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Drop Video File(s) Here: The Emergence of Free Quality Control Tools for Video Preservation

“The BAVC QC Tool Set is perhaps the most significant recent tool development for those working in the preservation of video. This tool set has provided a means of examining video material that previously would not have been possible for the majority of conservators and archivists. It therefore now forms a cornerstone to ensuring that the new generation of those who are caring for our collections are equipped with the skills and training to respond to a file based environment.”

—Pip Laurenson, Head of Collection Care Research, Tate

Introduction

The Quality Control Tools for Video Preservation (QCTools) project was born of a simple, yet singular idea: that video preservationists must not cede their own interest in the development of software tools designed to suit their own needs. This push for more self-determination—for an assertion of control over the quality control process, rather than reliance upon proprietary systems or outdated methods—has resulted in free and open source software that allows users to better understand and analyze their digital video files, whether “born-digital” or the result of analog-to-digital conversion.

With funding from the National Endowment for the Humanities’ Preservation and Access Research and Development Program, the Bay Area Video Coalition (BAVC) spearheaded this effort to develop and create a sustainable body of users for QCTools. While specifically targeting those at work in cultural heritage institutions (libraries, archives, and museums), the eclectic nature of QCTools generated an unexpectedly broad base of users, from media artists to software developers. Not only did these diverse communities bring new ideas to the table, helping to refine and expand the goals of the project, they also served as a powerful reminder that it is inclusiveness that will ultimately dictate the long-term prospects of all such efforts.

As with free and open source software communities more broadly, the true successes of QCTools lie not in its source code, but rather in the political, economic, and institutional implications that erupt from its new forms of social organization. In particular, QCTools reveals productive pathways through its companionship with the Audio/Visual Artifact Atlas (AVAA; <http://avaa.bavc.org>), its incorporation into the world of FFmpeg (<http://ffmpeg.org/>), and its dissemination through the web-based Git-repository Github (<https://github.com/bavc/qctools>). In a wider sense, QCTools marks the continuing spread of a free or open source ethos into the

audiovisual preservation community, one that is giving rise to new infrastructural models, new relational modes, and new ways of sharing knowledge.¹ While this could be easily dismissed as romanticization, as Steven Weber describes in *The Success of Open Source* (2004), the unlikely phenomenon of free and open source software is “in some ways the first and certainly one of the most prominent indigenous political statements of the digital world” (7). A “story of how social organization can change the meaning of property, and conversely, how shifting notions of property can alter the possibilities of social organization,” adopting this perspective allows us to recast quality control itself, thinking of it as more than a set of tools and processes, and rather, as a public good: something that should be shared, cared for collectively, and made widely available to all (1).

Given the intense pressures and demands of audiovisual preservation, this radical reorientation could not be more timely. Our future abilities to safeguard audiovisual materials—and to guarantee access to them over the long-term—will hinge in large part upon the continued support of projects that are striving to remove the barriers and obstacles impeding the progress of our time-sensitive, yet critical mission. Maximizing efficiency, exposing new and unexpected insights, and establishing an ever-evolving community committed to the very idea of free software playing an integral role in the future of this work—these are the lessons of QCTools.

Motivation: The Need for Free Quality Control Tools

Leaders in the field of audiovisual preservation are united in their predictions: whether invoking metaphors of catastrophe, crisis, or “gathering storms,” this much is clear—the combination of deteriorating or degrading analog physical media carriers and obsolete playback and peripheral equipment has made the task of protecting and preserving our audiovisual cultural heritage both immediate and immensely difficult (Casey 14). But, though the challenges of digitization and digital preservation may make some yearn for relatively more stable days of tape-to-tape preservation, the end of an entire industry (the Sony Corporation recently announced plans to “cease sales and distribution of Professional Video Tape Recorders/Players/Camcorders” by March 2016, with repair services offered until March 2023) makes even this nostalgia a luxury that few can truly afford (“Sony Announces Sales Discontinuation”).

For the caretakers of magnetic media (audio and videotape) collections, prompt and decisive action *is required*, and the only way to save this part of our cultural heritage is to play back tapes on obsolete equipment, creating digital surrogates through a process alternatively referred to as reformatting, migration, digitization, or analog-to-digital conversion. Unlike celluloid film, which is composed of discrete frames

¹ QCTools is certainly not alone in this regard. Though uniquely focused on quality control and digital video, QCTools is but one of many open source tools that have been actively embraced by archivists and preservationists. For more, see Kara Van Malssen’s “Tools for Smaller Budgets” in *AV Insider 2: Preservation in Times of Precarity* (2012).

that are visible to the naked eye, magnetic media show nothing of their inner nature without functioning playback equipment; they are dependent, their existence utterly intertwined with the technologies that brought them into the world.

In a 2013 presentation, “To Outsource or Not to Outsource,” Jonah Volk, Media Preservation Coordinator at the New York Public Library, sketched a telling portrait of quality control, situating “Quality Control: The Ideal,” on one end of a spectrum, and “Quality Control: The Reality,” near the far opposite end. For Volk, quality control—the effort to confirm that digital files have been created according to pre-determined specifications—has become an unfortunate risk/reward scenario; due to limitations of time and resources, many institutions have been forced into a weighing of the odds, potentially sacrificing thorough and complete quality control simply to get by. And even for these institutions—which are the lucky ones, blessed with the resources to embark upon digitization projects, it remains difficult to justify the additional expense of proprietary quality control software designed for the needs (and budgets) of the broadcast industry.

For institutions pursuing in-house digitization, QCTools offers a means of ensuring the creation of consistent, high-quality files. For institutions working with outside vendors, QCTools offers a means of verifying that digital files meet desired expectations/thresholds for quality. In both circumstances, QCTools serves an important communicative function, one that transcends institutional boundaries.

Background and Development

As a leader in the field of video preservation since its inception, BAVC has had a front-row seat to the acceleration of this impending crisis. Working with the oldest and most decrepit of magnetic media formats, BAVC witnessed firsthand the multiplying (and compounding) challenges that are associated with reformatting degrading tapes. It was this awareness—this acute understanding of the difficulties ahead—that prompted BAVC to develop quality control software capable of reducing some of the burdens placed upon the underserved, overlooked preservation community. For magnetic media to be granted a second life, they must undergo a complex, error-prone, time- and resource-intensive process. Before this project, extraordinary amounts of time were required to:

- (1) transfer videotape recordings to digital file formats, documenting errors/artifacts/adjustments;
- (2) review, in full, potentially problematic files, identifying compromises in tape playback or digitization tools;
- (3) analyze and identify problem areas and their sources; and
- (4) develop potential solutions to tape degradation, malfunctioning playback equipment, and computer hardware/software incompatibilities.

The urgent need to transform culturally significant tape-based materials into forms capable of standing the test of time is matched only by the need to do so in an

efficient, high quality manner. The incongruities of preservation workflows prompted Lauren Sorenson, a former member of BAVC's Preservation Department, to ask the question that has served as a beacon for the entire QCTools effort: "How might the archival and conservation community re-imagine software functionality" ("Capture Software Study for Preservation of Analog Videotape," 143). From the beginning, QCTools was about more than refusing to rely upon commercial software companies whose interests may one day diverge from our own; as BAVC imagined it, the imperative in quality control was to question the implications of allowing private, for-profit interests to dictate what this software looks like, how it functions, and who it was designed to serve.

The vision for QCTools emerged out of the collaborative work of BAVC, the Dance Heritage Coalition (DHC), and a technical team lead by independent consultant Dave Rice. Working to create the DHC's Secure Media Network (SMN), a digital preservation system made up of multiple digitization hubs ("digihubs") operating simultaneously throughout the country, it became immediately apparent that the DHC would benefit from adopting a coherent method for analyzing the digital video files produced by these various stations. In tackling the infrastructural, technical, and organizational challenges attendant to this digital preservation network, all three groups came to see that quality control was more than a local problem; it was endemic to the field of audiovisual preservation. Regardless of institutional alliances, preservationists *of all kinds* require the means to assess their digital video materials, whether created in-house or by outside vendors. Without proper protocols in place, the lack of quality control tools and expertise can result in technical compromises that go undetected, with minor flaws undermining all resulting digital media.

By taking a data-driven approach to the analysis of digital video, QCTools fills an important gap in the preservation community, becoming the "computer processable" companion to the more "human readable" Audio/Visual Artifact Atlas (AVAA), a web-based dictionary and repository for the most frequently occurring errors and anomalies of the digitization process. As with the AVAA—a partnership of BAVC, New York University's Digital Library Technology Services, and the Stanford Media Preservation Lab—QCTools is guided by the community-driven belief that:

Users can improve the outcomes of their media preservation efforts if they can properly identify and characterize signal issues and anomalies. With a tool to facilitate building a vocabulary of terms and supporting examples, users will be able to learn and communicate about problems with more clarity and understanding. With this understanding, it is more likely that fixable problems will be fixed, limited resources will be directed more appropriately, and the products of reformatting workflows will be of higher quality. ("About the AV Artifact Atlas").

The sheer variety of formats in the sixty-odd year history of video has presented AVAA contributors with a unique challenge: can errors identified in one format correspond in any noticeable way to their equivalents in different formats? While QCTools may not be able to overcome the challenge of getting a diverse group to adhere to a common set of terms, especially given the substantial distinctions differentiating video recording technologies, it does point to an alternate possibility, the “big data” future of audiovisual preservation, with information gathered and arranged in provocative new ways. If widely implemented, QCTools can help identify field-wide areas of concern, pinpointing the most problematic formats, or brands/stocks, and perhaps even the efficacy of tape treatment methods (such as baking tapes, a widely used means of countering “sticky shed syndrome,” or binder hydrolysis). Though this would depend upon a metadata model capable of bridging institutional gaps, what is most exciting about QCTools is that it spurs this type of thinking, moving it to the realm of possibility.

QCTools: Organizing Concepts and Principles

In its current incarnation, QCTools strikes a fascinating balance, alleviating some pressures through automation while prompting a deeper dive into the depths of digital video signals. At its core, QCTools reduces the need to rely so heavily upon human subjectivity and perception, bringing a concrete consistency to the task at hand, whether that be communicating common problems, or performing quality control on a batch of digital video files.

After a 2014 QCTools workshop, Erik Piil, Digital Archivist at Anthology Film Archives, struck upon two of QCTools’ strongest merits, its ability to catch what might be missed, and its unanticipated status as a new educational platform:

When feeding [QCTools] newly-created digital assets, it picks up almost imperceptible field-level errors and chrominance noise that could easily be overlooked by the fatigued eyes of a video technician and engineer.² From a more pedagogical standpoint, however, feeding files with known video artifacts through QCTools allows the user to learn a wealth of information about the signals themselves, through the patterns that the artifacts reveal. Since viewing and interpreting moving images is a complex process, observing the recurring patterns gives the user base a better, well-structured sensitivity to the problems.

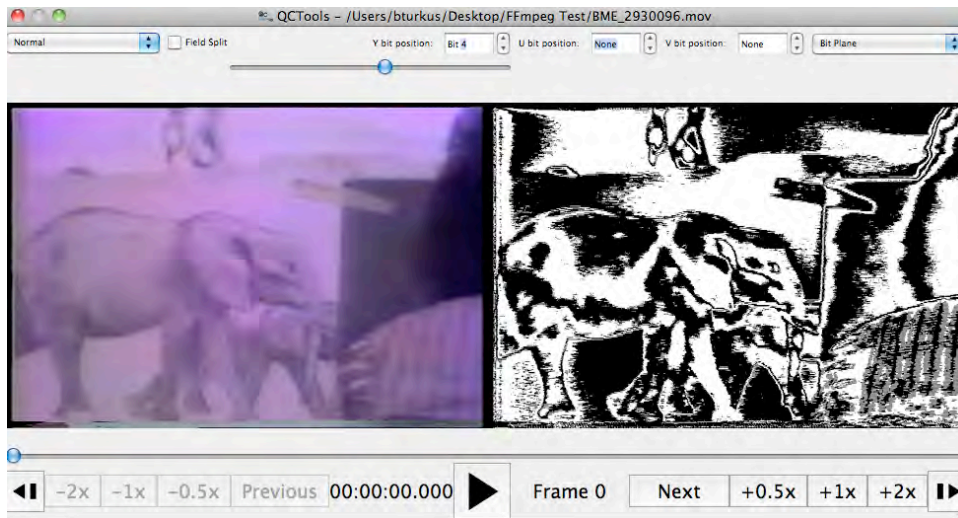
Here, Piil points to an exciting reversal: for many, QCTools is most noteworthy for its archaeological nature, for the ways it allows users to sift through layer upon pixelated layer of digital video signals, learning to think of digitization—and problems occurring during the digitization process—in new and different ways. By challenging our preconceived notions about digitization, QCTools encourages us to think more critically about the digital surrogates we are creating. And this

² http://avaa.bavc.org/artifactatlas/index.php/Chrominance_Noise

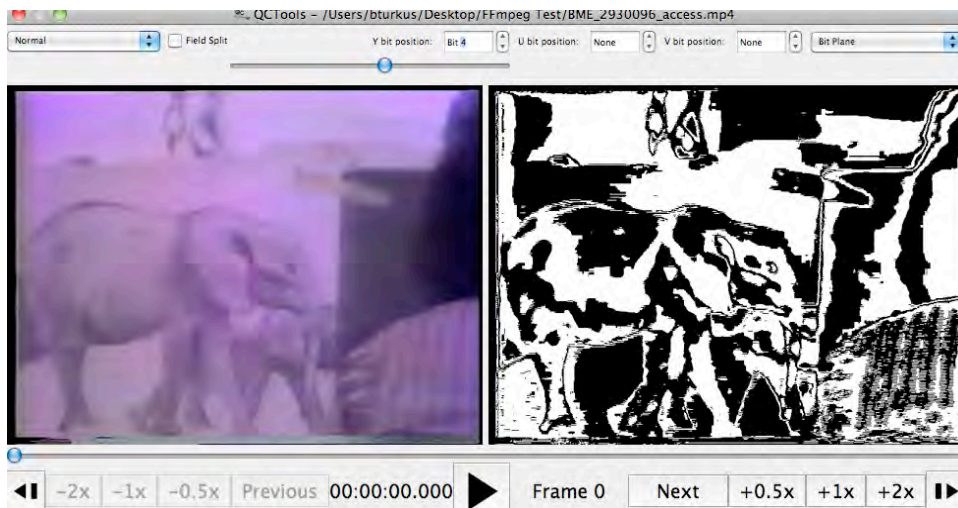
unexpected use of QCTools can be instrumental in efforts to convince the preservation community to embrace ideas that are at first uncomfortable. While QCTools may not end debates about the best way to encode or wrap digital video bit-streams, it can make these debates more informed, allowing preservationists to visualize the underlying differences between methods of encoding.

As Piil explains:

To take just one example, using the “bit [plane]” filter to examine sets of bits corresponding to a given bit position, one could ascertain whether a file had been made using a compressed (lossy) or an uncompressed (lossless) source. This information is crucial for the archivist and conservator, who can now sufficiently move statements of file fidelity through time with the proper documentation.



The analytical playback window of QCTools. Figure 1 (above): “Normal” view on the left; “Bit Plane” view of the fourth Y bit on the right, 10-bit uncompressed V210 encoding; Figure 2 (below): the same side-by-side, with H.264 encoding. Note the level of fine-grained detail.



When we speak of video, whether analog or digital, we are speaking of the transmission of visual and aural information. Video is an electronic medium, one that flows, moving constantly. Descriptions of the underlying mechanisms of analog video—“electron guns” and “cathode ray tubes”—can make the familiar feel foreign. In *How Video Works* (2007), Marcus Weise and Diana Weynand describe a process that astounds with its speed and immediacy:

The electron beam inside a video camera transforms a light image into an electronic signal. Then, an electron beam within a video receiver or monitor causes chemicals called phosphors to glow so they transform the signal back into light (15).

Despite their fluidity, video signals are composed of standardized, discrete units (lines, fields, and frames) that lend themselves to digitization, a two-part process that Charles Poynton, in *A Technical Introduction to Digital Video* (1996), breaks down into sampling (“The value of a bandlimited, continuous signal at an instant of time/and or space”) and quantization (the assignment of an “integer to the amplitude of the signal in each interval or region”) (294; 2). QCTools offers the digital video novice a better understanding of what a vast and comprehensive world this is; in a crude approximation of the National Digital Stewardship Alliance’s *Levels of Digital Preservation* (2013), this could be thought of as a super-charged version of “Level Two: Know Your Data.”

The difficulties that some users have reported in adapting to QCTools point to a focus of future educational efforts: video preservationists must be as fluent in the language of digital video as they are in the language of analog video. While the “under the hood” nature of QCTools has granted users an unprecedented ability to deconstruct digital video streams, analyzing them from different perspectives, in certain cases practitioners have continued to struggle with the complexity of analog-to-digital conversion, particularly the mapping of analog standards onto the digital realm. For example, many expressed confusion regarding the correspondence between the IRE scale, an analog mode of measuring video-specific units of voltage, from black (7.5 IRE) to white (100 IRE), and its 8-bit, Y’CbCr (color difference component digital video) equivalent (0-255).³

Has QCTools firmly and thoroughly straddled the specialist/novice divide? Not quite yet, but this is an ambition of the project. In many ways, the pedagogical potential of QCTools caught the development team by surprise, and though it has been

³ From Keith Jack’s *Video Demystified* (2007):

“The YCbCr color space was developed as part of ITU-R BT.601 during the development of a world-wide digital component video standard. YCbCr is a scaled and offset version of the YUV color space. Y is defined to have a nominal 8-bit range of 16-235; Cb and Cr are defined to have a nominal range of 16-240...Y and CbCr occasionally [go] outside the 16-235 and 16-240 ranges, respectively, due to video processing and noise” (19-20).

secondary to the desire to create a robust, functioning program, there is a vision of working to actively build upon this potential through future educational outreach.

FFmpeg and the Free and Open Source Software Movements

QCTools greets users with a clean, light grey interface; within, a file folder bisected by a downward facing arrow points to the simple dictum that could serve as symbol for the entire QCTools project: “Drop video file(s) here.”

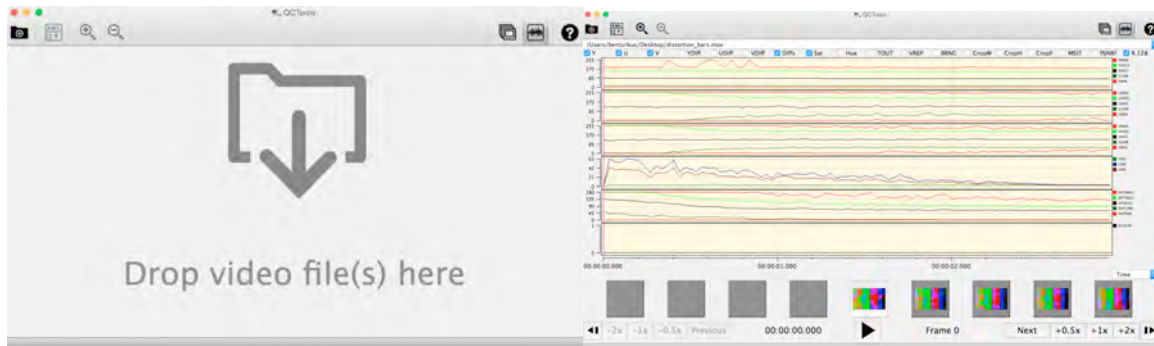


Figure 3 (left): The QCTools User Interface; Figure 4 (right): QCTools in graph mode

Follow this command, and QCTools will kick into multi-colored action, quickly analyzing the pixel information of a digital video file, spitting out multiple levels of crawling red, green, blue and black graphs. This is the first of QCTools’ three core analytical components, a macro view of the digital video and audio bit-streams, read from left (the beginning of a recording) to right (the end of a recording). At the bottom of the screen, a series of frame-level preview windows allows users to gain an instant impression of problematic areas requiring closer review. In an effort to make the program more approachable, QCTools defaults to a limited number of audiovisual metrics (YUV Values, which plot brightness (luma, Y) and color information (chroma, U/V); YUV Difference Values, which document the extent of visual (YUV) change from one frame to the next; Saturation, which offers an overview of the color saturation, or vibrancy, of the video; and R.128, a measurement the overall loudness of the audio stream, following European Broadcast Union (EBU) specifications).

In this macro-analytic view, users can also select from a number of other filter graphs: Hue, a plot of the average color value for each frame; Temporal Outliers (TOUT), which identifies pixels that vary drastically from their closest neighbors; Vertical Line Repetitions (VREP), a measurement of similar or duplicate rows of pixel data; Broadcast Range (BRNG), which detects pixels whose values are outside “legal” limits (16-235 for Y; 16-240 for U/V); and Mean Square Error per Field

(MSEf) and Peak Signal to Noise Ratio (PSNRf), two graphs that specialize in tracking differences at the field level.⁴

QCTools draws much of its strength from FFmpeg, a free software project self-described as “a complete, cross-platform solution to record, convert, and stream audio and video” (<https://ffmpeg.org>). Just as Linux often exists behind the scenes, powering many contemporary operating systems, FFmpeg forms a foundational layer for a number of media platforms, such as Google Chrome, YouTube, MPlayer, VLC, and xine (<http://en.wikipedia.org/wiki/FFmpeg>). Written in the programming language C, FFmpeg’s speed, reliability, and high functionality have made it an ever-increasing part of audiovisual preservation workflows, particularly for the following tasks:

- **Encoding:** “The process of converting one or more signals into a more complex representation, with the goal of reducing data rate for transmission or recording”;
- **Decoding:** “Converting one or more coded signals into uncompressed form, reversing a previous encoding operation that was applied to reduce data rate for transmission or recording”; and
- **Transcoding:** “Various methods of recording a compressed bitstream, or decompressing then recompressing” (Poynton *Digital Video and HD*: 617; 612; 661).

It was lead developer, Dave Rice, who had the critical foresight to align QCTools with this much larger, well-established effort. A contrarian in the sense that he brings a technical understanding to conversations and debates that studiously avoid technical specifics, preferring to remain surface-level, Rice immediately recognized that the sustainability and growth of the QCTools project would depend in large part upon our ability to reach outside of our circle, finding compatriots in communities other than our own.

Though it emerged out of the world audiovisual preservation, QCTools is not exclusive, or exclusionary, and can notably serve the needs of anyone working with digital video. This inclusiveness speaks to the long-term prospects of QCTools, and one of the signature achievements of the project was the incorporation of a QCTools-designed filter set, **signalstats** (<http://ffmpeg.org/ffmpeg-filters.html#signalstats>), into the release of FFmpeg 2.3. By complementing the core technical team (Jérôme Martinez, Devon Landes, Ashley Blewer, Mark Heath and Erik Piil) with an FFmpeg libavfilter specialist (Clément Bøsch), we were able to

⁴ More from Jack:

An interlaced video system is one where two interleaved fields are used to generate one video frame. Therefore, the number of lines in a field is one-half the number of lines in a frame. In 480i video systems, there are 262.5 lines per field (525 lines per frame)...each field is drawn on the screen consecutively—first one field, then the other (864).

optimize the signalstats filter set, ensuring that a broad base of users would be able to take advantage of QCTools-style reports and features directly through FFmpeg's command line interface.

This give-and-take is typical of free and open source software development, and a closer look at the licenses underlying QCTools reveals a true hodge-podge, one that reflects the diversity of the free and open source software movements themselves:⁵

- QCTools is licensed under a GPLv3 license (<http://gplv3.fsf.org/>)
- QCTools GUI and FFmpeg statistics filter are licensed under a the 3-Clause BSD license (<http://opensource.org/licenses/BSD-3-Clause>)
- Libraries from the FFmpeg project are licensed under a GPLv3 license
- The QT GUI Toolkit is licensed under a GPLv2.1 license (<https://www.gnu.org/licenses/lgpl-2.1.html>)
- The QWT Library is licensed under a LGPL license (<https://www.gnu.org/licenses/lgpl.html>)
- Tiny XML-2 is licensed under a zlib license (<http://opensource.org/licenses/Zlib>)

There is well-trod, overhyped ground of “frenzied argument” and “flame wars” characterizing the relationship between the Free Software Foundation (FSF) and the Open Source Initiative (OSI), but it is more productive to see these movements as partners in practices, and to consider how these practices have begun infiltrating the audiovisual preservation community (Kelty 112). The core of both movements is software licensing that insists upon the following:

- 1) Source code must be distributed with the software or otherwise made available for no more than the cost of distribution;
- 2) Anyone may distribute the software for free, without royalties or licensing fees to the author; and
- 3) Anyone may modify or derive other software from it, and then distribute the modified software under the same terms (Weber 5).

The singular genius of the free and open source software movements was to invert a copyright system that was determined in its vision of “locking up” culture, tipping

⁵ In the interest of conceptual clarity, the free and open source software movements have been treated as a singular entity, despite important differences between the two groups and internal squabbles within each group. Most important is what they share: unique licensing practices that subversively invert traditional notions of intellectual property. Though an oversimplification, the Free Software Foundation (FSF), founded in 1984 by Richard Stallman, treats software as a deeply political, libertarian concern; for the FSF, the issue is one of liberty and freedom of expression, with its own tagline: “Free as in speech, not as in beer” (*GNU.org*). On the other end of the ideological spectrum is the Open Source Initiative (OSI), founded in 1998 by Eric Raymond and Bruce Perens. Emerging at the same time as the public release of the Netscape Navigator search engine source code, the OSI approach, intentionally couched in less overtly political terms, is focused on economics, encouraging “commons-based peer production” (Berry x).

too far in the direction of protecting intellectual property (Boyle 9). In a paradoxical way, the expansive force of copyright stimulated its own counterforce, giving rise to new ways of conceptualizing intellectual property and new social practices based upon the belief that knowledge should always be unfettered, and freely distributed.

This radical reshaping of the politics of information would ultimately ripple outward, proving the power and simple effectiveness of “horizontal, informal cooperation” (Streeter 186). In both its creation and execution, QCTools is vivid evidence that the preservation community has gained more from the free and open source software movements than merely tools and a means of distributing them.

The Shift Toward Advanced Visualization Features

While the current state of QCTools may suggest that a grand vision and immediate consensus were formed in the early stages of the project, in fact, there was plenty of healthy and vigorous debate from the outset. Very little about QCTools was preordained, and one early critical difference of opinion concerned visualization features, what could be described as a shift away from analysis toward the decoding and playback of digital video files.

As originally conceived, QCTools was a statistical analysis engine, offering graphs and numbers that would allow users to collect and maintain quality control data in standardized ways. Over a series of cross-country Skype video sessions, however, Rice and BAVC’s then-Director of Preservation Moriah Ulinskas began to weigh the benefits and compromises that would be associated with incorporating enhanced visualization features into QCTools. An educator at heart, Ulinskas understood that QCTools had the potential to intimidate non-specialists; to counteract this possibility, she believed the software had to evolve, taking on a more visual nature. Though it was difficult to alter course (relying more heavily upon FFmpeg’s application programming interface (API) led to mini-roadblocks, such as reworking QCTools’ original source code, and having to wait for FFmpeg improvements in order to proceed), all involved recognized that a preview window environment held the key to allowing users to better explore and understand digital video errors and anomalies.

If the first of QCTools’ three core analytical components offers an overview of the audiovisual essence of a digital video file, breaking it down into its constituent parts, the second—a playback window for manual spot checking and in-depth analysis—offers the possibility of field-level, side-by-side visual comparisons. Taking as its launching pad traditional analog measurement devices (video monitor, waveform monitor, and vectorscope), this playback window lets users drill down deeper into problems first identified by the graphs.

Double-clicking on any of the frame-level thumbnail images that line the bottom of the screen in the graph mode of QCTools launches the playback window, which offers two viewing windows that can be set to different combinations of filters. This

split-screen view defaults to “Normal” on the left, a simple presentation of the video signal as QCTools interprets it, without any special effects or filters added, and “Vectorscope” on the right, a digital representation of the analog oscilloscope that is used to monitor the chrominance of a video signal.

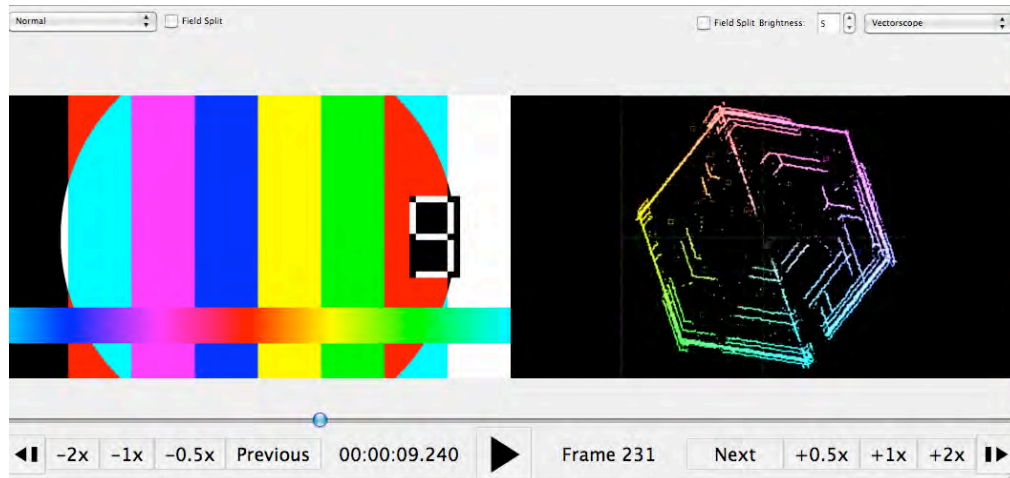


Figure 5: The QCTools Playback Window, “Normal” view of a color bar pattern on the left; “Vectorscope” on the right

Gaining the ability to see a video file as QCTools sees it is an illuminating experience, one that can complement, reinforce, and possibly even challenge the assumptions of a human being. The playback window encourage users to slow down, taking the time to examine errors and anomalies in different fashions, and it also offers views that are simply beyond human perception. The best example of this is the field-split filter, which separates the interleaved fields of the video frame, potentially isolating errors to a single field.

In the example below, the source of a compromised video signal can be traced back to one of the video heads that determine a videotape recorder’s (VTR) ability to recreate the video signal.⁶ In this case, a single video head has either become clogged with loose oxide, or is damaged beyond cleaning:

⁶ For all tape-based magnetic media, the content (signal) is captured in electro-magnetic particles that compose a complex binder matrix affixed to the tape base. Though it varies by video format, playback typically entails a set of electro-magnetic heads rotating at high speed, “reading” the signal as the tape passes over them. See “Video Head Clog,” AVAA: http://avaa.bavc.org/artifactatlas/index.php/Video_Head_Clog

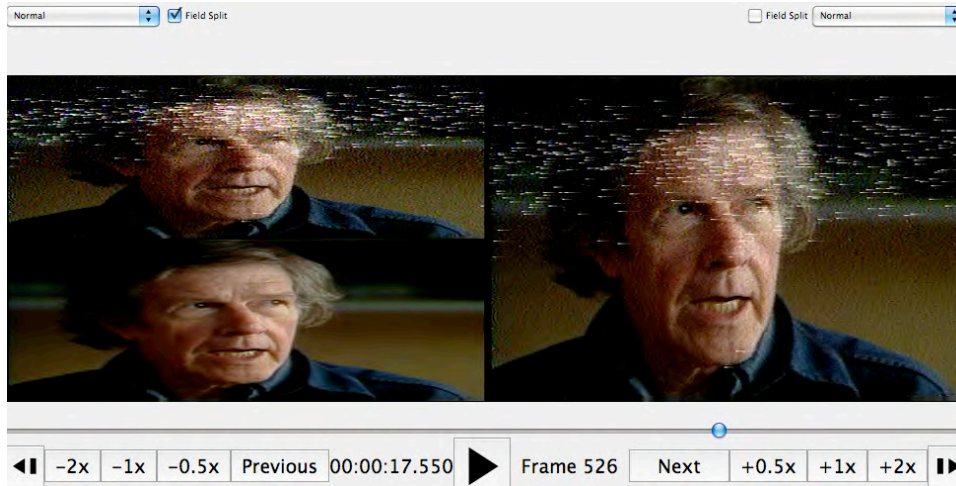


Figure 6: The QCTools Playback Window, “Field Split” on the left, “Normal” on the right

This newfound sight lifts a veil, and opens up a wealth of restorative possibilities: what if QCTools could be used to remove these split-second errors and anomalies, improving the condition of the video signal in cases where an alternate transfer might not be possible or beneficial? While this might be wading into ethically murky waters, again, what is special about QCTools is that it sparks new ideas and critical thought that could shape the future of audiovisual preservation.

The Field-Split and Vectorscope filters are just the beginning of QCTools’ analytical playback environment. By harnessing FFmpeg’s libavfilter library, QCTools allows users to mix-and-match from a variety of other filters: Histogram, which shows the frequency of occurrence of the YUV or RGB channels; Waveform, which plots the brightness of the video signal, with color-coded demarcations for “legal limits” or “broadcast range;” Line Select, which allows users to select one line of video to display as a waveform; Extract Planes, which removes the chroma data from the video, presenting something akin to histogram goggles; Bit Plane, which allows users to see the underlying structural patterns of YUV encoding methods; Value/Saturation Highlight, which allows users to specify ranges of YUV values, highlighting pixels that fall within or outside these zones; Chroma Adjust, which allows users to adjust the hue and saturation levels of a video signal; Color Matrix, which allows users to play back the video in various color spaces, visualizing the subtle yet significant differences between BT.601, BT. 709, SMPTE240M, and FCC; Field Difference, which presents deviations between fields of video; Temporal Difference, which presents deviations between frames of video; Broadcast Range Pixels/Broadcast Illegal Focus, which offer visualizations of pixels within/outside broadcast range; Vertical Line Repetition, which highlights repetitive lines of video data; Frame Tile, which offers a “tiled” mosaic of successive frames; and Zoom, which allows users to zoom to a particular point in an image on the X and Y coordinates.

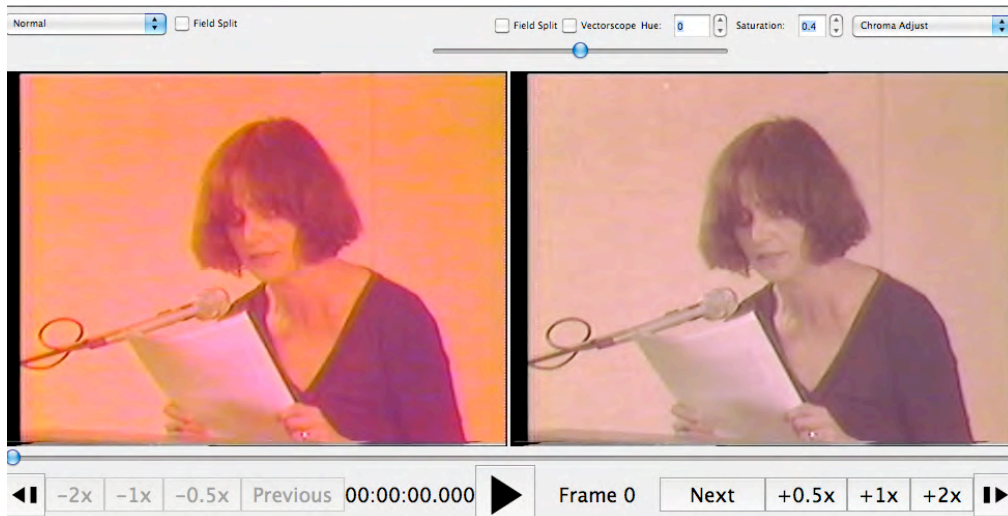


Figure 7: The QCTools Playback Window, “Normal” view of a color-imbalanced video on the left; “Chroma Adjust” view on the right, with moderate chroma desaturation.

Though focused on in-the-moment analysis, the playback window can also serve a documentation and communication function. As Peter Oleksik, Assistant Media Conservator at The Museum of Modern Art (MoMA), describes:

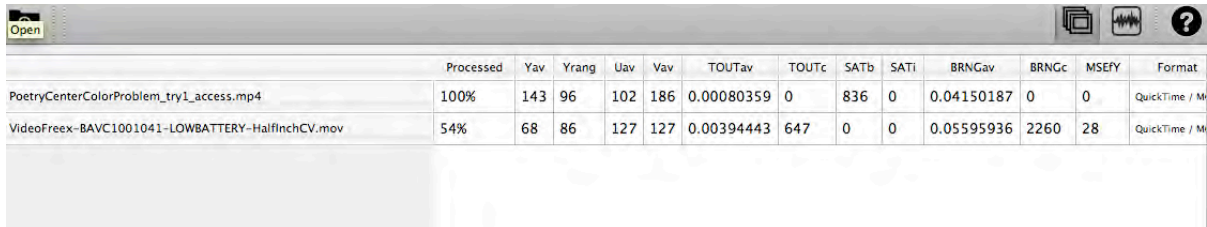
The filtering capabilities of the software are where media conservation sees the greatest benefit to our current documentation process. Using the various filters in QCTools that allow for multiple views of a video signal, errors or aberrations in the video can be accurately reported in our conservation reports alongside screen shots of the actual errors. In addition, these filters allow one to zero in on the specifics of an error, which will allow better communication with vendors to pinpoint and correct poor transfers.

The third of QCTools’ three core analytical components, the “List View,” complements the statistical graphs and visualization filters by offering technical metadata and summarization statistics. In this mode, users can watch as QCTools processes multiple videos, tracking both the percentage of completion and the accumulation of potentially problematic statistical averages. The technical metadata is similar to an abbreviated FFprobe (<https://www.ffmpeg.org/ffprobe.html>) or Mediainfo (<https://mediaarea.net/en/MediaInfo>) test, while the summarization statistics, introduced in QCTools 0.6.0, offer the following:⁷

- Y Average
- Y Range: average of YHIGH-YLOW
- U Average

⁷ QCTools offers the following technical metadata in its “List View”: Format, Streams Count, Bit Rate, Duration, File Size, Video Format, Width, Height, Field Order, Display Aspect Ratio, Sample Aspect Ratio, Pixel Format, Color Space, Color Range, Frame/Duration, Real Base Frame Rate, Average Frame Rate, Audio Format, Sampling Rate, Channel Layout, and Audio Bit Depth.

- V Average
- TOUT (Temporal Outlier) Average
- TOUT (Temporal Outlier) Count
- SAT (Saturation) Broadcast
- SAT (Saturation) Illegal
- BRNG (Broadcast Range) Average
- BRNG (Broadcast Range) Count
- MSEfY (Mean Square Error per Field Y)



	Processed	Yav	Yrang	Uav	Vav	TOUTav	TOUTc	SATb	SATi	BRNGav	BRNGc	MSEfY	Format
PoetryCenterColorProblem_try1_access.mp4	100%	143	96	102	186	0.00080359	0	836	0	0.04150187	0	0	QuickTime / M
VideoFreex-BAVC1001041-LOWBATTERY-HalfInchCV.mov	54%	68	86	127	127	0.00394443	647	0	0	0.05595936	2260	28	QuickTime / M

Figure 8: QCTools in “List View”

While the primary purpose of QCTools is to display information through graphs, visual side-by-sides, and statistics, the long-term retention of quality control data was also a critical component of the project. The 0.5.0 release of QCTools marked the addition of the “QCTools Document,” a self-descriptive XML document designed to store frame-level quality control metadata (compressed by the free software application gzip (<http://en.wikipedia.org/wiki/Gzip>), formatted according to FFmpeg’s FFprobe XML schema (<http://ffmpeg.org/schema/ffprobe.xsd>)).

The questions most frequently asked of QCTools—and the questions most difficult to answer—are typically a version of: “What does normal look like?” “What does aberrant look like?” “Can QCTools tell me when to go back and re-transfer a tape?” Though the answer to the last question is undoubtedly yes, there is an important qualification to make: as with Nicholas Carr’s description of predictive algorithms in *The Glass Cage: Automation and Us* (2014), QCTools is “indifferent to underlying causes or root phenomena;” false positives come with the territory. Is that tape damage, sync loss, or has the camera panned to a light-filled window? To QCTools, all three phenomena present themselves in the same fashion: spikes of luma, and pixels unlike their neighbors (Temporal Outliers) that might veer dangerously close to upper edges of “legality” (Broadcast Range). In its current state, QCTools indicates, it does not diagnose, and though it has made us faster and smarter, the contingency of circumstance will always prevail. While future development will certainly make QCTools itself smarter, we would do well to pay attention to skills we are gaining, *as well as* the skills we are losing or compromising, as we take audiovisual preservation in more automated, scalable directions.

Testing, Dissemination, Community-Building

As with the AVAA, the lifeblood of QCTools has been—and will continue to be, community involvement and participation. From the beginning, QCTools was designed to evolve in tandem with the ever-changing needs and requirements of preservationists working with digital video materials. While there was never an expectation that novice users would be able to pick up keyboards and begin instantly contributing lines of computer code, we did strive to level the playing field by encouraging users to help us identify problems to-be-fixed and directions for future development.

The smartest decision made to solicit more active community engagement was to move QCTools to the web-based Git-repository Github (<https://github.com/bavc/qctools>). With over nine million registered users, and twenty million regular monthly visitors, Github, founded in 2008, operates as a centralized marketplace for idea sharing in free and open source software development (Metz, “How Github Conquered Google, Microsoft, and Everyone Else”). Much more than a simple repository for the QCTools source code, Github proved to be an immensely valuable project management tool, allowing us to more easily and efficiently track: (1) the history of the development process, and changes made in successive releases; (2) any problems with the software, or bugs; and (3) user-desired features or enhancements. Github was also, critically, a place to connect QCTools to other free and open source projects, and a place to find unlikely collaborators.

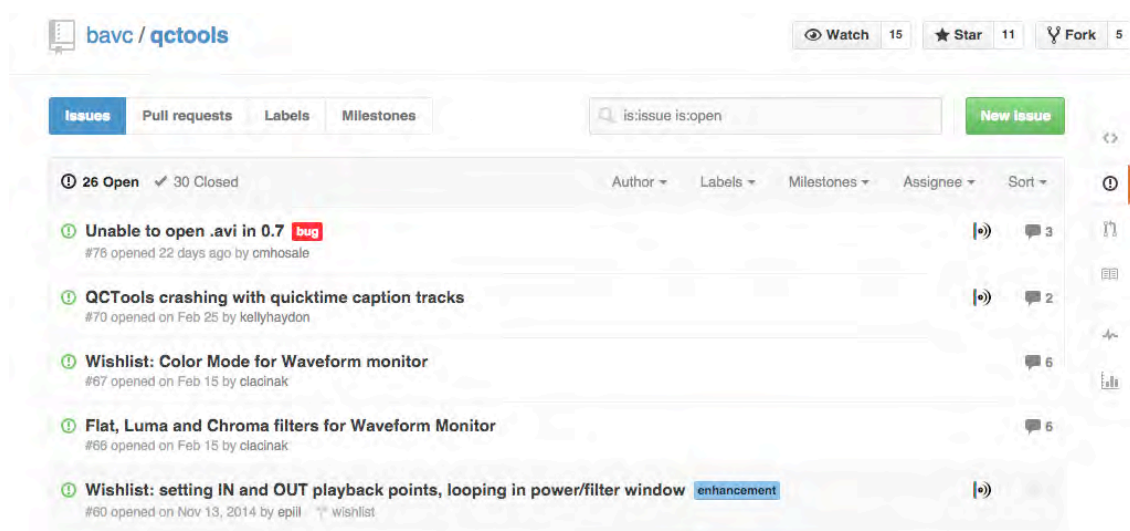


Figure 9: The QCTools Github “Issue Tracker,” with user-identified “bugs” and “enhancements”

In order to gain in-depth feedback from QCTools’ intended audience, BAVC hosted a two-day workshop at its headquarters in San Francisco in March 2014. The aim was to present the latest version of QCTools (at the time, version 0.4) to a range of archivists, conservators, and technicians, all specialists in the preservation of analog video. By engaging this group of users in training, testing, and discussion, we were able to set goals for the remainder of the project.

Attendees included:

- Michael Angeletti, Moving Image Digitization Specialist, Stanford Media Lab
- Tom Colley, Collection Manager, Video Data Bank
- Rebecca Fraimow, Project Assistant, Dance Heritage Coalition
- Martina Haidvogel, Advanced Fellow in the Conservation of Contemporary Art, SF MOMA
- Ludovic Jolivet, Preservation Technician, Dance Heritage Coalition
- Kristin Lipska, Project Assistant, California Audiovisual Preservation Project (CAVPP)
- Kristin MacDonough, AV Artifact Atlas Coordinator, BAVC
- Joanna Phillips, Associate Conservator of Contemporary Art, The Guggenheim
- Erik Piil, Digital Archivist, Anthology Film Archives
- Peter Oleksik, Assistant Media Conservator, MOMA
- Jon Shibata, Assistant Film Archivist, Berkeley Art Museum/Pacific Film Archive



Figure 10: The “QC Testers” during a March 2014 workshop at the Bay Area Video Coalition

Throughout the development process, the QCTools team made a concerted effort to introduce the software to as wide an audience as possible, participating in a number of professional conferences and holding in-depth workshops. Relevant presentations/workshops include:

- In November 2013, Devon Landes and Dave Rice presented “QCTools: A Report on Open Source Tools for the Quality Control of Digitization” at Association of Moving Image Archivists (AMIA) annual conference.
- In June 2014, Kristin MacDonough presented “QCTools and the AV Artifact Atlas: Open Source Tools and Resources for Quality Control in Digitization” at the America Library Association (ALA) annual conference.
- In July 2014, Dave Rice participated in a QCTools/FFmpeg training workshop at the Tate in London.
- In September 2014, Devon Landes and Dave Rice were interviewed for the Library of Congress’ Digital Preservation blog *The Signal*, “QCTools: Open Source Toolset to Bring Quality Control for Video within Reach.”
- In October 2014, Sam Long and Dave Rice presented “QCTools: Official Launch” as part of the Open Source and Digital Preservation and Access stream of the AMIA annual conference.
- In October 2014, Kristin MacDonough presented “A/V Artifact Atlas: Cultivating a Living Glossary for Audiovisual Errors” at the Visual Resources Association (VRA) Local conference.
- In December 2014, Kristin Macdonough presented “Diagnosing Audiovisual Errors with QCTools and the A/V Artifact Atlas” at the Art Libraries Society of North America Mountain-West Chapter virtual conference.
- In March 2015, Dave Rice participated in a QCTools workshop at Flemish Institute for Archiving (VIAA).
- In May 2015, Dave Rice and Ben Turkus presented “QCTools: A Consideration of Free Software for the Quality Control of Digital Video” at the American Institute of Conservation (AIC) annual conference.

Crisis and Response: The Future of QCTools

Imagine free quality control software that allows users to digitize their video materials to chosen specifications, with real-time analytics, visualization features, and frame level checksums. Imagine free quality control software that accommodates large-scale workflows, increasing efficiency and reducing human error. Imagine free quality control software that closes the gap between the digital video novice and the digital video expert, elevating the quality of work being performed at a range of cultural heritage institutions.

The QCTools project is far closer to reaching these goals than one might expect; it is poised, ready to respond to the increased demands of audiovisual preservation.

While audiovisual materials of all kinds make up an ever-increasing part of the archival and cultural record, a false sense of dormancy masks an inescapable inevitability (of degradation, obsolescence, and loss) in many contemporary audiovisual archives. Indiana University Bloomington, an exemplar in the realm of campus-wide commitment to the cause of audiovisual preservation, offered a dire forecast in *Meeting the Challenge of Media Preservation: Strategies and Solutions*, a

2011 report detailing its multi-year effort to identify and preserve over 560,000 endangered audio, video, and film assets:

Media archives have reached a critical point in their history marked by the simultaneous deterioration of unique original materials, the development of powerful new digital technologies, and the consequent decline of analog formats and media. Rapidly advancing obsolescence—of playback machines, spare parts, technical expertise, tools, and formats—combined with degradation of carriers multiplied by large numbers of archival recordings have resulted in a necessary *race against time* to preserve important holdings...It is now widely thought that a fifteen- to twenty-year window of opportunity exists—even less for some formats—before the combination of degradation, obsolescence, and large numbers makes it *either impossible or prohibitively expensive* to do this work (24, emphasis added).

One could object to the specificity of these predictions, or perhaps the doomsday apocalypticism of the sentiment, IU's Mike Casey would likely push back, pointing out two indisputable facts: (1) tapes *are* degrading, and “there is no guarantee that future playback will achieve the same fidelity and accuracy as playback today;” and (2) “the work ahead to digitally preserve media recordings is massive, and preservation strategies must scale to incorporate very large numbers” (15).

But for institutions that are fighting for every preservation dollar, the challenges of “scaling up” can seem insurmountable. With continued support, QCTools will evolve to meet these demands, offering in-depth reporting that will democratize access to the tools of large-scale digitization. The future of QCTools will include batch processing, user-defined thresholds for quality, and various visualizations that allow for the easy identification of suspicious files. BAVC will also continue pursuing QCTools capture functionality, work that began as part of the Knight Foundation's Prototype Fund in the fall of 2014. The shift from Apple's Final Cut 7 to Final Cut X was a rude awakening for the preservation community, a reminder that tape-based workflows have become as obsolete as the tapes themselves. QCTools can step in and fill this gap, bringing control to an earlier stage of the digitization process.

Projects such as QCTools emerged out of a sense of shared duty and responsibility, a recognition that the quality of the digital files we will be caring for over the long-term—until we pass that baton on to future generations—will largely be determined by our actions in this arena. Will we step up to make the twin pillars of quality and scale attainable, or will we allow them to remain out of reach, the domain of the fortunate few? QCTools provides an important vehicle enabling us to ensure the quality of the digital files being created to preserve our video and audio heritage. At the same time, it provides the ability for many more people to engage effectively in this essential and critically time-sensitive preservation effort.

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