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A Race Against Time: Best Practices for Preservation Digitization of Video

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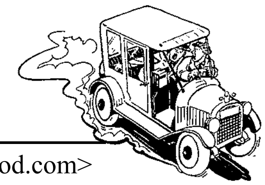
A Race Against Time: Best Practices for Preservation Digitization of Video



by **George Blood** (President, George Blood, L.P. and George Blood Video) <george.blood@georgeblood.com>

Background

*About 15 years ago I attended a pre-conference workshop offered by the **Society of American Archivists**. The topic was audiovisual preservation. The instructor, **Alan Lewis**, who at that time oversaw the moving image collections at the **National Archives and Records Administration**, started the workshop by putting A/V in the context of traditional archives. One of the observations was "the basic struggle for audiovisual archives is that the archivist working with these materials, and probably also their boss, was 'paper-trained.'" It wouldn't be the last groaner, or otherwise humorous insight, of the workshop! Nonetheless, the expression has stuck with me not only because my humor runs along the same lines as **Alan's**, but also because it neatly sums up the challenges faced by archivists with traditional books and paper and objects training. That tradition is strongly focused on preservation of the original objects, be they paper, vellum, wood, metal, or other physical material. Audiovisual materials are machine-dependent, an inherent vice not shared by many archival materials. Within the profession of audiovisual preservation, we generally separate the carrier from its content. The carrier, most often a tape, has limited Artefactual value. We are generally focused on "the essence," the information encoded on the carrier. As we dis-intermediate the carrier from its contents, our goal is made clearer: that we seek to preserve through digitization the essence. As archives begin to grapple with digital records, A/V straddles the old analog world and the brave new world of file-based records.*

Audiovisual records are subject to the same laws of physics that affect all objects. These forces (entropy) can be slowed with environmental controls — lower heat, humidity, and light exposure generally help A/V objects last longer. Familiar to anyone who has wrestled with more complex objects — works of art or even a book composed of paper pages, leather cover, string bindings, hide glue, etc. — the care of A/V objects has similar challenges. The physical care of A/V means facing the complexities caused by the variety of formats, formulations, and impact of deterioration during playback. Many deterioration vectors are only marginally documented or understood, especially when compared to our deep knowledge on the aging of cellulosic media.

None of this compares to the challenges of machine dependency. Machines are no longer made to reproduce most analog audio formats, and none for analog video. Machines for tape-based digital audio formats are long out of production; likewise for video. While it is still possible to acquire new machines for very few formats, and there are used machines around, the number of hours of reproduction available falls well short of the volume of media sitting on shelves in archives. Maintaining this hardware is a struggle, with finding technicians knowledgeable in these machines, providing them with test equipment and jigs that are no longer available, and getting spare parts where the parts suppliers are unable to get raw materials from their suppliers.

For many years, the archival community — cultural heritage, corporate, and others — set A/V aside behind other priorities because standards and best practices for digitization had not yet evolved. Best practices for audio digitization were established in the seminal work by the Technical Committee of the **International Association of Sound and Audiovisual Archives** in their publications TC-03 and TC-04, followed by the **National Endowment for the Humanities** funded *Sound Direction,* as well as the involvement of the professional communities of the **Association for Recorded Sound Collections** and the **Audio Engineer Society**. Specifically, the best practices call for 96kHz/24bit linear pulse code modulation encoding in the broadcast wave wrapper (standardized in EBU3285). This practice, or specifications, closely aligned with and informed by these works, has been adopted by nearly every audio archive worldwide.

Video is significantly more complex than audio, and historically the technology arrives 80 years later.[1] It's not surprising that the digitization best practices developed later, too. Many large archives, especially national archives, have adopted MXF as the wrapper for long-term video preservation. Unlike other wrappers, MXF is open source and a true standard (SMPTE 377M). Other commonly used wrappers, such as AVI and MOV, while open, are owned by corporations. These same large archives often adopt the lossless JPEG2000 compression to reduce the file sizes while retaining 100% reproduction of the originally encoded digital bit stream. We'll return to JPEG2000/MXF later.

Archives have found themselves caught between the race against time of aging media and machine obsolescence on the one hand, and the lack of standards, best practices, or even clear direction on how to digitize these media on the other. If audiovisual preservation can't wait but the standards aren't ready, what's to be done?

In 2011 the **Library of Congress** commissioned a white paper[2] seeking recommendations for the interim storage of digital video that would give direction on how to digitize while machines are available, and storage in formats that would neither lose information nor present obstacles to migration to the long-term preservation file format once standards and best practices are established.

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George Blood began recording live concert events as a teenager while earning a BA in Music Theory at the **University of Chicago**. Since the early 1980s, he has documented over 4,000 performances, from student recitals to major opera and symphony orchestra performances. From 1984 through 1989 he was a producer at WFMT-FM, and recorded and edited some 600 nationally syndicated radio programs, mostly of **The Philadelphia Orchestra**. He has recorded or produced over 100 CDs, 3 of which were nominated for **Grammy Awards**.

His work can be heard on EMI, Toshiba/EMI, New World Records, CRI, Pogus Records, Albany Records, Newport Classics, and others. He was Recording Engineer for **The Philadelphia** for 21 years, serving **Maestros Riccardo Muti** and **Wolfgang Sawallisch**. **Mr. Blood** founded Safe Sound Archive in 1992 to house the recital archives of the **Curtis Institute of Music** and the concert recordings of **The Philadelphia Orchestra**, and to serve as a repository for the thousands of recordings he had accumulated as an engineer. In the fall of 2010, **Mr. Blood** made a decision to phase out the Safe Sound Archive identity, opting instead to bundle the corporate audio and video entities under the name **George Blood, L.P.**

Today, he oversees **George Blood Video**, which is responsible to the digitization of historic analog and born-digital video collections, and **George Blood Audio**, which provides recording services for classical musicians and ensembles in and around Philadelphia, and which digitizes approximately 1,000 hours of audio collections from around the country each month. He and the staff are active in research into workflow, best practices, metadata, authentication, and interchangeability of digital information.

Mr. Blood is an active teacher and presenter at conferences, sharing these findings with members of the trade and collections managers. **Mr. Blood** and his wife, **Martha**, have four daughters and one son. An unapologetic preservationist, **Mr. Blood** lives in Philadelphia where he and **Martha** are renovating a 1768 house.

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Working with the staff at the Library, especially at the **Packard Campus** of the **National Audio-visual Conservation Center** in Culpeper, VA, and in consultation with industry professionals, a set of minimum requirements were established:

- Creating lossy compressed formats was forbidden
- Tape or other media storage was rejected
- Resolution of 10-bits per video signal channel minimum

Lossy compression has long been frowned upon for archival digital preservation due to the information loss inherent in compression.

Tape or other "tangible" media were rejected due to 1) machine obsolescence for all formats, 2) nearly all media require real-time playback, meaning that the next migration cycle would be labor intensive, especially compared to copying digital files, and 3) all commercially available tangible-media formats use compression, violating our first premise.

Resolution of 10-bits was established to be certain enough gradations of luminance and color were available to avoid banding artifacts. That is, in the luminance (black and white) channel, there would be enough information captured between full black and full white so there would a smooth gradient through the greys.

As the range of source formats was considered, from 2" quadruplex video and ½" EIAJ, from Betamax to Betacam, from D-1 to D-9, from standard definition to high definition, and from tape to PD to DVD and Blu-Ray, it became evident that a single, uniformed, "one size fits all" solution wasn't the best possible, much less likely, outcome.

Typically the discussion on standards or best practices travels either of two routes. One route focuses on "high-quality" vs. "low-quality" source material. In this realm, consumer formats such as VHS, Betamax, Hi8, and even the very common low-end professional format U-matic, qualify as low quality due to their less stable image, less inherent analog resolution, and often poor quality input signals. These are differentiated from so-called broadcast quality formats such as 2" quadruplex, 1" Type C, and BetacamSP. As we will soon see, this route is littered with assumptions that turn out to be in direct conflict with the structure and resolution of the various video sources, high or low quality. The other route seeks a uniform solution applicable to all source video formats. This is also in conflict with the nature of the variety of source video formats.

It is Useful to Review Some Fundamentals of How Video Works.

Many problems of capturing and recreating the illusion of motion capture were solved with motion picture film. Video builds upon those fundamentals. In North America, film is captured as a series of equally spaced still images 24 times per second. In some parts of the world the standard is 25 frames per second.[3] In the beginning film was black and white. A photosensitive material captured gray scale images 24 times per second. Later, three photosensitive materials were used to capture cyan, magenta and blue. These three combined reproduce close to the full spectrum of visible colors.[4] As mentioned, video builds on these basics, with 30 frames per second, and captures and reproduces in a three-color system, in this case red, green, and blue.[5] While film can capture the picture information in a frame all at once, by exposing all the photosensitive material concurrently while the shutter is open, video cannot. NTSC video captures 486 vertical lines across the picture frame. Each of those lines is a contiguous analog signal. When digitized 720 samples are taken and stored as pixels. The image "raster," as it's called, is 720 pixels wide across 486 lines.

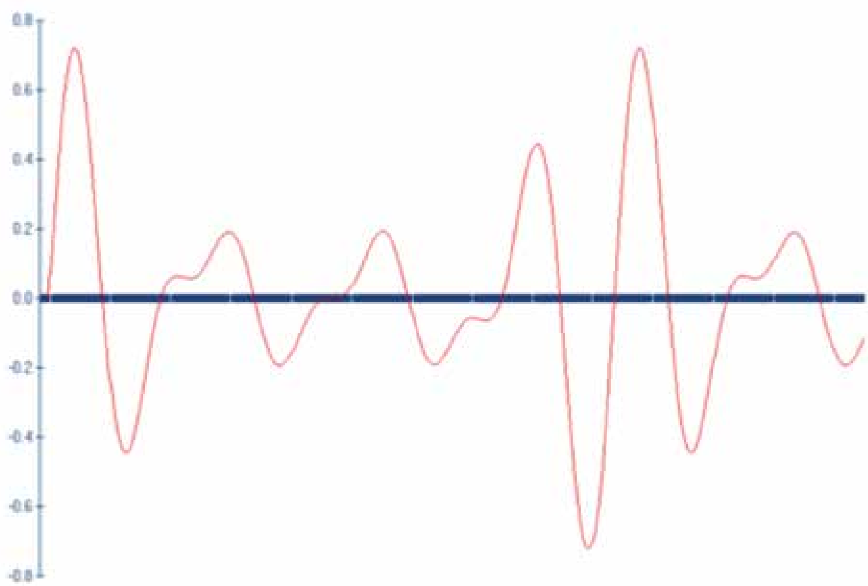
Think of it this paper-trained way: a frame of video (or film) contains information, just as a page in a book contains information. Like a book, the information is structured into discrete lines. The information on each line is represented by a set of discrete elements. In text those elements are letters; in video they are pixels.

When people expound to use lower data rates for lower quality video, they're advocating for compression. The arguments against compression in an archival setting are well understood. Let us consider a simplified system of compression for images. By the way, this applies the same to still images as well as moving images, film, and video.

Common techniques for compression begin by subdividing the image, in the case of NTSC video a 720 x 486 image, into blocks 8x8 pixels square.

The encoder uses advanced mathematics to represent each block, more or less independently of its neighbors. By dividing the image into discrete blocks and encoding them separately, the encoder has fundamentally altered the structure of the information. While video, like text,[6] has discrete vertical structure of horizontal lines, it does not have a horizontal structure. It's as though you've cut a page of paper vertically, then glued it back together. No amount of long fiber Japanese paper and wheat starch paste is going to restore the fundamental strength and structure of the paper fibers that have been cut.

Consider How this Works for a Single Line of Video.



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Recently reconnected with an old friend, **Dimi Berkner**. **Dimi** was at home recuperating after back surgery so we had time to talk. **Dimi** is Executive Director, **Berkner Associates**. She has also worked for **Wiley**, **Jossey-Bass**, and **Columbia University Press**. What a career she is having! Anyway, as most of you have observed, I almost never use **Facebook** and when I do it's usually because my daughter posted something for me. So — imagine this — **Dimi** and I talked through **Facebook Chat**. Like wow! Are you impressed?

Speaking of **Facebook**, I received a book the other day. It's called *Marketing the 21st Century Library: The Time is Now* by **Debra Lucas-Alfieri**. **Debra** says that social media is very important and points out how **Facebook** has rekindled many old friendships. I guess it sure did because I would never have connected with **Dimi** again! **Alfieri** has many great tips and the book is short and very readable. Once upon a time, libraries didn't have to market so

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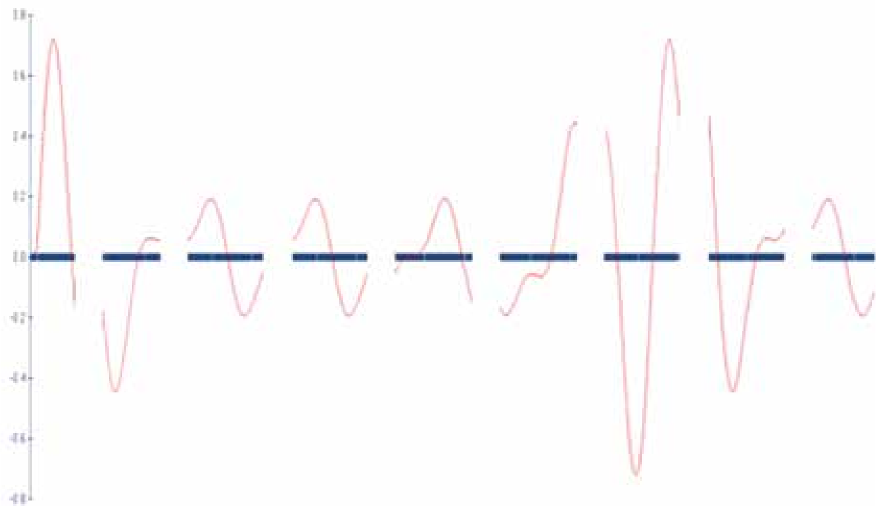
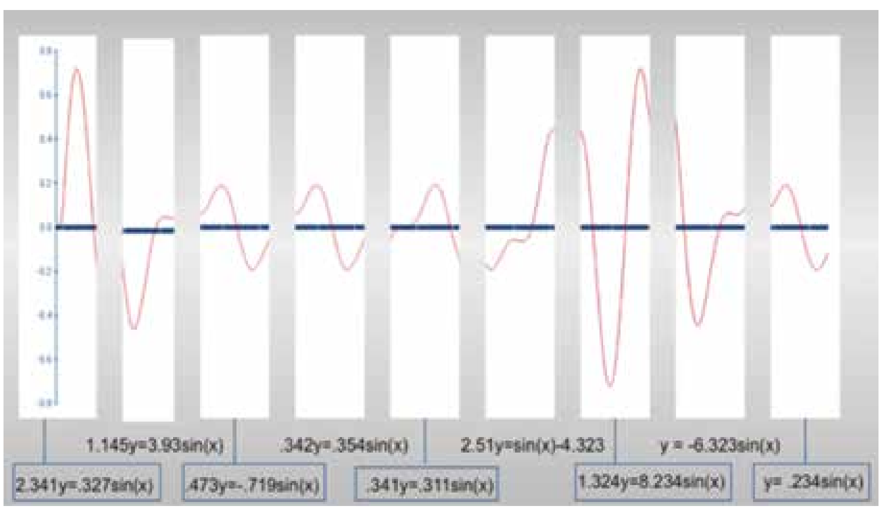
The line would be divided into segments (each 8 pixels wide).



Back in junior high school algebra you graphed functions. Choose a value for X, solve for Y. Then with a sharpened #2 pencil put a dot at those coordinates on a piece of graph paper. Choose a different value for X, again solve for Y, and put another dot on the graph paper. After a few dots you would connect the dots to create a line or a curve. No matter how sharp your pencil, the curve never looked quite right. It's simply too difficult to accurately place the dots and connect them.

Imagine doing this in reverse: you start with the curve and derive a formula for the curve.[7] Repeat for every segment of the signal.



Several types of errors are creeping in. First is the mirror one you struggled with in junior high school. The formula cannot 100% match the curve. Second, when the segments are stitched back together on playback they rarely line up exactly correct. There's always a small offset where the 8x8 blocks are stitched back together. Third, to keep the image from looking blocky around these seams, the image is deliberately softened to blend the pieces back together. At each step we get further and further from the image we seek to preserve.

Beware of the expression "visually lossless," too. The compression algorithm makes decisions based on the psycho-visual sensitivity of the eye. It discards information the eye is less sensitive to. Compression "tricks," if you will, the viewer into believing the information is more faithful than it really is. This can become a problem later when the image is transcoded to a new codec (which likely considers different psycho-visual components), or if any image processing is needed (such as color matching to other images in a series).

All this applies to all analog video regardless of its "quality." All analog video is structured the same way. Otherwise there would be limited interoperability. A television station can broadcast from a Betamax as well as a Betacam, because they hew to the same standard![8] Likewise, whatever the videotape played on any television station in North America, it is broadcast the same way and captured and can be recorded on any videotape machine at the other end. Some do a better job than others, but they are fundamentally identical at the signal layer.

This brings us to the first category defining "Suitable Digital Video Formats for Medium-term Storage." In the full report a full page of specifications is devoted to each category. They are summarized here:

Category 1, All Analog formats

720x486, 10-bit uncompressed

Category 2, Digital tape, non-transcode possible

Migrate bits from tape to file, retaining original coding and structure.

Category 3, Digital tape, transcoding necessary

Machine decompresses information which is captured in a file the same as Category 1.

Category 4, Born digital, non-tape based formats

Remove from original carrier, store as files, evaluate for file format support according to repository policies; if not supported, create file same as Category 1.

Category 5, Optical discs (DVD and BluRay)

Migrate to ISO disc image; may be necessary to transcode a proxy for access.

In Category 1 the recommendation is for *all* analog video to be captured as 720x486, 10-bit uncompressed. These files, in standard definition video, are 100GB per hour. Even for VHS and U-matic.[9]

Category 2 and Category 3 are very closely related. Both categories deal with born-digital video formats on tape.

Video formats in Category 2 give the user access to the underlying bit stream. In these formats, such as DV, it is possible to copy the bits from the tape medium to another medium as though copying data from a hard drive to another hard drive. Since one of the starting assumptions was that the digitized information would be stored in files, the information, already in digital form, is copied from tape to hard drive. All video in this category are *born compressed!* While our starting assumptions declare we will not *make* lossy compressed files, we may inherit them. Cf. Category 4.

Video formats in Category 3 do NOT give the user access to the underlying bit stream. In these formats, such as Digital Betacam, since it is NOT possible to copy the bits from the tape, the process is to have the machine decode the information on the tape in the digital domain, output the decoded bit stream via a serial digital interface (SDI) and capture the output. The relevant parts of the SDI specification, SMPTE 259M, quite conveniently, are the same as Category 1. In this way resultant Category 1 and Category 3 files would be the same. Except for their provenance[10] and the inherent strengths and weaknesses of the respective original capture formats, a file output from analog BetacamSP looks no different from a file output form DigitalBetacam.

Category 4 contains all file-based capture, be it to hard disc, flash drives, PD discs, cell phones, etc. Nearly all these are born compressed, and there is a wide variety of codecs, some of them proprietary. Here the archive enters into the realm of file format

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obsolescence evaluation. A policy assessment is made for each file type on whether to retain the file in its original codec or to transcode to a codec that is supported. Best practices declare the archive shall retain the original, even if it cannot or chooses not to support that codec. Recalling the starting assumptions not to create lossy compressed files, the recommendation is to decompress the codec and store a 10-bit[11] uncompressed file. In many cases this will mean storing a master that is 20-100 times larger than the original file.

Category 5 covers the potentially rich environment of optical discs, DVDs, and Blu-Ray. These media often contain additional content, from menus and special features, to additional language streams and subtitles. A single linear representation is often not a complete and accurate reproduction of the entire object. The recommendation is to store these as an ISO disc image,[12] though it may be necessary to also store an access proxy as some software will not play an ISO image.

To summarize, the white paper dispenses with both the idea of single, uniform recommendation and strongly rejects the division into high- and low-quality sources.

- The division is instead between born-analog and born-digital formats.
- Digital formats are divided into tape-based and file-based originals.
- Tape based born-digital are further subdivided into those where the user has access to the bit stream and where the user does not.
- A separate category is used for the non-linear formats on DVD and Blu-Ray.

What about MXF?

MXF is a wide-ranging set of specifications intended to have options for every possible use case. The original standard committee knew it would be impractical, if not impossible, to create an application that would write or read all possible variations within the specifications. SMPTE standard 377M subdivides MXF into operational patterns, each addressing one of these variations. The industry has worked together to develop Application Specifications suited to different user communities, such as production, distribution, etc. Since 2011 a committee has met for AS-07, the application specification targeted at the preservation user community. As of May 2015, the committee completed a draft that was open for public comment, those comments were considered and the specification revised. Sample files and reference implementations are being produced. In this process some conflicts and clarifications are being resolved. The committee expects the specification to be adopted as a standard sometime during 2015.[13]

What should you do at this time? Should you follow the recommendations of the white paper or adopt MXF and the JPEG2000 lossless compression? Some institutions will be bold early adopters. Most institutions will want to wait another year or two for tools to become more widely available, for interoperability to be worked out between vendors, and for other practical issues of working with the files on a day to day basis to settle out. For instance, only the most powerful desktop computers can decode JPEG2000 lossless video in real time. Windows Media Player and QuickTime require plug-ins that have limited functionality. Very few video editors support JPEG2000.

The 2011 task description letter from the **Library of Congress** to write the white paper described in this article set a time estimate of 3 to 7 years. In 2011, AS-07 looked a long way off, but now in 2015, the 3 to 7 year window looks amazingly prescient.

Endnotes

1. This is based on **Edison's** first recording in 1877 and **Ampex's** demonstration of the quad videotape recording in 1956. If we nod to phonaudograms in 1860 and to the BBC's experimental VERA video recorder (*https://www.youtube.com/watch?v=0f1GDQDB0Ss*) and other early video experiments, the time span is a little longer, but still about 80 years.

2. The reader may find it useful to have a copy of this paper handy while reading this article. "Determining Suitable Digital Video Formats for Medium-term Storage." *http://www.digitizationguidelines.gov/audio-visual/documents/IntrmMastVidFormatRecs_20111001.pdf*

3. This relates to the electrical system used in different parts of the world. In North America where the electrical line current has a frequency of 60 cycles per second (Hertz), 24 frames per second is used. This allowed film systems to "lock" to their power source. The two numbers 60 and 24 are both multiples of 6. In other parts of the world where the line current has a frequency of 50Hz, film systems run at 25 frames per second, as 50 and 25 are both multiples of 5.

4. The author asks forbearance from his fellow geeks where liberties are taken with the technical details to simplify topics for a more general audience.

5. However, video *stores* information in yet another system called color difference. One channel is the black and white information, and 2 of the 3 colors are *stored.* The third color is calculated from the difference between the 2 stored colors and the black and white information. This is often referred to as YUV, which, strictly speaking, is the modulation technology for PAL video, not the NTSC system used in North America, which is YIQ. At this point the author hopes you understand these are topics for another article and why the author has asked forbearance for the technical details.

6. Yes, for Western languages. However, an equivalent metaphor works for vertically oriented text in Asian languages, rotated 90 degrees.

7. This is definitely *not* junior high school math. The formulae shown are complete nonsense and for illustration only.

8. That same standard also defines hue. Like I said, **Alan Lewis** and I share the same sense of humor.

9. And you thought arguing with IT to store TIFFs was a challenge.

10. Which you will dutifully capture in your provenance metadata!

11. It is likely the original compressed file was 8-bit. If this is the case, then it may be possible to store an uncompressed 8-bit file. This decision is codec dependent. When in doubt, store the extra bits in a 10-bit representation.

12. Instructions on making ISO disc images can be found at: *http://www.digitizationguidelines.gov/audio-visual/documents/Preserve_DVDs_BloodReport_20140901.pdf.*

13. For his tireless commitment, leadership, and hard work on AS-07, **Carl Fleischauer** of **NDIIPP** at the **Library of Congress** deserves the gratitude and appreciation of world of media preservation.

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there is little history of marketing libraries or library services but things are different now!

Speaking of friends and books, got the incredible **Rita Ricketts** new book published by the **Bodleian Library** — *Scholars, Poets and Radicals: Discovering Forgotten Lives in the Blackwell Collections* (dist. by The University of Chicago Press). Trying to persuade a few of my old **Blackwell** friends to review it. Any takers?

Speaking of marketing, **Allison Korleski** has joined **Midwest Library Service** as Sales Representative for the Mountain Plains Region. The announcement was made by the magnificent **Howard N. Lesser**, president of **Midwest**, which has been providing many services to academic and public libraries for more than a half-century. **Korleski** brings nearly 20 years of experience in book purchasing, content development, and special sales to her new role. Her previous employers have included **Princeton University Press**, **Barnes & Noble**, and **Interweave Press**.

I have to insert some personal experiences about **Midwest** here. I began my job as an Acquisitions Librarian at the **College of Charleston** a long time ago before y'all were born. I had been a medical librarian and knew zero about acquisitions. The College Library had a total materials budget of $150,000 for books and journals. Our serials vendor was **Faxon** and book vendor was **Blackwells** and **Midwest Library Service** which is located in St. Louis, home of the famous Arch. **Dave Genaway** held two Acquisitions Conferences

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