Wide Scenario for Network-Based Photolog Servers

Upgrading of Existing PLV Stations with New PC's and DVD-ROM

Prior to this writing, 34 "Mini-PLVs" were being shared within various operational areas within the Department. With the implementation of this project, 102 Department workstations now have DigitalHIWAY installed on both notebook and desktop PCs, retrieving digital images from either DVD-ROM drives or accessed over the network. Additionally, eleven-megabits-per-second wireless network cards are providing good performance by allowing PCs the ability to roam freely about the Research & Materials Testing facility in Rocky Hill, Connecticut, without having to reassign IP addresses.

Over the last year, ConnDOT staff were required to install internal DVD-ROM drives in older Department PC's, since they were not provided under the existing State procurement contracts. At this time, the State contract permits the purchase of new PCs with an optional DVD-ROM drive.

Analysis of Production Schedule and Delivery of Product Timetable

An analysis of all production-related image-collection and pre-mastering duties was undertaken. A typical production season is comprised of various tasks that need to be completed within a stringent timeframe. This schedule (listed in Table 4 and described below) ensured that the transition from laser videodisc to DVD would not contribute to delaying the delivery of the annual Photolog DVD library:

- Two ARAN™ vehicles, each staffed by a two-man crew perform the annual roadway-image and data acquisition from May through October.

- Pre-editing is performed on two PC editing workstations from October through December. Digital-audio-tapes (DAT) contain all the backed-up roadway digital-video PVD files. Restoring the entire season's worth of these 8mm X 160m tapes requires about 140 gigabytes worth of hard drive space. Each route is then reviewed for accuracy using a video monitor and PC.

- Compressed JPEG Library (CJL) file creation is undertaken, concurrent with the pre-editing process. Two staff members and PC's produce over 900 individual route files in both forward and side camera views.

- DVD Pre-master tapes are then created on one PC workstation for the entire collection of CJL files. The files are organized during the pre-mastering procedure, by moving 8.5 GB of data into each DVD/title's folder. Once the folder has been filled up, the pre-mastering software creates the necessary DLT pre-mastering tapes. This task is performed throughout the month of January.

- DVD mastering and replication occurs, concurrent with the pre-mastering efforts. As ConnDOT creates sets of DLT tapes, they are sent to the production facility along with ConnDOT's label artwork. DVD label artwork is submitted by utilizing the vendor's artwork layout templates from the CD-ROM that they provide. Quarkxpress™ software is used for producing a (.qxd) formatted design file. This is submitted on CD-R along with any logos or other design elements in either the bitmap (.bmp) or encapsulated postscript (.eps) format. ConnDOT chose a two-color layout for their DVD label design. The

colors were referenced from the standardized Pantone color chart, thus minimizing any color interpretation problems. The production companies' artwork department verifies all submitted material for quality and compliance. If a check or test disc is ordered, it requires customer approval before proceeding with that title's production run. Normal turn-around from DLT submittal to receiving the final DVDs is approximately 7 to 10 business days. ConnDOT typically receives all required DVD titles by the end of February.

PRODUCTION TASK	FROM	REQUIRED RESOURCES
Roadway Image and Data Collection	May-Oct.	ConnDOT, 2 two-man crews
Digital-video pre-editing	Oct.-Dec.	ConnDOT, 2 PC-Workstations
Compressed JPEG library creation	Oct.-Dec.	ConnDOT, 2 PC-Workstations
DVD Pre-master tape creation	Jan.	ConnDOT, 1 PC-Workstation
DVD Mastering and replication	Feb.	DVD production facility

Table 4. Tasks and Timeframes for a Typical Photolog Production Season

DVD vs. Laser Videodisc Performance Comparison

This task identified the fundamental operational differences between using an analog-optical disc-based viewing station and a DVD-based viewing station.

- DVD facilitated the departure from analog-optical disc's 425 usable lines-of-resolution. By virtue of DVD's 500 lines-of-resolution, and the CJL digital image format, a noticeable improvement in overall image quality was obtained.

- Distribution and access of network-based Photolog images finally became feasible with the adoption of the new CJL digital-image format.

- DVD based Photolog viewing hardware is much less complex, and the footprint and cost of each workstation was reduced by eliminating the $1,000 laserdisc player and the $800 video capture/overlay card.

- Final product distribution for DVD is easier. A typical annual laser videodisc library consisted of 15 double-sided discs and weighed in at a hefty 10.2 lbs. A complete set of DVD-9s (17 discs) only weigh a measly 12 ounces! Additionally, archive storage space requirements are reduced, due to the smaller physical dimensions of DVD. 5” X 5” of storage space is required for a stack of DVDs, as compared to the 12” X 12” space required for analog-optical storage.

- Forward camera and side camera views are “housed” on the same side of each DVD-9. This provides the ability to seamlessly access supplemental roadway views, without swapping discs. The 12” Philips format disc in CAV mode did not provide sufficient storage density for providing this functionality

Feasibility of Internet Distribution of Digital Photolog Images

The distribution of Photolog images via the Internet was beyond the scope of this project. Internet distribution will present a unique set of challenges as compared to our Departmental-network utilization. Access by the private sector would consist mainly of 56K modem via telephone lines. This will likely require re-structuring of the new digital-image file format. Future research in this area will address preserving the usefulness of lower quality images while reducing the time required for downloading them.

No significant investigation into Internet distribution was undertaken in this study. Instead, a proposal called E-HIWAY: Internet Distribution of Photolog-images will be prepared to address these issues during a separate study.

Conclusions

At the time of this writing, the project has provided the Department with a fully implemented digital-image-based Photolog viewing station capability, running under NT 4.0 service-pack 6. This highly useful application is currently available to any Office that requires access to images and geometric data on the State's more than 12,000 bi-directional kilometers of roadway. The majority of legacy laser-videodisc-based PLV stations have been replaced with a 400 MHZ or better, Pentium-3 PC, configured with internal DVD drives and DigitalHIWAY version 2.0 client software. The following key points contributed to a successful implementation.

- Over one million roadway images are contained within 1500 compressed JPEG libraries. They are organized by route, direction and camera view. Storing and manipulating large numbers of discrete images within the same directory/folder is to be avoided, as it severely impacts PC hardware resources and performance.

- Complete DVD libraries, consisting of the entire annually updated state-maintained highway system, are provided to personnel each year. These are housed on twelve-to-fourteen DVD replicate discs.

- The DVD-9 format provides an excellent storage medium that efficiently and economically meets the Department's current Photolog-image storage needs. In the very first year of DVD production the $60,000 savings realized in not producing analog optical discs, provided the means for the Department to "grow" it's Photolog user base by more than 80 workstations. In the future, it is anticipated that the higher storage density of DVD-18 will be considered for adoption in Connecticut. This decision would be subject to future availability of DVD-18 production/replication services and cost.

- Testing the robustness of the DigitalHIWAY network-servers consisted of 20 users simultaneously connecting to an 800 MHZ workstation-class PC acting as the server, and continuously calling for images. Based on the test results, a server should be capable of servicing up to 50 users each. Each server

requires on-line storage for two years worth of Photolog images and currently cost approximately $6,600 each.

- Network access is currently being provided to a limited number of operational areas. Several client-side "throttling" strategies were implemented in software. Both forward- or reverse-motion scan commands automatically terminate after receiving 120 images and must be manually restarted. The other workstation network-bandwidth limiter is the rate at which frames are called for, which is limited to two frames per second.

- It is anticipated that Department-wide network implementation will expand gradually as resources permit. For the foreseeable future, the combination of network access and CJL libraries on DVD-9 will be used to provide Photolog images and data to all who require them.

Recommendations

1) DVD-18, a dual-layer, double-sided medium, would cut the total amount of master discs in half by providing twice the storage density of a DVD-9. Further consideration will be warranted in the future if the image-sampling interval was to be increased from 10-meters to 5-meters or when DVD-18 production services become more readily available.

2) Consider using more economical ATA-100 7200-RPM EIDE hard-drives for on-line storage of Photolog images in DigitalHIWAY servers, for further cost reduction. These drives currently provide storage densities of up to 80 GB and appear to provide sufficient performance for network-based Department servers at a much lower cost than equivalent size SCSI drives.

3) Create a future version of DigitalHIWAY server software to run as a service. This would provide a higher level of reliability and dependability when restarting a server following a power failure.

4) In the next proposed version of the DigitalHIWAY server software, the network administrator will be provided with a maximum bandwidth limit capability, thereby allocating a maximum data rate in kilobits-per-second. Additionally, the total number of simultaneous users per each DigitalHIWAY server needs to be constrained as well.

5) In the event of catastrophic server hard-drive failure, hundreds of gigabytes of image-data will need to be restored. At the current time, Photolog image retrieval is not considered to be mission-critical. Therefore, the use of some level of redundant-array-of-independent-drives (RAID) for the storage and retrieval of Photolog images was not justified, since the cost for the required redundant hard-drives is substantial. In the future, as hard-drive storage prices continue to decline, purchase of a low-cost RAID would be warranted, as Information-Systems and Data Services personnel would save many hours of labor when recovering from hard-drive failures in DigitalHIWAY servers.

6) Reduce the complexity and steps required in the annual creation of over 1,500 CJL files. To accomplish this goal, identify new all-digital

color still-frame cameras, which output images in the new JPEG-2000 format. By virtue of wavelet compression, improved image quality and reduction in overall storage requirements could be realized. Using these new digital cameras, daily offloading the final digital-image files from the vans could occur directly to the pre-mastering suite and greatly simplify and speed up most production related tasks. This would facilitate the eventual goal of 1-day turn-around from field-collection to desktop viewing via network distribution. Replacing the currently utilized video cameras with suitable color digital cameras would eliminate the following production steps:

A. Backup-Exec scheduling software would no longer be required to run on a nightly basis, for offloading the digital-video PVD files from the vans. This is currently accomplished by using a local digital-audio-tape drive or the network.

B. Restoration of the backed-up DAT tapes to the pre-editing workstation would no longer be performed, prior to pre-editing.

The PVD-to-CJL creation and compression software, called KOMP, would need to be replaced by new, simpler and faster JPEG-to-CJL creation software that would simply collect all required JPEG images and incorporate them into their respective CJL file.

Appendix A

DRAFT SPECIFICATIONS FOR DVD-9 DIGITAL VERSATILE DISC PRODUCTION

GENERAL

Contractor shall master and produce a *pre-determined number* of Digital Versatile Discs. Each DVD-9 will be formatted as a single-sided, dual-layer disc, whose storage capacity shall be approximately 8.5 billion bytes. It must conform to the Micro UDF and or ISO-9660 standards for DVD-9. Each disc (title) shall have a pre-determined number of replicates per each disc (title).

The customer will utilize the DVD-9 as a DVD-ROM. No MPEG-2 encoding or DVD-MOVIE authoring is required. *The customer*, using ForDVD UDF- formatting software shall perform all required pre-mastering. No additional pre-mastering shall be required of the contractor. *The customer* shall supply all source material for each Disc (title) on two (2) DLT4000 Type IV digital-linear-tapes. One DLT-tape shall be comprised of layer-1 files. The other DLT-tape shall be comprised of layer-2 files. Each tape shall contain approximately 4.25 gigabytes data-uncompressed. *The customer* shall use ForDVD software for creating all DLT source tapes. A *pre-determined number* of separate-title alpha/check discs/copies *may* be required. These shall be used for verifying compliance of *the customer's* pre-mastering procedure. If an alpha/check disc is requested it must be approved by *the customer*, prior to the contractor mastering and replicating that disc (title).

SPECIFICS

DVD Type: To be DVD-9, created as a single-sided dual-layer disc. Each shall contain approximately 8.5 gigabytes of data per individual disc (title). All DVD-9s shall be Micro-UDF and or ISO-9660 compliant.

Volume label: Contractor shall create all DVD-9 master-discs with a unique volume label. The format will be similar but not limited to CT_ROUTE_1999_1 or CT_RAMP_1999_1.

Source Tape: *The customer* will supply pre-mastered source material on two (2) DLT4000 DLT type-IV tapes. The first DLT tape-#1 will be provided for all layer-1 files. Not exceeding 4.25 gigabytes, it will contain the following files:

1) Ddpid *384 bytes*
2) Control.img *32,768 bytes*
3) Layer01.img *approximately 4.25 gigabytes*

The second DLT4000 type-IV DLT tape-#2 will be provided for all Layer-2 files. Not exceeding 4.25 gigabytes, it will contain the following files:

4) Ddpid *384 bytes*
5) Layer02.img *approximately 4.25 gigabytes*

Both DLT Tape-#1 and DLT Tape-#2 shall contain approximately 8.5 gigabytes of data, for use by the contractor in producing each DVD-9 disc/title, replicates or alpha/check discs.

SPECIFICATIONS AND REQUIREMENTS
FOR PHOTOLOG DVD-9 PRODUCTION

DLT Tape-Backup Procedure: *The customer* will create each title's source-material on two (2) DLT-4000 tapes using ForDVD software.

DLT Tape-Restore Procedure: Contractor will utilize *the customer's* properly formatted source material from supplied DLT-4000 tapes, at their replication and mastering facility.

Pre-mastering: *The customer* will pre-master all source material in-house, utilizing ForDVD-version-5.7 UDF-formatting software.

Mastering: Contractor shall master and create a *pre-determined number* of DVD-9 discs (titles).
They shall be compliant with the Micro-UDF and or ISO-9660 standards

Replication: Contractor shall produce a pre-determined number of replicates for each DVD-9 disc (title).

Alpha/Check disc: Contractor shall provide a *pre-determined number* of Alpha/Check discs for any discs (titles). This shall consist of one (1) Alpha/Check-disc and four (4) copies of that disc (title). *The customer* will use these for pre-mastering and product verification, prior to mastering the final DVD-9 and replicates. Alpha/Check discs are only to be provided by Contractor when authorized, by *the customer*. *The customer* will specify which titles will be provided alpha/check discs after contract award has been made.

ADDITIONAL SERVICES AND PRODUCTS

The contractor shall provide the following products and or services:

Additional DVD-9 Mastering: Contractor shall provide a unit cost for each additional DVD-9 master produced in excess of the original *pre-determined number* of discs.

Additional DVD-9 Replication: Contractor shall provide a unit cost for each additional DVD-9 replicate produced in excess of the original *pre-determined number* of discs.

Additional DVD-9 alpha/check disc: Contractor shall provide a unit cost for each additional DVD-9 alpha/check disc produced in excess of the original *pre-determined number* of titles. Each additional alpha/check disc shall include four (4) copies.

SPECIFICATIONS AND REQUIREMENTS
FOR PHOTOLOG DVD-9 PRODUCTION

The contractor shall provide the following products and or services:

Artwork

Disc artwork shall consist of two-colors. The substrate "color" shall be utilizable. Quark and or PageMaker v6.5 shall be used for submittal of the DVD-9 artwork layout to the contractor. The PC-file format shall be acceptable.

Packaging

Contractor shall provide the following packaging:
All DVD-9 discs shall be inserted into paper sleeves with flap. It shall have a plastic see-thru window. All DVD-9 discs shall be pre-inserted into sleeves. The artwork on the DVD is to be visible through the window.

Shipment

All paper-sleeved DVD-9s shall be packaged in a suitable carton. Shipment of the DVD-Discs from the contractor's facility shall be made via acceptable carrier. The customer's DLT source-tapes shall be returned within 3 months of DVD-production. All DVD-disc (titles) shall be insured for their replacement value, should they become lost or damaged in transit. Shipment of all DVD-discs, DLT tapes, and artwork CDs with all appropriate insurance costs shall be borne by the contractor.

Final Acceptance

The customer's **designated representatives shall review each DVD-title as it is received. The set of replicates will be checked for conformity of artwork, and proper volume labeling and file inventory. All data must be accessible on the DVD using consumer-level DVD-ROM players. Data dropout shall cause the customer to reject that title and replicates. They will be returned to the contractor, together with the pre-master DLT-tapes for the production of (a) new DVD(s) at no cost to the customer.**

Payment shall be made on the basis of each DVD (title) with corresponding replicates produced and accepted by *the customer*. This price shall include all labor, materials, handling costs, postage and shipping etc., pertinent to the production of each DVD (title).

Appendix B

Appendix B contains specifications for equipment that was successfully utilized in the implementation of this project. This does not imply that other equipment could not perform in a similar capacity.

PRODUCT ELECTRICAL SPECIFICATIONS FOR DPS PVR-2500 DIGITAL VIDEO RECORDER BOARD

Output Signals:
Composite (BNC).....1V p-p 75 Ohm
S-Video (4-pin Min-DIN):
Y Signal.....1V p-p 75 Ohm
C Signal (Burst).....286 mV p-p 75 Ohm
Component Betacam (BNCs):
Y Signal.....714 mV p-p 75 Ohm
R-Y, B-Y (Pr, Pb) Signal.....700 mV p-p 75 Ohm
Component MII Mode (BNCs)
Y Signal.....700 mV p-p 75 Ohm
R-Y, B-Y (Pr, Pb) Signal.....486 mV p-p 75 Ohm
Genlock Input (BNC):
Composite.....1 V p-p (Loop or 75 Ohm)
GPI Trigger (RCA).....Negative Edge TTL or Contact Closure
Video Performance:
Frequency Response.....0 - 5.0 MHz (+/-0.25 dB)
.....5.0 - 5.5 MHz (+/-1.5 dB)
K-Factor (2-T).....<1%
Differential Phase.....<1 degree
Differential Gain.....<1%Signal/Noise (Luma Weighted).....>68 dB (Playback Mode)
.....>58 dB (All Modes)
Raster Size.....720 x 480
Digital I/O
DPS CVE-2 Bus
For AD-2500 Real Time Capture Daughter card (40 pin internal header)
Hard Drive I/F
Fast SCSI-2 (internal 50 pin header)
Total Power Consumption. .....11.5 Watts
Dimensions:
Height.3-7/8", Length.12-1/4", thickness.1/2".

PRODUCT ELECTRICAL SPECIFICATIONS FOR JVC BR-D50U PLAYBACK DECK

Sampling:	4:2:2, 8-bit Y: 13.5 MHz R-Y/B-Y: 6.75 MHz
Compression:	3.3:1 DCT based intra-frame coding
Data rate:	50 Mbps
Frequency response (analog out):	Y: 0 to 4.5 MHz, +1.0/-2.0 dB (analog out) R-Y/B-Y: 0 to 2 MHz, +-1.0 dB
S/N (analog out):	55 dB
K factor	2%
SDI output (unbalanced	Option
Analog output (75 ohms, unbalanced	Composite: 1 Vp-p Y/C: Y: 1 Vp-p, C: 0.286 Vp-p (burst) Component: Y: 1 Vp-p R-Y/B-Y: 0.7 Vp-p Reference: 0.45 Vp-p (loop)

PRODUCT DESCRIPTION FOR SONY DXC-9000 PROGRESSIVE SCAN VIDEO CAMERA

Compact 1/2" IT Hyper HAD (tm) 3-CCD color video camera

Progressive scan feature outputs all electric charges accumulated every 1/60 sec. to provide a complete frame

Utilizes square pixels for computerized image processing

Built-in memory provides 3 types of output signals: VGA mode, normal mode and frame shutter mode

Freeze function

Long-term exposure function

High sensitivity of f/5.6 at 2000 lux

700 lines horizontal resolution, 480 lines vertical resolution

Auto white balance, auto tracking white balance

1/60, 1/100, 1/125, 1/500, 1/1000, 1/2000, 1/4000, 1/10,000 sec. shutter speed selection

CCD IRIS and auto gain control functions

3-pattern light metering system with selectable detection area

On-screen menu

Built-in RS-232C

Appendix C

KOMP Internal Header Structure and Description

The following information is contained within the header and is comprised of the following information.

- **File Creation and Statistics Section**
  - CJL compressor software version.
  - Person operating the compressor software.
  - PC network name on which compressor resides.
  - CJL byte size of largest compressed frame.
  - CJL frame location of largest compressed image.
  - Total amount of frames within the CJL file.
- **Visual Database Identification Section**
  - This information is used to build each unique CJL file name.
- **Source PVD File Section**
  - Provides PVD file name and creation date.