The benefits of migrating content to the cloud: How mass tape-to-cloud migration services helped the Rock & Roll Hall of Fame preserve music history

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Abstract When the Rock & Roll Hall of Fame opened the doors on its library and archives in 2012, magnetic backup tape storage was the right solution for managing large files like the ones for its induction ceremonies, original concerts, education series and programmes. Over time, however, many of those tapes became less accessible due to hardware and software failures and onsite storage limitations. In 2018, after the Rock Hall evaluated its underlying technical infrastructure and needs, it decided to do what a growing number of organisations have been doing: migrate to the cloud. This case study examines how mass tape-to-cloud migration services helped the Rock Hall move data stored on Linear Tape-Open (LTO) tape storage to the cloud, where it can be preserved for years to come while being instantly accessible at any time and from anywhere.

KEYWORDS: digital asset management, DAM, linear tape-open, LTO, cloud migration, stiction, hierarchical storage management, HSM, on-prem, sticky shed syndrome, orphaning, archives, preservation

INTRODUCTION

The value of data is directly proportional to its accessibility. For instance, having the best footage of a legendary Prince guitar solo – like that for the Beatles song 'While My Guitar Gently Weeps' from the 2004 induction of Georg Harrison – is just a myth until it's not.

As content-rich organisations worldwide speed up their digital transformations, they inevitably scope out their projects by thinking through the issues they need to contend with, including the volume of material — past, current and future — and look to mitigate the challenges they will encounter along the journey.

The Rock & Roll Hall of Fame Museum (Rock Hall) in Cleveland, Ohio, opened its doors in 1995. In 2007, the Rock Hall broke ground for a separate library and archives (L&A) on the Metro Campus of Cuyahoga Community College (Tri-C) to collect, preserve and provide access to the institution's archival collections that include millions of documents, audio and video recordings, photographs, digital files and other materials chronicling the evolution of rock music. The L&A was established as a department in 2009 and opened to the public in 2012. The Rock Hall's mission is to engage, teach and inspire through the power of rock and roll. As part of that mission, the L&A seeks to collect, preserve and provide access to resources for researchers, educators, students, journalists and the public to broaden the awareness and understanding of rock and roll, its roots and its impact on society.

The L&A's four-storey, 22,500 square-foot facility holds the world's most comprehensive repository of primary and secondary materials relating to rock and roll, the musical genres that contributed to its creation (eg blues, country, R&B and gospel) and the genres that grew out of its influence (eg soul and hip hop). The archival collections include the personal papers of radio disc jockeys, photographers, journalists, critics, historians, poster artists, collectors, fans and fan clubs; the business records of record executives, music labels, producers, stage lighting and sound designers, tour managers, recording studios and television series; and historically valuable items from performers, including personal letters, handwritten lyrics and rare concert recordings. The L&A contains approximately 4,500 linear feet of physical archival collections and 650,000 files (about 430 TB) of born-digital or digitised archival content over the span of 1,194 collections. The materials in the collections document nearly 100 years (the 1920s–2020) of rock music and its roots, from early sheet music from Les Paul from the 1920s to video oral history with 1960s English rock bands and 2019 inductees The Zombies. The Rock Hall continues to add to the archival collections with its oral histories, performances, induction ceremonies and other recorded events and programmes.

The library collection includes popular and academic commercially published works, including 9,000 books, over 1,500 periodical titles, more than 100,000 commercial audio recordings and 1,200 video recordings that support research in the archival collections and provide reference materials on Hall of Fame inductees and other influential figures, genres and moments related to the story of rock and roll and its role in shaping history and culture. The lives and music of thousands of musicians from around the world are documented through materials in the collections, including Hall of Fame inductees Aretha Franklin, The Beatles, Chuck Berry, Janet Jackson, Jimi Hendrix, Joan Jett, The Police, The Rolling Stones and Led Zeppelin, to name just a few. The collections also document many important events in rock and social history, such as Woodstock, Wattstax, Live Aid, MTV, the TAMI Show, the Winter Dance Party, Farm Aid, Artists Against Apartheid, Rock Against Racism, Rock the Vote, USA for Africa, riot grrrl and third-wave feminism, Black Lives Matter and much more.

Since 2010, the Rock Hall primarily used Linear Tape-Open (LTO) tape storage and backup to preserve its files. Specifically, its digital preservation video files were stored on a LTO-5 tape library and managed via an open source instance of the digital repository Hydra (now Samvera) that the Rock Hall's former systems librarian had built. The systems librarian used the open source discovery platform Blacklight to allow the Rock Hall to provide public access to the Machine-Readable Cataloging (MARC) data for its library collections, the archive's metadata exported as Encoded Archival Description (EAD) Extensible Markup Language (XML) from Archivists' Toolkit and the files and associated instantiation-level PBCore metadata from Hydra. However, the librarian left before he could complete the other pieces of Hydra that would have allowed the Rock Hall to also manage digital preservation images, documents and audio. As a result, that content was stored on a combination of servers, external hard drives and network-attached storage (NAS) as the collections grew.

Digital preservation video files were bagged, using the Library of Congress BagIt application, with their corresponding metadata in a sidecar, and BagIt allowed the Rock Hall to verify the integrity of the files through transfer from the original digital media to the LTO-5 tape library. The system all worked well until the Rock Hall started to have issues with the mechanics and software for the library, 5–6 years into the project.

When the Rock Hall opened its doors in 1995, magnetic tape was the right solution for managing large files. Over the years, the magnetic tape infrastructure became outdated, overly costly to maintain, and prone to failure. The Rock Hall was also beginning to collect even larger preservation video files in high definition, which required more space than the tape library could accommodate. Additionally, many of the Rock Hall's LTO tapes were not easily accessible because of hardware and software failures and onsite storage limitations. The system became unmanageable and unsustainable, with priceless files on media that staff could not easily access. The significant catalyst for making a change came when the Rock Hall's tape library became untenable and it was no longer possible to download or export files without the help of external consultants.

The need was clear: the Rock Hall needed a better way to manage, store, preserve and provide access to its digital content.

In 2014, the Rock Hall launched a new strategic plan focused on encouraging innovation, improving internal efficiencies and enhancing the museum's learning experiences through exhibits, programmes, outreach and an online presence. The Hall wanted to get to a point where its files were readily available and easy to find, so the L&A staff did not have to perform detective work every time something was needed. In late 2018, an assessment of the state of the Rock Hall's infrastructure was undertaken by the technology division. The outcome of the assessment was that the Rock Hall needed a centralised digital media repository capable of handling multiple assets with varying metadata schemas, along with highly configurable user access. At the same time, the Rock Hall urgently needed to preserve the 300 TB of video content held on the L&A's inaccessible LTO tapes and the several hundred additional terabytes of images, audio and other archival content. However, because of a lack of access to functional database software, issues with unreliable hardware and the inability to grow the tape library to keep up with onsite storage, Rock Hall leaders soon realised they would need assistance. The Rock Hall needed a solution that could handle the sheer volume of its assets and allow for future growth while maintaining affordability because the Rock Hall is a nonprofit organisation with a limited budget.

CHALLENGES

Digitising the magnetic tape in the Rock Hall's collections, which at the time represented 25 years of induction ceremonies and education programming, was one of the first projects undertaken by the L&A due to the endangered status of magnetic tape and magnetic tape playback equipment.

In general, the biggest challenges the Rock Hall had with its digital archival content were disparate storage locations, slow search/discovery user experience; limited access to the storage; and staff having to use preservation files to create proxies. The Rock Hall's file-naming conventions and folder structure allowed for searchability; however, using something like File Explorer to search across uncompressed preservation files was not exactly a fast solution. For security purposes, access to this unique digital preservation content was also limited to L&A staff only. While this prevented preservation files from being accidentally deleted or changed, the lack of readily available proxies meant that L&A staff were still having to touch the preservation content in order to create proxies for use.

A digital transformation project like the one undertaken by the Rock Hall is a lot like peeling back the layers of an onion. The layers for the Rock Hall digital preservation project were highlighted by three major concerns:

- tape deterioration;
- orphaning and equipment shortages; and
- the fact that content written to LTO tape is often encapsulated around a proprietary format system.

Tape deterioration

Video in the Rock Hall's digital asset management (DAM) system slated for digital transformation and preservation had been recorded on LTO media. The Rock Hall initially made a great choice when choosing LTO media for its video storage as it was the best solution available at the time. Although LTO is generally robust and used across many libraries, archives and museums, it can experience issues as time passes.

LTO is an open standard created by a consortium of Hewlett-Packard, IBM and Seagate.[1] The latter company's magnetic tape division was later spun off as Seagate Removable Storage Solutions (later called Certance) and then acquired by Quantum in 2004.[2] While announcing the formation of the consortium in 1997, the three companies agreed to introduce a tape technology 'aimed at simplifying the complex enterprise and network storage industry' and chose an open format as an alternative to the wide variety of incompatible technologies that existed in the storage industry at the time.[3]

The companies wanted to design a tape drive that could be manufactured by multiple vendors, helping to prevent a single manufacturer from being the sole responsible custodian of the largest collections of data in the world. When the finalised technology was announced in 2008, the consortium announced that 'LTO technology combines the advantages of linear multi-channel, bi-directional formats with enhancements in servo technology, data compression, track layout and error correction code to maximise capacity, performance, and reliability'.[4]

The introduction of LTO had two major effects. First, because the standard was published, anyone who wanted to — and could afford to — could manufacture drives, thus opening up competition. This should have been a good thing for the industry; however, the development of LTO also meant that manufacturers who backed the specification could also create a lower-cost 'compatible' version of the media. The dangerous side effect of this was that, although the media met the technical specifications, the media would not necessarily stand the test of time due to degradation.

One of the major issues with tape media degradation has long been stiction

(also known as sticky shed syndrome).[5] During the 1960s and 1970s, manufacturers used polyester urethane binders for audiotapes, while some videotapes used polyether urethane binders in reaction to performance-driven changes that were made in the oxide component.[6] Back coating was typically added to tapes at the same time.

During the 1970s, however, it was discovered that tape moving through tape transports physically stuck to the tape head. It was later learned that a similar result happened due to the degradation of the tape's binder layer. Although all tape binders absorb moisture, some seem to do it more than others. And, as that absorption happens, the binder ends up softened by the chemical changes that have taken place. The problem is made even worse by the expansion that can occur as a result of temperature and humidity fluctuations, resulting in increased internal pressure inside a tape reel. While pressure builds, the binder's softened components serve as an adhesive that can glue consecutive layers of tape together, 'bricking' the tape. Some binders degrade in only a few years.[7] Tapes that have been impacted by stiction often create an increase in audible noise. Other signs of stiction include erratic movement of the tape through the tape path and peeling of the tape from the input reel instead of a smooth release. Damage to the tape often happens when a tape affected by stiction is read on a high-speed drive or cleaned, and in many cases, the damage can be severe, with large parts of the tape becoming unusable.

Magnetic media deterioration was a key reason why the Rock Hall digitised all its induction footage and educational programmes back in 2010.

Orphaning

Another issue with LTO media and the consortium's strategy was that it built a road map for newer technology with plans to store more and more data on a similar-sized tape. This too should have been a good thing for the industry because it allowed for growth in data storage. Again, however, the solution had a dark side: drive manufacturers started to produce newer drives faster than ever before, which caused difficulties for those trying to keep up with the newest storage technologies. Backup tape drives started lasting for shorter periods of time, from about 10–15 years to only 2 or 3 years.

This level of obsolescence is especially problematic when new technology is not completely backward-compatible with older media types. In the case of LTO, each tape drive generation is only backward-compatible with the prior one or two generations. As a result, tapes — and the data stored on them — are becoming orphaned increasingly quickly. And, as drives become scarcer over time, the ability to access the data becomes harder.

The format issue

In the end, the most complex part of the Rock Hall project was the format that the tape was written in. Archivists can spend a lot of time looking at open formats and long-term archive formats for universal access but may be unaware that the final backup to tape can add an additional format to the process.

The Rock Hall's tapes were written in the IBM Tivoli Storage Manager (TSM) format. Generally, to restore these tapes back to the original files, TSM software is needed to decapsulate the data. This requires a licence for TSM.

TSM is not a simple format to decapsulate manually. TSM's Hierarchical Storage Management (HSM) capabilities are very robust and are used by large corporations as well as some of the premier galleries and universities around the world. However, that robustness comes with complexity, and that complexity makes the restoration of tapes without a current TSM system challenging.

If one has TSM tapes and no current TSM software to read the files, things can get pretty difficult — as was the case for the Rock Hall. Compounding the system's intricacies, TSM holds a database inside the application with the index to the files on each tape. The index is held separate from the tapes — so if one is lost or inaccessible, then the other is not very useful.

OPTIONS AND CRITICAL SUCCESS FACTORS

The Rock Hall had a few options to consider. First, it could have made the changes needed internally. However, that would have required a sizeable chunk of tedious, manual work.

There were, meanwhile, several critical success factors that were important to the Rock Hall, as they required a solution that would not only serve the L&A's expectations for preservation and access but the growing digital needs of the entire organisation. For the tape migration specifically, those factors included affordability, high retrieval rates and minimal file migration between storage solutions, which would help to maintain the validity and authenticity of the files.

For cloud storage, the critical success factors were affordability; scalability; tiered storage to ensure both the preservation of files and speedy access to those requiring immediate and frequent access; preservation — maintaining the validity and authenticity of files over time; and backup/restoration — multiple copies over multiple locations.

For a DAM solution, the critical success factors were user interface — ease of use regardless of staff technical abilities; a personalised dashboard dependent upon departmental/individual staff requirements; affordability; scalability so that, as organisational needs change, so could the DAM system; security for different levels of user access; records management/records scheduling; definitions of formats for ingest acceptance and deliverables; automatic proxy generation; the ability to edit within the system in order to keep down file retrieval costs; flexibility with metadata schema — for instance, support for the Dublin Core Metadata Initiative (DCMI), PBCore and International Press Telecommunications Council (IPTC) metadata; and automatic transformation to preservation file formats based on archival standards and best practices.

SOLUTIONS

The Rock Hall decided to adopt Amazon Simple Storage Service (Amazon S3) and subsequently Amazon S3 Glacier Deep Archive storage to preserve the museum's digital media. Selecting Amazon S3 and S3 Glacier Deep Archive provided the Rock Hall with the confidence that its digital storage would be enterprise-scalable, secure, resilient and low-cost, while its digital media would be preserved and still easily accessible. Amazon S3 storage classes and life-cycle policies also allow the Rock Hall to optimise costs based on the access needs of specific content pieces and to move media files automatically from S3 to Glacier Deep Archives based on designated time frames, format or use of content. As the Rock Hall has grown, so too has its use of Amazon Web Services (AWS), and it has utilised more of the platforms and cloud solutions offered through Amazon's robust partner marketplace. However, long-term storage was only one piece of the puzzle. The Rock Hall still needed to recover the data from the LTO tapes.

At that point, Tape Ark was introduced to the Rock Hall through AWS. Tape Ark is an AWS technology partner that has performed similar complex projects with critical collections around the world and has demonstrated its ability to peel back the layers on projects like this both meticulously and effectively. Fortunately, Tape Ark had also successfully undertaken TSM retrievals in the

past without either the TSM software or the TSM database. It is a skill that takes time to acquire but can help save companies from significant expenditures and the purchase of software licences to restore data.

Tape Ark successfully restored 99.99 per cent of the data from the LTO tapes. Working with AWS, Tape Ark ingested the files into S3 Glacier Deep Archive via six AWS Snowball Edge Storage Optimised devices. Using AWS Snowball Edge helped to address the common challenges with large-scale data transfers, including high network costs, long transfer times and security concerns. Snowball devices were sent, loaded with their valuable content back to AWS, and the data ingested into the Rock Hall's Amazon S3 bucket. Once the Rock Hall's digital media were in Amazon S3 in the AWS Cloud, Amazon S3 life-cycle policies were set up to move the media files automatically from Amazon S3 into S3 Glacier Deep Archive to reduce storage costs. For the Rock Hall, the process was easy and effortless, with Tape Ark managing the end-to-end migration.

With the Rock Hall's assets preserved and safe, the next step was to enable its staff to access and use assets quickly and efficiently in their day-to-day business. With a rich media archive of musicians and other popular figures, facial training and recognition were critical for the Rock Hall's use case. This was primarily because, for the most part, legacy Rock Hall files did not contain embedded metadata. Therefore, if staff did not have access to the original Hydra instance that managed the files, or the institutional memory to decipher the file name to know what archival collection and finding aid it was tied to, it would be difficult to search for assets.

To address the issue, the Rock Hall partnered with GrayMeta, another AWS Partner Network (APN) select technology partner. Using the GrayMeta platform Curio, the technical and machine-learning metadata generated allowed the Rock Hall team to better understand its assets and search instantly through and discover images, audio and video. The files from other external hard drives and servers on-prem at the L&A facility will also be run through Curio's artificial intelligence services, including optical character recognition (OCR), speech to text and facial recognition. For example, through Curio, the Rock Hall uses a combination of services from Google Vision to detect and extract text from images; Amazon Transcribe for speech to text recognition; and Amazon Rekognition and GrayMeta Facial Recognition for visual analysis, detecting objects and faces. Going forward, the Rock Hall is also embedding descriptive metadata into all its digital files using Adobe Bridge and the IPTC Core metadata schema.

The next step is for the Rock Hall to select a DAM system that will allow them to bring together their legacy metadata: embedded IPTC metadata, PBCore instantiation metadata for video from Hydra, and the associated metadata created in Axiell Collections and Curio, with the digital assets in AWS, to allow staff across the Rock Hall to easily ingest, search, locate, and utilize the institution's digital history. Simultaneously, the Rock Hall needs to be confident that their data is being backed up and preserved for the long-term. Requirements the Rock Hall has for such a system include the automatic inspection of image and audio files and transcoding to selected preservation formats, as well as a simple data entry form for new content, requiring information on the who, what, when, and where of file contents and any associated rights information. Additionally, the L&A staff need to have the ability to verify that metadata and assign rights to the files.

The DAM team work with representatives across the institution to create governance rules for using a DAM in conjunction with on-prem Rock Hall storage and following the Rock Hall's records retention schedule. The team is also working with other departments to determine the best workflows for ingest and description of

their legacy content in order to expand cost savings to the institution by shifting from on-prem to cloud storage for the majority.

The types of metadata that can now be derived by the preservation industry through the use of machine learning will open a new chapter in metadata schemas and management. The granularity and depth of metadata typically generated at an asset level will need to expand to much finer segments of an asset in essentially a three-dimensional matrix that goes past the exoskeleton of a digital asset, into increments that use time and space. As an example, metadata descriptions of video assets will start to include details not just about the asset as a whole, but also metadata on a per-frame, per-second, per-megabyte, or even per-event basis — such as objects moving in certain trajectories across frames or time spans.

Given that one of the principal purposes of metadata is to help describe an asset, it is usually the case that the more metadata generated, the better described an asset will be. For archivists, the existence of additional metadata does not increase the preservation quality, but it does greatly enhance the discoverability of the asset. So, for those who spend their careers wanting to deliver maximum asset protection while at the same time being able to share the assets as widely as possible with interested parties, the additional metadata will prove to be a valuable addition to their collections.

RESULTS

The Rock Hall hopes to go live with a new DAM system in 2022, at which time staff across the organisation will be able to digitise, preserve and instantly search a wide variety of content. The final step will be making that content available to rock researchers and fans around the world.

The results of the project include the liberation of digitised and born-digital video files from complex tapes that were previously written in a proprietary format. Specifically, over 1,800 files were retrieved from the Rock Hall's tape library. Thirty files were lost, of which only about half were born-digital, and in all but four cases, lower-resolution surrogates were found, so they were not completely lost. For those unretrieved files that were digitised from physical tapes in the archives, those analogue assets still exist and can be digitised. To get this result, the Rock Hall did not need to buy TSM or any hardware, which represented significant cost savings. Additionally, the Rock Hall did not need to purchase new tapes for the retrieved files, as it chose an evergreen cloud solution. Evergreen solutions essentially involve a commitment by the cloud provider to keep the file protected for as long as the file owner wishes, so the owner never has to worry about how it is stored, leaving the owner to determine how to consume it, present it or share it.

At the same time, Amazon S3 and S3 Glacier Deep Archive will help improve Rock Hall staff efficiency. The speed of accessing files will be a huge benefit. In the past, staff would have had to download a preservation file overnight and hope it worked by the time the team came back in the morning. Now, the Rock Hall can download that same file in only about 15 minutes.

Rock Hall staff are also confident that their unique assets are safe. In addition to having all of the Rock Hall assets in S3 Glacier Deep Archive, knowing that AWS is making duplicate copies and has disaster planning and recovery is taken care of is a huge relief. Amazon claims to offer '11 nines of durability', which means the company guarantees that 99.999999999 per cent of the data it hosts will be recoverable. The fact that the Rock Hall was able to realise all these benefits and still save significant costs with S3 Glacier Deep Archive, compared with the cost and overhead of managing its own tape library, was an added bonus.

KEY LEARNINGS

The Rock Hall's key learning was prioritising institutional needs. So, if another institution is looking to take on a similar project, those managing the project should determine needs across the departments affected and prioritise those needs so that the best vendor, product or service can be chosen. Which of those features are requirements the institution cannot live without? What features would be nice to have but are not essential to the institutional or departmental mission or the strategic plan? Which are features that could wait to be potentially added at a later date, once more is known about how the institution actually uses the product?

Beginning DAM governance discussions from the outset of the project is essential. Organisations need a prioritized list of requirements and use case scenarios in place before selecting vendors for enterprise systems. Interviewing and meeting with other departmental stakeholders to determine what content already exists, what is being created, assessing legacy assets and their associated metadata and known rights, and conducting an analysis and revision of current records management policies and schedules can only hep to provide clarity to the process. One has to understand what content they have and the challenges of that content in order to make informed decisions regarding whether a system meets the bulk of an organisation's needs. Before a project starts, it is also important to figure out where the organisation stores all its metadata and how to deal with metadata coming from different sources or, does metadata even exist? If so, the organisation should assess whether it wants all the metadata mapped to a single stream for ease of use going forward, or if it wants to retain separate streams for authenticity, in order to plan the work of cleaning up all the data as soon as possible. Otherwise, the length of time to catch up on this work will be significantly increased as the team tries not only to fix legacy metadata but also to add and/or verify metadata for incoming content once staff start to use the system.

Trying to figure out rights in advance for how content can be used is also essential. Depending on what rights are known, it may be necessary to ensure chosen solutions allow for rights to be assigned to or edited for digital assets in large batches to provide a starting point for this work. Organisations should also come up with strategies for how to address rights if they are unknown for large parts of collections.

Knowing what it does today, the Rock Hall would have looked at the collections management and DAM systems as a single project from the outset, so that interoperability, metadata, workflows, records management and preservation storage — the entire collections-related stack — could potentially have been as a comprehensive solution. As it is, the chosen solutions will likely require application programming interfaces that allow the Rock Hall to integrate systems so that metadata can flow between them.

CONCLUSION

There are many compelling reasons why any museum or archives that use LTO tape may want to move forward on liberating their content to the cloud. There can be significant cost savings and a serious reduction in complexity. For many organisations, complexity often means cost and access issues.

Breaking free of tape media, or what one could call 'data liberation', also brings flexibility: the flexibility to use or share the data, or in fact, to monetise the data — such as the possibility to license rare, never-before-seen performance footage owned by an institution. This may present a double benefit as the options will not only curtail expenditures but may also generate revenue.

Best of all, from an archives and preservation point of view, the cloud can

manage preservation with a guarantee of access at any time in the future. For archivists, evergreening is really a dream come true.

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