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Whitepaper

Digital Camera Masters Lifecycle

From Shoot to Archive with LTO/LTFS

Digital production has rapidly evolved in the media and entertainment industry resulting in a significant shift from film to digital formats. Digital cameras are now being used for the majority of film and television productions, and with this change to digital, there has been a substantial increase in the volume of camera master data being created. Today's professionals working in pre- and post production are challenged by the dramatic rise in the amount of file-based content to be managed and the requirement for more reliable, efficient, and cost-effective media storage.

Media storage options

Storage area network (SAN), network-attached storage (NAS), and locally-attached redundant array of independent disks (RAID) are viable storage options for short-term storage of dailies (rushes), and finishing data. However, this may become expensive for medium to long-term storage needs due to the cost of storage and significant energy costs to power and cool the hardware. Another alternative is removable hard drives, which are not designed for long-term project archive and are prone to failure from knocks or by simply being left unpowered on the shelf. Compared to Linear Tape-Open (LTO) media, which costs up to USD $0.05 per GB, hard drive storage costs range from USD $0.10 for removable hard drives, to USD $2.00 and up per GB for SAN/NAS storage. Optical Blu-ray Disc™, the most readily available optical format, stores a maximum of 50GB, but at a higher cost and much lower density than LTO tape.

LTO with LTFS technology for archival storage

LTO technology was introduced to the market over a decade ago by the LTO Consortium, comprised of HP, IBM, and Quantum. LTO is a standardized digital tape-based storage medium and today there are hundreds of millions in use due to its ability to provide long-term shelf-stability, high capacity, reliability, and high performance. LTO-5 is the fifth generation and it can store 1.5TB (1.2TB useable), of raw data per tape, with a shelf life of up to 30 years. Throughput to and from LTO-5 tape is up to 1.1Gbps (140Mbps), which is faster than Gigabit Ethernet. LTO-6 was released in 2013 and increases the storage capacity to 2.5TB (2.2TB useable), and the data transfer rate to 160Mbps.

Until recently, LTO technology has been used as a traditional tape backup with the data files encapsulated in .TAR files. The resulting LTO tapes were less than friendly to restore from because the content was hidden inside the .TAR files. With the release of LTO-5, came the introduction of Linear Tape File System (LTFS), an open file system developed by the LTO Consortium specifically for LTO tape. It is designed to provide an open and more efficient way to access files on LTO tape, enabling files to be accessed as a user would from a hard drive, and allowing the tapes to be interchangeable between LTFS-equipped drives. In addition, the direct access nature of LTFS enables LTO tape to be used as a nearline medium versus a non-accessible storage platform. Vast quantities of file-based media can be directly accessed from LTO tape when using LTFS workflow solutions. By combining nearline and archive directly on LTO tape, this storage infrastructure solves challenges and positively impacts storage costs, data management, and overall efficiencies of file-based workflows from acquisition to post.

The deployment of LTO with LTFS technology can be scaled to suit the needs of a production, from on-location solutions, such as a MacBook® Air with Thunderbolt™ connected to a single LTO drive, to multi-drive, multi-slot autoloaders for broadcast or post facilities.

Growth of file-based data

Various factors contribute to the accelerated growth of file-based data in production and post production environments, including higher resolutions, advanced camera formats, high frame rates, and post production file formats.

+ **Resolution:** In digital media, resolution refers to the number of dots, called pixels, which are used to represent the image. For example, a 1080p High Definition (HD) image is 1920 pixels wide and 1080 pixels high. (For feature films, the number of horizontal pixels is used to reference the resolution.) As a comparison, a typical 2K image is approximately 2048 pixels wide by 1200 pixels high, and a typical 4K image is approximately 4096 pixels wide and 2400 pixels high. Increasing the resolution allows for greater detail to be contained in the image, however going from 2K to 4K results in four times the amount of data.

+ **Advanced formats:** These camera formats, including ARRIRAW (ARRI® ALEXA), RED® RAW (RED's Epic, Scarlet), and SRMASTER (Sony® F65), can hold enhanced image information with greater image latitude, such as greater detail in the shadows or in the highlights (bright areas), and color information, which can be exploited in post production. These formats may also use compression to reduce overall data volume.

+ **Stereoscopic 3D (S3D):** An S3D camera rig uses two 2D cameras to capture both the left and right eye views resulting in double the amount of data that would be acquired in a 2D shoot.

+ **High Frame Rate (HFR):** Conventional feature films are shot and projected at 24 frames per second (FPS). HFR films are shot at higher frame rates, such as 48fps and 60fps, to capture smoother movement. This means that a 48fps shoot will acquire double the amount of data compared to a 24fps shoot. It should be noted that HFR is normally associated with S3D, producing even higher amounts of camera master data.

+ **Post production file formats:** These formats include log DPX, OpenEXR, and Academy Color Encoding Standard (ACES). A key feature of these formats is that they maximize image quality over storage size, which means they can consume large amounts of data storage. In addition, they generate a separate file or image sequence for each frame. As an example, for one second of 24fps footage shot, there will be 24 separate files or image sequences.

+ **Shooting ratio:** This is the ratio of content shot during production relative to what content is part of the finished project. For example, a shooting ratio of 10:1 means ten hours of content was shot to make a one hour finished piece, so only 10% of what was shot will be seen by the audience. In the real world, shooting ratios range from 6:1 to 500:1 depending on the nature of the shoot. Variables may include child actors, improvised dialogue, multi-camera, complex stunts, and special effects, such as onset water, fire, and explosions. Recently, the highest shooting ratio of 10,000:1 was for a reality television series shot with multiple cameras over a period of 24 hours. For this project, 10,000 hours of content was shot for every hour of finished program.

+ **Total content shot:** A tremendous amount of file-based data is created for each production shot. Currently, the approximate range of data being acquired per shooting day is between 500GB and 12TB, and the 5K camera, S3D, and HFR add more file-based content to those figures. The total amount of footage shot for a given production may result in a range of 30TB to over 1.5PB (1500TB) of data.

Camera master data life cycle, shoot to archive

A typical workflow for feature film and television productions may involve: the shoot, the archive of media, dailies (rushes), and finishing. LTO with LTFS technology can then be used to archive and restore the large amounts of content generated in production and post production workflows for the long-term protection of the file-based assets.

+ **Shoot:** Images are captured to camera media, either on-board the camera or via an external recorder.

+ **Archive:** Data is securely copied from the original camera media to intermediate storage (SAN, NAS, or locally-attached), and verified LTO tape (typically two LTO tape copies).

+ **Dailies:** This includes color correction and transcode to editing media (DNxHD and ProRes), and the Quality Control (QC) process to check for image-related issues.

+ **Editing:** The editor works with low-resolution, lower quality files, and the much smaller editing media allows for greater efficiencies during editing for speed and data storage requirements.

+ **Finishing:** When the edit is locked, the editor produces an EDL and guide for the complete project. This EDL is used to pull the shots and associated metadata from the original data. Depending on the finishing facility, the original camera files may be supplied or they may require a transcode to a post production format.

+ **Long-term archive:** The production's file-based content will be moved to long-term storage via LTO with LTFS technology when all deliverables have been created and delivered. Media can be easily restored when required again for other processes, such as an alternate cut, restoration, or a re-release.

Replacing costly HDCAM-SR

During the transition from videotape to file-based workflows, HDCAM-SR became the most common format used for HD broadcast deliverables requiring high cost videotape recorders (VTR) and tape. As file-based workflows increased, productions only needed a traditional HDCAM-SR VTR to fulfill contractual deliverable requirements. In addition, many broadcasters had also transitioned to file-based formats, so using the HDCAM-SR was becoming less applicable. In 2011, the tragic events of the Tōhoku, Japan earthquake and tsunami occurred, and amongst the devastation was the factory that produced the majority of the world's supply of HDCAM-SR tape. The lack of supply of HDCAM-SR tape prompted a rethinking of broadcast deliverables. At this time, LTO with LTFS technology emerged as a viable format, as it offered the stability of error-corrected tape with an open IT architecture. As LTO with LTFS solutions are a fraction of the cost of HDCAM-SR VTRs, the substantial difference in cost also contributed to the transition to the new format. For many major broadcasters, LTO with LTFS is now the preferred deliverable format.

Conform from LTO for HD and 4K

LTFS-based solutions may be used to conform directly from LTO by using LTO tape as a raw master format. With suitable management software, conforming from LTO is a straightforward process. Driven by an AAF, XML or EDL from an editing system to identify the raw media from LTO tapes, conforming is used to bring back only the files that will be used in the finished piece. Compared to a traditional videotape-based workflow, conforming from LTO tape is far simpler and uses multiple-slot autoloaders for automated tape changes.

Currently, the majority of productions will be finished at the HD resolution of 1920x1080 or 2K for cinema release. 4K to the home is now gaining momentum, with 4K content already available online via Websites such as NETFLIX® and YouTube®. This change is similar to the introduction of HD, at a time when most primetime productions were finished in standard definition from film. Before shows were shot in digital HD, HD finishing was accomplished with an offline/online workflow by re-conforming from the high-resolution film. Today a similar workflow can be achieved with digital camera masters using LTO with LTFS technology. Camera master data can be archived with LTO/LTFS and used for HD finishing with the conform from LTO process. In the future, the original camera master files can be re-conformed for a 4K finish at the highest quality.

Conclusion

It is possible that in the near future it will be a requirement that all camera master data from a production be archived to LTO tape by film studios, production companies, broadcasters or insurance companies for a completion bond. LTO tape is a viable and proven storage medium for file-based assets and LTFS technology allows LTO tape to be used in a more open and useful way. LTO tapes can be used throughout the lifecycle of digital camera master data from shoot to long-term archive and can replace the majority of spinning disk storage used by a production at a far lower cost. LTO with LTFS technology can help to simplify file-based workflows and manage the unprecedented amount of content being created in pre- and post production and environments.