Video and Data Projection Systems

By Kevin Scott

Many planetaria find video to be an integral part of their presentation format. Whether it is used to create seamlessly blended effects, reproduce live video feeds, or simply put a computer image up onto the dome, video is a powerful medium. Perhaps the most significant barrier to widespread use of video is cost, followed by the complexities of creating original material. Video projectors and playback devices are expensive and can be temperamental. Creating video sequences is often time consuming and resource intensive. For all these difficulties, it has become a key feature in most newly constructed planetaria.

We'll address video and data projection systems in three sections: 1) projection devices, 2) video sources, and 3) transport and routing. In addition, we'll discuss common projector layouts, all-dome video systems, and other ways video and data projection systems can be used in the context of a presentation. Keep in mind that this is a rapidly changing field. Some of the details in this document will become dated sooner or later. Dome-L listserv and IPS Conferences are good places to find out the very latest in technical developments in this field.

Projection Devices

There are now three basic "breeds" of video projectors. The original (and most widely used in planetaria) is the CRT based video projector. These projectors use cathode ray tubes (television screens) to create the images and light that is focused on our domes. Larger projectors use separate red, green, and blue CRTs to enhance image brightness and color saturation.

Outside of planetaria, digital projectors are perhaps the most common. These projectors can be defined by their use of a separate light source and either a liquid crystal display (LCD) or tiny mirrors to reproduce a video image. Within this broad category there are a number of technologies being employed by various manufacturers to offer a range of projectors that vary in physical size, price, light output, resolution, and other features.

The newest breed of projectors use laser light and mechanical scanning technology to reproduce a video signal. Laser video projectors have the potential to reproduce ultra-high contrast images with excellent color saturation at up to High Definition resolution. Initial demonstrations of this new technology show it to be very promising for use in planetaria.

Planetaria impose a unique set of requirements on video projectors. In some cases, the projector may be called upon to reproduce a planet amid the starfield. At other times, it may compliment lecture in the dome with online web pages or a digital slideshow. There may also be a production where a video image is framed on the dome by other means. It could be in full-dome video.

For most planetaria, Black Level control is one of the key issues. If you want to, you should be able to eliminate the gray rectangle of the video frame to reproduce "formatless" video. This allows spacecraft, planets, stars, and other astronomical video effects to appear unbounded by the extents of the video image. When elimination of the video frame is a requirement, CRT projectors are the technology of choice. By and large, digital projectors always emit a small amount of residual light that prevents them from achieving full black. Laser projectors (circa 2000) come very, very close and may achieve full black in the near future.

Other projector considerations include compatibility with modern automation systems, overall image brightness, throw distance, focusing range, power and cooling requirements.

CRT Projectors

CRT projectors work well in planetaria because they are capable of achieving full-black and are able to accept the widest range of input signals. Most CRT projectors can handle a variety of input resolutions, signal frequencies, and aspect ratios. As an analog device, they can also produce a very smooth, non-pixelated image. With additional electronics, such as line scalers and doublers, it is possible to project a seamless image, eliminating the scan lines normally present over large throw distances or when the image is optically enlarged.

ADVANTAGES

Extensive Geometric and focus correction

Projected image can be warped, distorted, and focused to compensate for curved projection screens.

Full black capability

Useful for projecting “formatless” video, or images without a gray frame or border.

Variable output resolution

CRT projectors do not project hard pixels and most can handle both standard and high definition video signals. Note that just because one projector **can** display high definition video doesn’t mean that it will look better (qualitatively speaking) than another projector.

DISAVANTAGES

Often bulky, heavy

The Barco 1029 series of projectors, for example, weigh 82kg (181 lbs) and are 117.4cm x 78.2cm x 35.5cm (46.2in x 30.8in x 13.9in) Split-head versions are available which separate the projector electronics from the lens assembly.

Projector Convergence

Three gun video projectors (those using separate red, green, and blue CRTs) must be “converged” for optimum performance. That is, each CRT must be aligned such that the images exactly overlay one another. These settings must be tuned for each input signal, and they change over time as the projector and CRTs age.

Color adjustment is non-trivial

In situations where two or more projectors are being used to create a single seamless image (as in all-dome video systems,) color balancing across multiple projectors can be quite challenging.

Limited Brightness

When compared to other projector types, CRTs are almost always at the bottom of the brightness scale. This problem is exacerbated in planetaria where video is often projected across the diameter of the theater creating a larger, dimmer image.

Digital Projectors

There are several different types of digital projectors including LCD, DILA, ILA, and DLP/DMD. Liquid Crystal Display projectors use either a transmissive or reflective LCD panel to generate the video image. Other projectors use a Digital MicroMirror Device for image production. Image Light Amplifier projectors are sort of a hybrid, combining the input and geometric flexibility of a CRT (or in the case of DILA, a digital pixel map processor) with the high-brightness normally associated with other digital projectors.

ADVANTAGES

Very bright, high contrast images

The use of a separate light source can provide light output levels orders of magnitude greater than CRT projectors.

Small, light, and relatively portable

While some non-CRT projectors are quite large, most are much smaller than their CRT counterparts.

Ideal for computer screen projection

In some cases, it is possible to match the resolution of your computer output to that of the LCD/DMD in the projector. When you do, you get a pixel-for-pixel representation on the screen without any scaling artifacts.

No need to worry about convergence

Most digital projectors use a single light path, eliminating the need to converge separate RGB sources. Very few multi-LCD projectors require convergence, but there are some on the market that do, particularly the ILA variety from JVC.

Adjustable image size

Many digital projectors have a built-in zoom lens.

DISADVANTAGES

Residual light output

Most digital projectors cannot reach full black without a mechanical iris or shutter.

Fixed output resolution

In order to display images that do not match the native pixel count of the LCD/DMD, the input signal must be scaled. This can result in image artifacts that make text difficult to read or cause unnecessary distortions. Some projectors handle this scaling better than others, but it is not necessarily a function of cost.

Lack of true geometry correction

Many digital projector manufacturers claim to be able to do geometry correction in their systems. There is currently no way to physically morph the pixel locations on a LCD/DMD. These projectors actually perform high-level image warping techniques on the video signal and then feed that to the LCD/DMD for output.

To learn more about DLP/DMD projectors, visit http://www.ti.com.
To learn more about ILA and DILA projectors, visit http://www.hughesjvc.com.

Laser Projectors

The concept of using laser light as the basis for a video projector has been around for decades. In the last few years this technology has begun to mature, and a few laser video projectors are now commercially available.

ADVANTAGES

Bright, high contrast images

Outstanding image brightness and contrast are two of the primary selling points for laser video projectors. In addition, laser projectors can produce a wide range of colors beyond what is possible with CRT or LCD systems.

No convergence necessary

The red, green, and blue laser light are optically combined

Zoom capability

The Zulip projector from Zeiss has a zoom lens that allows on-the-fly scaling of a projected image

Almost unlimited depth of field

Images are in focus when projected onto surfaces of nearly any shape.

DISADVANTAGES

Residual light output

Laser projectors can suffer from a slight amount of internal scattering and the beam attenuation crystal always emits a very small, though nontrivial amount of light when blanked.

High Initial Expense

Laser projectors are relatively scarce and are generally more expensive than more traditional projector types.

Operational considerations

Laser projectors may have special electrical and cooling requirements. In addition, there may be governmental regulations regarding the operation of the projector and the ways in which it may be installed and used.

Common video projector layouts

The number, type, and placement of video projectors in a planetarium is a function of budget and programming philosophy. In many new planetaria, you'll often find a mixture of larger long throw projectors and smaller short throw projectors. Larger projectors are often mounted in cove space, with the bottom of the video frame resting on the springline of the projection dome. Springline mounted video has the advantage of being able to present images that break the bottom of the visual frame without destroying the illusion of the dome as "space." Additional long-throw projectors can be mounted as needed or for specific programming. Smaller projectors are often installed in a projection pit and roughly mimic the positions of various slide projectors. Being able to move a video image around on the dome is certainly a nice feature that can be accomplished by moving the projector itself, using a movable front surface mirror, or some combination of the two. The Conic pan/tilt video mount is an example of such a device. The Zulip laser projector from Zeiss also has an optional pan/tilt mount. Slewing video images are dynamic and can provide a great deal of production freedom.

All-Dome video systems

Most dome video systems use some variation on the theme of several large projectors mounted in cove space. Location and installation specifics vary with each vendor. In general, there are a number of projectors equally spaced around the perimeter of the dome (usually five or six) and then an additional projector (or two) aimed from the cove toward the zenith. Normally all-dome video installations use CRT projectors, though there are theaters with LCD installations. For those that do use CRTs, the split-head projectors from Barco are a space-conscious option. In these projectors, the CRT tubes are separate from the electronics and power components to reduce the amount of cove space needed.

There are two primary forms of all-dome video systems currently available. Real-time systems (Goto, Evans & Sutherland, and SGI/Trimension) all utilize raw computing power to create dome imagery on the fly. These systems are designed to allow audience interactivity and provide a great deal of production freedom. Playback systems (Sky-Skan) utilize pre-rendered imagery stored on hard disks and work best in linear productions.

Other Uses

Digital projectors are nice for lectures and times when you want to have the lights up a bit. Many of these projectors have direct inputs for computers and generate a pristine image. Some LCD units have built-in (or optional) shutters so that they can be used in more traditional star shows. You'll probably want to use it as a television format image (possibly framed by another projector,) or if the overall scene is bright enough to make any format outlines negligible. It is possible to mask the output of an LCD projector such that circular objects like planets can be cleanly projected. The folks at SkySkan produced a nice implementation of LCD masking in their Sun/Moon projectors.

Another popular idea is to extend a computer network into the planetarium. Many theaters find it quite useful to be able to show live web sites and other computer imagery directly on the dome.

Video Source

In the early days of television, engineers began looking for a simple, standard way to synchronize video images from the originating camera to the viewing set. They decided that the frequency of the electricity powering the television would be a good timing signal to keep the video images in sequence. From that basic decision, the world's television signals became divided.[1] Much of the Americas and Canada use a 60Hz Mains power frequency and a video standard called NTSC. Most European countries use a 50Hz Mains frequency and a video standard called PAL or the French variant called SECAM. Other countries, in general, follow this pattern of matching their video standard to their Mains frequency, using PAL, NTSC or some variation thereof.

Today we're on the verge of another standards crossroads – that of "Advanced" or "High-Definition" Television. These systems are still quite young, however, and the migration process will leave us in a transitional period for many years. In the meantime we have to contend with decades old video standards and the uncertainty of new technologies.

Standard Definition

Standard Definition (TV) video is defined by the NTSC, PAL or SECAM standard and each dictates the number of lines in the picture, how the color information is defined and the speed with which the lines are "written" to the screen from top to bottom (refresh rate).

TV signals have a set number of horizontal lines of picture information. In NTSC that number is 525; in PAL and SECAM it's 625. Within these numbers, there are a few non-visible blanking lines hidden at the top and bottom of the screen. These blanking lines contain no picture information and bring the actual total of visible information to only 483 lines in NTSC and 576 lines in PAL and SECAM.

TV signals are "interlaced," meaning that each full "screen" of information is actually composed of two separate "fields" – the odd lines and the even lines. First the odd lines are painted on the screen. Then, before the odd lines have had time to completely fade, the even lines are "painted" in between the odd lines. This process is almost beyond human perception, especially when viewing moving images. This interlaced method isn't the best solution for displaying certain non-moving objects, particularly those with thin horizontal lines. For

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[1] For additional information on the history of television standards and global power, check out this web site:
http://www.ee.surrey.ac.uk/Contrib/WorldTV

example, fine horizontal lines may appear or disappear depending on how the odd and even picture fields have been encoded.

Composite video is perhaps the most common way of encoding a video signal's color and sync information all together. Other variations break up the signal into its component parts in an attempt to improve picture quality. For example, S-Video separates the chromanance (color) from the luminance and sync information. Professional video equipment often deals with the signal components on an even more elemental level. While all of these formats differ in the way the video information is combined into a signal, they still have certain things in common. They are all interlaced and they have standardized refresh rate. Both NTSC and Pal compose frames of video from two interlaced fields. NTSC draws a new fame 30 times each second (a rate of 30 Hz.) PAL and SECAM, draw new frames 25 times each second (25Hz).

High Definition

There are some commonalities between competing Hi-Def delivery systems and a handful of companies have products in the market. The Advanced Television Systems Committee (an international organization) has defined a number of potential standards (Glossary, Table 1), though none has emerged as the most widely accepted and implemented. The primary roadblocks to ubiquity are issues of image size (measured in pixels or lines) frame rate, and whether the signal is interlaced or not. Computer companies are vying for a non-interlaced standard in hopes that computer screens will be directly compatible with the new television signal. The broadcast industry is trying to determine what to do with legacy systems and what is the most economical upgrade path. It's still somewhat early in the game to know exactly how High Definition television will develop over the next several years, though it is likely that television and computer video standards will continue to merge.

Computer Video

While broadcast television parameters are rather specifically defined, the range of options in computer video is much greater. The number of horizontal lines on a computer display can vary anywhere from 480 on up to 1280 or more. Nowadays, most computer video cards allow a choice between several different display resolutions. Compared to 525 or 625 lines in broadcast video, computer video is ideal for high detail images and crisp text.

Computer video signals are scanned progressively. That is, the horizontal lines on a computer screen are written in order, left to right, top to bottom, in one single pass. Progressive scanning reduces horizontal motion flicker and, along with generally higher refresh rates, produces a much more stable image. Most computer video signals redraw the entire screen between 60 and 100 times each second. The tradeoff for increased resolution and image stability is the need for a great deal more signal bandwidth – more processing power and a fatter "pipe" to carry the computer video signal.

Computer video signals do share a common standard of defining color information for the monitor. Nearly every computer platform delivers the chrominance and luminance of an image via separate red, green and blue video signals. The additive nature of the RGB color system is well understood and provides a very wide spectrum of reproducible colors. Video sync information is often separated out as well, further reducing distortion and increasing overall image quality.

Video Media and playback formats

Laserdisc

12” laserdiscs have been fairly common in planetaria. Laserdiscs from large production runs are normally made of plastic, while one-offs or masters are often made of glass. Many laserdisc players provide frame accurate video searching and the ability to display relatively high quality still frames. Some units can play backwards and forwards at varying speeds so that you can change the length of a particular effect to match your script, within reason.

VHS (and S-VHS) Tape

VHS is perhaps the most ubiquitous consumer video format in the world. While VHS is generally considered to have the lowest picture quality, it is by far the least expensive video format to work with. Most VHS decks do not offer accurate searching or external interfaces that can be utilized by theater automation systems. That said, anyone comfortable with electronics and a soldering iron can usually rig up a functional automation interface in a matter of hours. Even if VHS is below your quality standards, it’s nice to have a player/recorder in your theater to accommodate visiting lectures or to archive special events.

DVD

In North America, DVD players have grown very popular and have captured market share faster than VHS did when it was first introduced. They are replacing laserdiscs and have become the new consumer video standard. DVD offers almost all of the same features as laserdisc, though the video should be of higher quality, and the DVD specification allows for a wider variety of audio information to be stored on the disc. Most automation system providers including SkySkan, East Coast Controls, Spitz and Commercial Electronics support the Pioneer Industrial model DVD players.

8mm (and Hi-8) Tape

8mm tapes are quite popular as a camcorder format though not so much in home recorders. As a capture medium, it is quite convenient though it is difficult to find robust playback devices suitable for daily use in a planetarium.

Betacam Tape

Sony’s Betacam is probably the most widely used broadcast format. While professional Digital Video (DV) products are starting to chip away at the Betacam market, it is still ubiquitous in the broadcast world and somewhat common in larger planetaria. Digital Betacam is gaining acceptance though player/recorders are quite expensive. Digital Betacam performs a 2:1 compression scheme on the video frames but is essentially free from visual artifacts.

DVCAM, DVCPRO, DVPRO Tape

There are three primary DV tape formats that compete at the professional level. Each is based on the DV standard though there are slight differences between them including tape formulation, tape speed, track pitch, and compression ratio. Each of the manufacturers gives various reasons for deviating from the DV standard, though in reality it all comes down to market share and differentiating their products to consumers. On average, frames of DV are compressed at a rate of 5:1. This level of compression can develop visible artifacts under known conditions. Subjectively, there is very little visual difference between video images originating from Betcam and these professional DV formats, given that the source material was captured with identical cameras and lenses. In fact, when using DV equipment at this level, most visual problems are attributable to a disregard for professional recording practices, or the use of low quality cameras and lenses – not any sort of compression artifact. At the consumer level, there are a number of manufacturers that offer inexpensive DV products. DV camcorders and DV based video capture cards make it a rather simple matter to shoot and edit your own video projects. IEEE-1394 (also known as FireWire or I-Link) is simply a data transmission standard capable of handling the high bandwidth that digital video requires. FireWire equipped computers and video recorders allow you to transfer video to/from your computer without the need for compression/decompression of the original data.

Digital Hard Disk Player/Recorders

Instant searching, compression can be tricky to make it look good. The DPS Perception Video Recorder can respond to Sony's control protocol so any automation system that can control a RS-232 or 422 serial device can control the PVR. Bowen Productions has a product that recognizes Pioneer laserdisc control protocol – making it plug-n-play with most automation systems. Each hard disk unit uses its own mechanism to encode the video data digitally. Some use compression. Of those that use compression, those that use MPEG compression deserve special mention. MPEG is gaining wide industry acceptance from the consumer level on up through high-end broadcast equipment. MPEG 2 is the compression standard used by the DVD consortium and probably the most widely supported. There are several companies that have MPEG 2 compatible digital disk players on the market, and it is becoming very easy to encode your own MPEG 2 video. MPEG (1&2) (Soloist from Adtec, DVM2 from Alcorn-McBride, and Bowen products)

HDTV playback

As an emerging technology, High Definition video equipment is quite expensive. There are both tape and hard disk based systems out there. It's something we'll have to watch over the next few years, because from a quality standpoint, it's where we want to be.

Direct from computer

Computer and broadcast video signals differ greatly. Fortunately, most video projectors accept input from a computer video card. Alternatively, you can use a device called a scan converter to transform the computer video into an NTSC, PAL, or SECAM compatible signal.

There are many other video formats out there – from consumer through broadcast grade. Please don't take an omission here as a value judgment.

Routing, switching, and video conversion

Making connections between all your video devices and projectors can be quite challenging in and of itself. Automation systems can help ease the confusion by abstracting the functionality a bit, but also impose a layer of complexity.

Most planetaria will encounter several different forms of "video." Broadcast television and cable systems transmit a modulated video signal with accompanying audio. Your home television receiver, VCR or cable box picks out the desired video channel and separates it from the rest of the broadcast signal.

Composite video is the name given to this extracted video signal without audio. You'll find composite video connectors on VCRs, camcorders, laserdisc players, DVD players, and some computer graphics cards.

High-end video equipment often tries to improve on this basic format by separating out the component color, luminance, and synchronization information into discreet signals. There are many different variations on a theme here. In fact, most professional videotape machines offer multiple forms of component video output, including RGBHV (Red, Green, Blue, Horizontal Sync, Vertical Sync), ITU-R 601(Y, Cr, Cb, Sync), and S-Video. Television studios use these formats to maintain high-quality images from capture through editing to transmission. All of these forms of video use the same 50/60Hz refresh rate and broadcast line resolution. Even new component digital formats are simply an analog video signal digitized (as you would digitize audio from a microphone) such that it can be sent as a high-bandwidth digital signal over a single cable instead of multiple cables carrying the individual RGBHV signals.

Line doubling and quadrupling

In planetaria, line doublers and quadruplers are most often used to reduce the visibility of scan lines in projected video. They can also be used to transform the video signal such that can be displayed by non-interlaced equipment such as computer monitors.

As noted previously, there are 483 visible lines in an NTSC signal; 576 in PAL and SECAM. At its most basic level, a line doubler generates a new video signal where it outputs two copies of every input line, effectively "doubling" the video image and the overall vertical line count. Similarly, quadruplers output four copies of every input line. Line doublers may also work in the horizontal dimension. In general, this process cannot add any information to the input image. Most line doublers try to be a bit more intelligent, utilizing various methods to improve the overall picture quality.

Line doublers do have limitations. Because they exactly double or quadruple the video signal, further processing is necessary to make line doubled output compatible with standard computer resolutions. Less expensive line doublers can degrade the picture during this process or produce unwanted image distortions or cropping. Line doublers are also limited in that they normally produce 60Hz vertical refresh rates, when many computer screens and digital projectors are capable of handling much higher rates. Finally, most line doublers cannot support picture aspect ratios beyond 4:3. This isn't much of a problem today, but may become so with the proliferation of High Definition signals.

Video scaling

Like line doublers and quadruplers, a video scaler combines the information in the odd and even fields of an incoming video signal into a single, non-interlaced picture. Then, the video scaler uses various image processing algorithms to manipulate the video stream changing its resolution, refresh rate, aspect ratio, and other attributes. Finally, the scaler outputs standard computer and native digital projector resolutions for crisp, clean images.

Video scaling eliminates most of the limitations imposed by line doubling and quadrupling. Perhaps the most significant of which is the ability to generate a video signal that exactly matches the native resolution of your digital video projector.

Scan Converters

Scan converters are devices that allow you to view computer generated images on ordinary television sets. In the future, this process will become less important as we move toward digital television systems. But today scan converters are needed in many planetaria where the common video signal is not high definition or digital video, but plain old NTSC, PAL, or SECAM.

Scan converters come in three forms. The first is integrated onto a computer video card. These scan converters can be tuned to the capabilities of the parent video card, though often provide only basic functionality and minimum output quality. Consumer grade stand-alone scan converters are the most popular option. They usually have a few simple options built-in such as image scaling and under/over scan. Image jitter and difficulties with fine text and line details are common on most all consumer grade units. Broadcast quality scan converters employ custom electronics to create the most stable, high quality image but at an enormous cost. When considering the purchase of a scan converter, try to audition several different models in various price ranges. You may find inexpensive units that produce acceptable output and some costing several times as much producing rather poor images.

Audio/Video Matrix Switchers

If you have more than one video source (VCR, laserdisc player, etc.) and more than one video projector, you should definitely consider a video matrix switcher. Switchers allow you to connect all of your input sources and outputs to projectors into a single device. Once connected, you can manually, or via automation, connect any input to any output. Professional switchers will make the connection during the video signal's vertical blanking interval, thus providing a seamless and immediate change of source to output. Matrix switchers come in various configurations, with options to handle all forms of video source and any number of inputs and output channels. Many switchers also offer RS-232 control such that they can be operated by an automation system. Some automation system vendors have developed proprietary audio/video switching systems that are tightly integrated into their control software.

Video Production

More and more planetaria are exploring the complexities of video as a presentation medium. Production difficulties and overall cost are still the two greatest hurdles to widespread installation and use. With some careful research and soul searching, you can probably get yourself up-and-running and a feature-rich, functional video production system that doesn't require taking out a second mortgage.

Perhaps the simplest solution involves a single video projector (or overhead projector with an LCD panel) and computer, projecting the computer screen directly onto the dome. PowerPoint slides, graphics, and web pages are all appropriate. You can create simple animations, and even include found audio/video clips into the mix. Next, you could create your own QuickTime, AVI, or MPEG movies with something like Adobe Premiere or any number of other video editing software products. Composting software (like After Effects) is nice because it lets you add motion to otherwise static images. Doing pan-and-scan techniques, zooms, and 3D movements can add a professional touch.

For those with more time and money to invest, look into video interface cards for your computer. Then you can record video into the computer, work with it, and feed it back out to a video tape recorder. There are also several companies that offer all-in-one production solutions that pair computer hardware and software together in various combinations. These sorts of solutions are nice if you don't have the time or don't want to invest a lot of energy into researching what products will work well with each other and which are compatible with your computer setup. Here are some issues to consider when building your own video production system:

- Start with your playback capabilities and work backwards. Design your production system such that you can create content compatible with your playback hardware, be it a computer, VCR, or other tape player.
- Video production generally requires a hefty computer. Large amounts of RAM and hard disk space are essential and sometimes more important than processor speed.

- Video capture and output cards are finicky devices. You'll need to be sure that your computer system can support the card itself, and then handle the high data transfer rates that will be necessary to work with video. Several video capture cards are also integrated with display cards for viewing video on computer monitors or television screens.
- Digital video editing has progressed quite a bit and is now quite affordable. Digital camcorders, IEEE 1394 (FireWire) interfaces, and new software raise the bar on image quality at attractive price points.

Check out these resources for further information:
Film and Video Primer by Jeffrey Mills
http://www.iocommunications.com/info/filmvideo.html
The Art of Digital Video by John Watkinson
http://www.nab.org/nabstore

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