Through the Light Beam:

Preserving the Crazy Films of François Miron

by

Alyosha Nowlin

A thesis submitted in partial fulfillment

of the requirements for the degree of

Master of Arts

Moving Image Archiving and Preservation Program

Department of Cinema Studies

New York University

May 2022

ABSTRACT

This thesis outlines a preservation strategy for six short works by Canadian experimental filmmaker François Miron. Efforts to preserve these 16mm motion-picture film prints began in 2018, with the production of digital surrogates delivered to the filmmaker. No further preservation activities were pursued at that time, and it has since become clear that a number of decisions made in the initial processing of these files should be revisited. Image sequences were captured and stored in a proprietary file format, and cannot be processed in an open-source software environment, posing a number of challenges for digital preservation. This project will address previous errors, and implement an improved model for the preservation and collection of Miron's selected oeuvre. The project's main preservation activities will involve processing these raw image sequences from their proprietary format into an open-source preservation master format, and creating derivatives for production use and online access. The work will follow a *microservice* model, identifying and applying discrete, independent tools, and using them interactively in a manner tailored to the project's objectives. Conversion to an open-source format will compress the raw image sequences without loss, and facilitate their processing in a wider variety of preservation architectures. In addition to these preservation and access goals, deliverables will be prepared in BluRay format for collectors, and in DCP format for festival exhibition. The project will ensure that the filmmaker receives high quality copies of his works, and that the files may be preserved at a collecting institution. Releasing the artist's films in non-archival formats[1] will enable access for festival audiences and the underground film community more broadly. Selected by the filmmaker for a decade-long retrospective, these six films comprise the finest of Miron's optical printing experiments.

---

[1] That is, BluRay and DCP.

PART I: ARTIST'S BIOGRAPHY 1

PART II: A BRIEF HISTORY OF AVANT-GARDE FILM 4

PART III: WORKS SELECTED FOR PRESERVATION 8

PART IV: PROJECT OVERVIEW 11

PART V: PRESERVATION OF MOTION PICTURE FILM 12

- 5.1 Photochemical Duplication 12
- 5.2 Digital Reproduction 14
- 5.3 Automated Restoration Tools 15

PART VI: ETHICS 16

PART VII: METHODOLOGY 22

- 7.1 Proprietary vs. Open-source Software 22
- 7.2 Monolithic vs. Microservice Architectures 24
- 7.3 Command-line Interface vs. Graphical User Interface 25

PART VIII: PROJECT DETAILS 26

- 8.1 CRI to DPX 27
- 8.2 DPX to FFV1/Matroska Preservation Masters 29
- 8.3 ProRes Mezzanine Files 36
- 8.4 H.264/MP4 Access Derivatives 37
- 8.5 AVID/MXF Production Masters 40

PART IX: QUALITY CONTROL AND METADATA GENERATION 42

PART X: ARCHIVAL PACKAGING AND STORAGE 49

PART XI: DIGITAL POST-PRODUCTION 51

PART XII: DISTRIBUTION AND EXHIBITION 54

- 12.1 Digital Cinema Package 54
- 12.2 BluRay 65

CONCLUSION 67

PART I: ARTIST'S BIOGRAPHY

François Miron is a filmmaker and professor at the Mel Hoppenheim School of Cinema in Montreal, one of Canada's largest film schools. He has been awarded the "Prix des arts et des lettres du Quebéc", won "Best Experimental Film" at the Ann Arbor Film Festival, and received a Juno Award for the cover of Arcade Fire's "Neon Bible" album, lauded by *Rolling Stone* magazine as one of the five best album covers of 2007.[2] His films have been used in ambitious concert light shows, including an early performance by Godspeed You Black Emperor.[3] Miron has screened his works at dozens of film festivals in Paris, Vienna, Hamburg, New York, Chicago, Los Angeles, Toronto, and Montreal, to name a few. His films are held at La Cinémathèque Quebécoise, the Paris Modern Art Museum, the Canadian Filmmakers Distribution Center, and the Canadian Film Archives. A "master of the optical printer"[4] Miron taught a renowned optical printing class at Concordia University, and has been making films for over three decades.

As a teenager Miron visited New York City, where he first encountered experimental cinema while waiting in line for a musical performance. "This dude came out, and he's like 'don't go in there. That's…that's a crazy film, man.'"[5] François walked in, despite the warning. The picture was Paul Sharits' dual projection film *Razor Blades,* and inspired Miron to begin experimenting with Super 8 film. These early experiments led to a BFA in Film Production at Concordia, where Miron first obtained access to a JK optical printer.

---

[2] "Weekend Rock List: Best Albums Covers of 2007," *Rolling Stone* online, December 28, 2007.
[3] François Miron, interview by Jack Johnson, *Flake,* KSLO Radio, 2002.
[4] Michael Zryd, "A Short Institutional History of Canadian Experimental Film," in *Moments of Perception: Experimental Film in Canada,* ed. Jim Shedden and Barbara Sternberg (New Brunswick: Goose Lane, 2021), 146.
[5] François Miron, in discussion with the author, December, 2021.

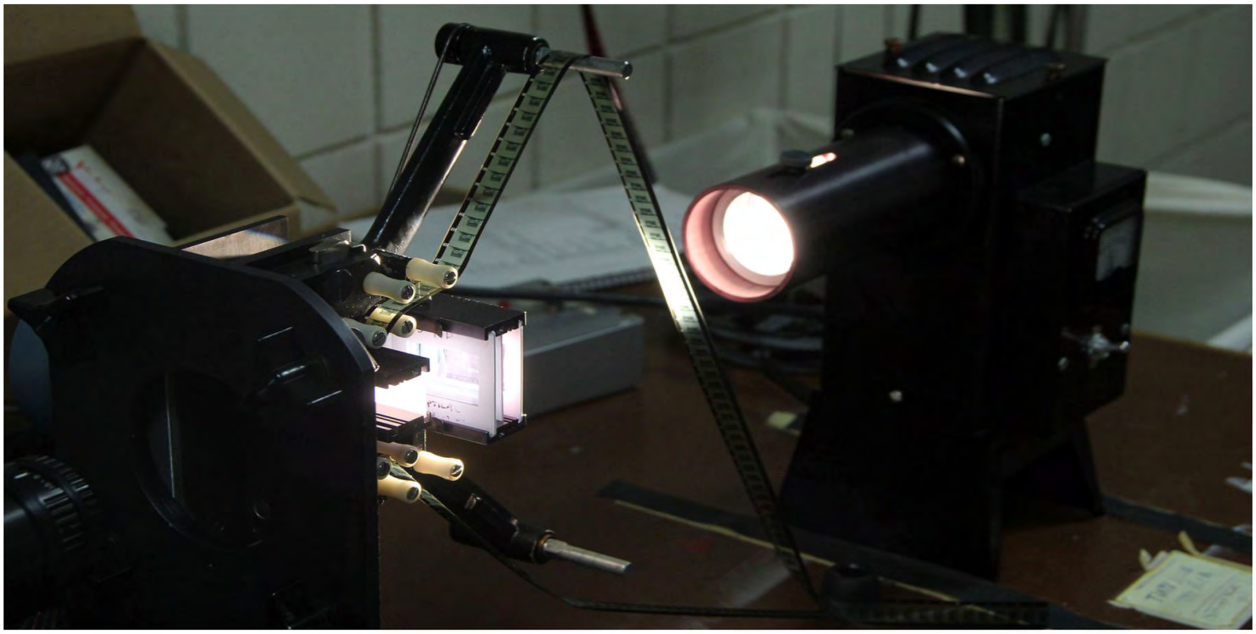


Figure 1. JK Optical Printer (University of Iowa)

"They're notorious to have problems, and we were adding problems […] you could only do, I don't know, thirty seconds without the machine fucking up".[6] Collaborating with friend Mark Nugent, Miron's optical printing work at Concordia eventually earned him a full merit scholarship to the School of the Art Institute of Chicago in 1987.

It was during Miron's years in Chicago that he produced *What Ignites Me, Extinguishes Me,* as well as the dual-projection film *Dismal Universal Hiss.* At the Art Institute, he worked with an Oxberry 1600 optical printer. "*What Ignites* was shot in Plus X and Tri X reversal B/W film, it was then printed with intermediate film 7272 and printed on 7384, the originals were shot with a Bolex R5, the printer used for effects was an Oxberry".[7] He earned his Master of Fine Arts degree in 1990.

---

[6] François Miron, in discussion with the author, December, 2021.
[7] François Miron, email message to author, January 23, 2022.

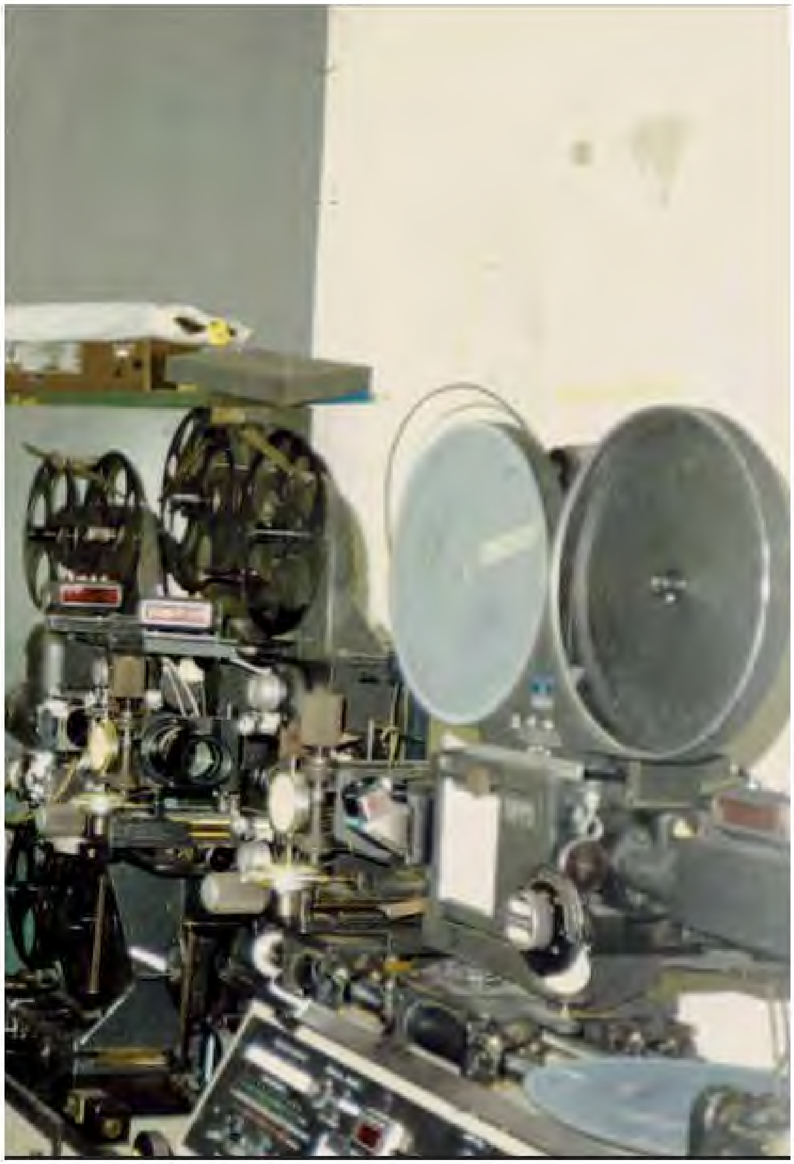


Figure 2. Oxberry 1600 optical printer (Desrosiers)

After leaving the Art Institute, Miron moved to San Francisco to work at Interformat, where he used an Acme optical printer, and a more sophisticated Oxberry machine. “[It was] a quadra-beam Oxberry with everything motorized on it. [That machine] could have done the end sequence of *2001*”.[8] Returning to Montreal in the early 1990s, Miron was given a defective JK optical printer by a friend, and, with some tinkering, was able to complete the award-winning

[8] François Miron, in discussion with the author, December, 2021.

Evil Surprise. [9]

"*The Evil Surprise* was shot mostly with 7248 Eastman film, 7362 and 7369 Hi-Con was used to create the mattes, and the film was printed onto 7386, this film was done with a J/K Optical Printer and assembled together at the NFB with a Bell and Howell contact printer".[10] Miron was also employed at Film Optical/Luminifex, where he worked on personal projects after hours with an Oxberry 1900. "That very printer ended up being donated to Concordia so I used it (and students used it) to do optical printing films, I was teaching the class for like 20 years, but everything switched to digital so the class ended".[11] Since then, Miron has continued to teach digital filmmaking courses but has made the shift reluctantly: "I never actually transitioned to video, I hate video. What we have now as an acceptable replacement for film is digital cinema. Once the "video" became hi-rez and was frame by frame and approached film aesthetics and frame rates etc., I became OK with it, I still have my issues".[12]

PART II: A BRIEF HISTORY OF AVANT-GARDE CINEMA

Production of films by artists, towards purely artistic ends, was discussed by Futurist, Dadaist, and Constructivist groups as early as 1909.[13] *Non*-filmic Cubist experiments, pioneered by Braque and Picasso, held significant influence during the formative years of 'film-as-art' in Europe, until at least the mid-1920s. Referred to by the painter Derain as a mode foregrounding "deliberate disharmonies", the disjointed language of Cubism and Dadaism paralleled the growing use of dissonance in literature and music in the early 20th Century. An "art of fragments", Cubism is known for "depicting objects from a sequence of shifting angles and then

[9] François Miron, email to Walter Forsberg, December 3, 2021.
[10] François Miron, email message to author, January 23, 2022.
[11] François Miron, email to Walter Forsberg, December 3, 2021.
[12] François Miron, in discussion with Clint Enns, 2005.
[13] A.L. Rees, *A History of Experimental Film and Video: From the Canonical Avant-Garde to Contemporary British Practice* (London: British Film Institute 2011), 22.

assembling images by a collage of [...] materials".[14] Emerging theories of perception and time as manifest in art, as well as the growing popularity of cinema generally, led artists to "put 'paintings in motion' through the film medium".[15] Such tendencies are central to Miron's experiments.

The origins of early art cinema are truly diverse and not simple to outline briefly. Emerging mostly from Europe, some seminal abstract films include *Anemic Cinema* (Duchamp 1926), *Ballet Mecanique* (Leger; Murphy 1924), and Surrealist horror titles such as *Un Chien Andalou* (Bunuel, 1929). Also canonized are such 'absolute films' as *Rythmus 21* by Hans Richter (1921), and Viking Eggeling's *Diagonal Symphony* (1924). The concept of the avant-garde or art film, first in Europe and later in the USA, connected those factions of artists "opposed to mass cinema".[16] Out of the American experimental scene came now-classic works of pop-fetishism, such as *Scorpio Rising* (Kenneth Anger, 1963), and structuralist, psychedelic 'flicker' films like *T,O,U,C,H,I,N,G* (Paul Sharits, 1968). From Oskar Fischinger to Maya Deren, Stan Vanderbeek to Stan Brakhage, the 20th century saw a steady increase in the production of film-as-art, and new opportunities were emerging for film artists.

The National Film Board of Canada (NFB) subsidized a number of renowned experimental films and filmmakers during this time. One is Arthur Lipsett, who joined the NFB in 1958 as an editor, and soon began creating film and audiotape collages assembled from fragments discarded in the editing rooms.[17] By scrambling and descrambling images and sounds, his collage films, such as *Very Nice, Very Nice* (1961), straddled the "multifaceted 'image

---

[14] Ibid

[15] Ibid

[16] A.L. Rees, *A History of Experimental Film and Video: From the Canonical Avant-Garde to Contemporary British Practice* (London: British Film Institute 2011), 33.

[17] "Arthur Lipsett Biography," National Film Board of Canada, accessed February 20, 2022.

realities' of modern life and effectively confound[ed] the codes of the actual".[18] For Lipsett, perception, affect, sensation and semiotics are connected through what he termed the 'Nexus' of the visual image.[19] Lipsett's montage experiments foregrounded thought as expressed through image --- meaning as revealed through the layering of picture and sound over time.[20] Another pioneer at the NFB was Norman McLaren, who assembled the first animation team there, and innovated with paper cut-outs, systematic cross-fading, and optical printing techniques. In *Begone Dull Care* (1949), McLaren was an early adopter of painting on film "as if it were a long, thin canvas".[21] Synchronized to music by Oscar Peterson, "images and music interact through a network of associative connotations that reveal their essence, their rich texture, patterns and energy".[22] Blessed with the endorsement of public institutions like the NFB, the Canadian experimental film scene, in its own way, flourished throughout most of the 20th Century. Into this already fertile and imaginative history, François Miron emerged as a singularly innovative experimental film artist.

Working in the tradition of the avant-garde films of the 1970s, Miron lists Michael Snow, Karen Aqua, Craig Baldwin, Peter Kubelka, Deborah Stratman, and Hollis Frampton as influences. While Pat O'Neill influenced his optical printing experiments, it is without a doubt American filmmaker Paul Sharits who has most significantly and consistently shaped Miron's artistic vision: "this experience changed my life and my mind".[23] Inspired by Sharits' dual-projection flicker films, Miron set up multi-projection screenings at cinemas and galleries in San

---

[18] David R. Cole and Joff P.N. Bradley, *A pedagogy of Cinema* (Rotterdam: Sense Publishers, 2016), 36.
[19] Ibid 41.
[20] Ibid 36.
[21] "Norman McLaren Biography," National Film Board of Canada, accessed February 20, 2022.
[22] Ibid
[23] François Miron, in discussion with Clint Enns, 2005.

Francisco during the 1990s; his early works use "altered perception and psychedelic experience as code, as a style of language".[24]

Films selected for this thesis project make innovative and ambitious use of optical printing technologies. As Miron explains: "Optical printing is a technique of image manipulation; it is basically re-photographing other images, already processed".[25] Optical printers can *isolate* images and *layer* them to create abstract, and unreal scenes in which "one color behind another creates color harmonies and resonance".[26] "It's a really good tool to create surreal things […] you can push it really far, where you get color separation".[27] Where Miron's found-footage collages layer images, sound and text to subvert social conditioning, his original cinematography is more fluid and painterly.[28] Both modes rely heavily on the use of optical printing techniques, and the selected films showcase ten years of Miron's work in this style.

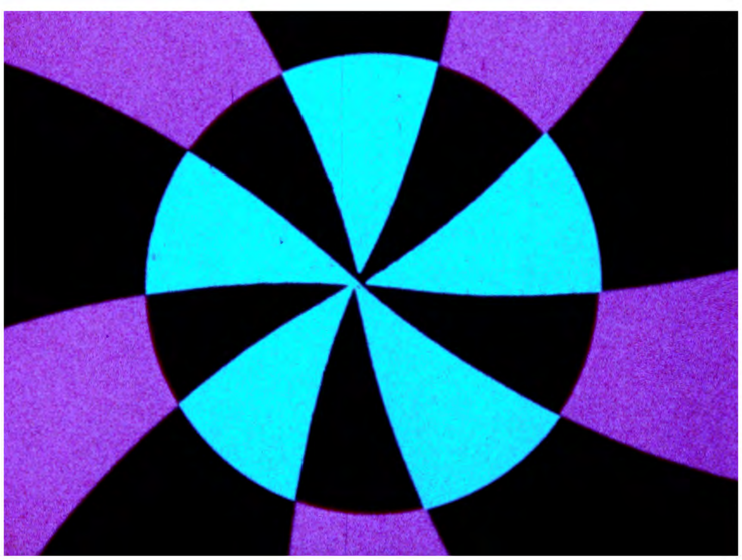
[24] Ibid
[25] François Miron, interview by Jack Johnson, *Flake,* KSLO Radio, 2002.
[26] François Miron, in discussion with Clint Enns, 2005.
[27] François Miron, interview on KHUM Radio, 2002.
[28] François Miron, interview by Jack Johnson, *Flake,* KSLO Radio, 2002.

PART III: WORKS SELECTED FOR PRESERVATION

The Evil Surprise (1994, 16mm, color, 15 min, sound, 24 fps)

In the shape of an irreverent conspiracy theory, "ten pseudo-educational sequences" deconstruct the techniques and teleology of science and medicine.[29] As recycled classroom film fragments attack the central and peripheral nervous systems, a "shapeless and frenzied gangrene" eats through layers of stock and emulsion, ever deeper until the sonic boom of grinding guitars reaches its zenith and concludes the film.[30] "Wow! This place is really groovy!"[31]

The Gap in the Curtain (1989, 16mm, color, 5 min, silent, 18 fps)



[29] Etienne Desrosiers, *François Miron: Films Experimentaux,* (Montreal: Filmgrafix, 2010), 21.
[30] Ibid
[31] The Evil Surprise (Miron 1994).

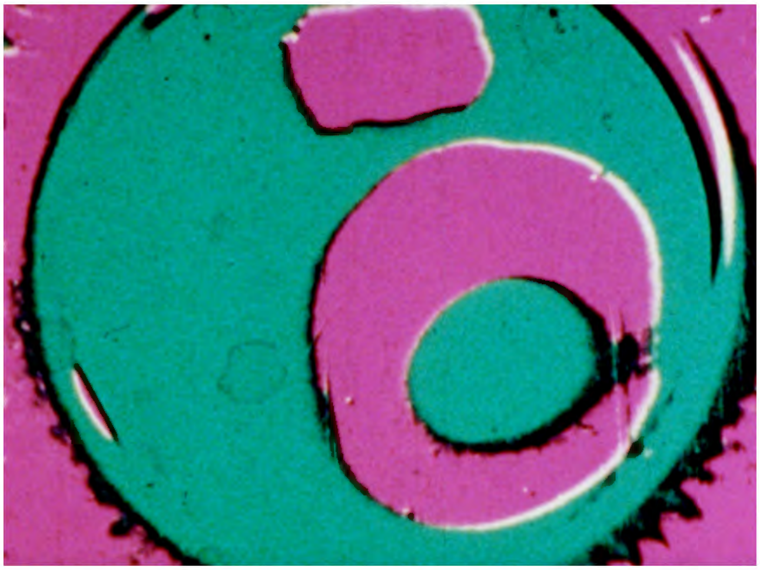
Short sequences of flickering circles, squares and spirals in black, red, yellow, violet, cyan and magenta. Meant to be viewed at 18 fps, the film is a "study of visual perception based on the persistence of vision, and a tribute to the work of American filmmaker Paul Sharits".[32] This film has been encoded and preserved at its native frame rate of 18 fps, which is needed to view the film as intended, and has also been duplicated at the rate of 24 fps, as required by DCI and BluRay disc standards.

La Poursuite de l'Art / The Quest (1999, 16mm, 10 min, sound, 24 fps)

Digitally remastered from a composite work print, this piece celebrates creative energy as an antidote to consumer alienation.[33] A jazz soundtrack shadows *le savant fou* through nighttime lights, as the lines between art, chemistry, color and Kraft Dinner are blurred.

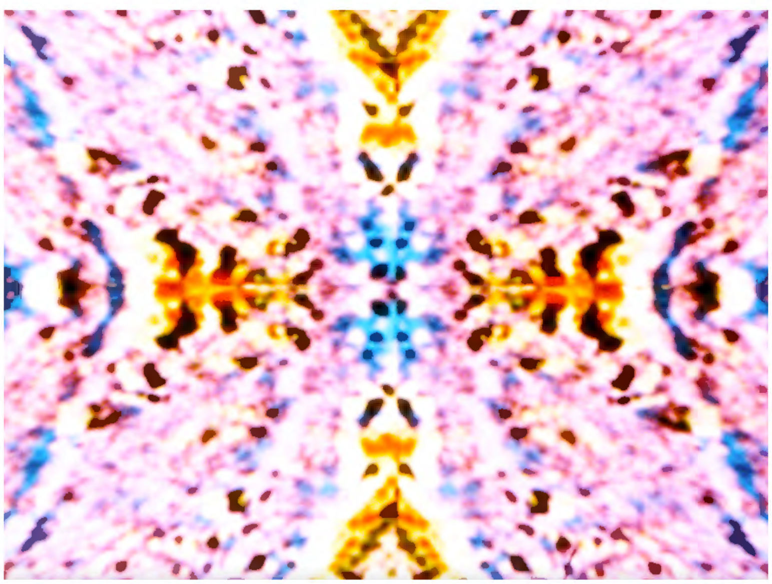
[32] Etienne Desrosiers, *François Miron: Films Experimentaux,* (Montreal: Filmgrafix, 2010), 19.
[33] Ibid 22.

The Square Root of Negative Three (1991, 16mm, color, 8 min, sound, 24 fps)



Dark noises from Coil's album *Horse Rotorvator* accompany an advertisement for *Ka-bala,* "the mysterious game that foretells the future".[34] Eyeballs scan a "barrage of optical effects"[35] applied to sterile laboratory scenes.

The Ultraworld (1997, 16mm, color, 17 min, sound, 24 fps)



Earth, Fire, and Water, the terrestrial elements merge gradually into Rorschach-inspired color abstractions, intercut with boreal vistas and close-ups of flora and fauna. What begins as a serene

[34] Square Root of Negative Three (Miron 1991)
[35] Etienne Desrosiers, *François Miron: Films Experimentaux,* (Montreal: Filmgrafix, 2010), 20.

lakeside sunrise grows progressively unhinged until the viewer is gently returned to a peaceful repose at the shore.

What Ignites Me, Extinguishes Me (1990, 16mm, color, 9 min, sound, 24 fps)

This is an "industrial self-portrait" where crumbling forces of production symbolize the artist's mental state. Filmed in the abandoned mills of South Side Chicago - where packs of feral dogs threatened production - *What Ignites Me* opens with its namesake quote from William Shakespeare's Pericles: "Quod me alit, me extinguit."[36]

PART IV: PROJECT OVERVIEW

The following work will plan and implement a preservation strategy for the six selected works. In 2018, enhanced, digital surrogates were produced, and delivered to the filmmaker. Films were scanned by Alyosha Nowlin, a member of Concordia University's Global Emergent Media Lab in Montreal, Quebec, using a BlackMagic Cintel film scanner and the non-linear editing (NLE) suite DaVinci Resolve. Preservation Master files were stored in a proprietary Cintel Raw Image (CRI)[37] format, Production Masters were cropped and subjected to color-correction, and no access copies were produced. One hard disc drive containing Production Masters was delivered to the filmmaker, and three additional hard drives, containing both raw

[36] Ibid
[37] See Appendix I

sequences and Production Masters were kept by the digitizing technician. Since then, no further preservation activities were pursued, and it has become clear that a number of decisions made in the initial processing of the files should be revisited.

First, the CRI file format is proprietary, and can therefore not be used outside of a DaVinci Resolve environment. Second, Production Masters were graded, cropped, and delivered in the Apple ProRes 4444 XQ file format, which is a needlessly large file size for production use. Moreover, no unrestored Production Masters were created: some photographic information was lost prior to delivery, and these files do not offer a neutral starting point for future work, should that become necessary. No preservation plan was created at the time of delivery, no backup copies are possessed by the filmmaker, and files are not held on redundant storage. Files were not delivered in the requested format of Avid DNxHD, no plans were made to donate copies to a collecting institution, and copies were not written to Linear Tape Open (LTO) format for long-term digital preservation. This project addresses these errors, and implements a new workflow for the preservation of Miron's works. What follows is a contextual introduction and detailed description of this improved work model as applied.

PART V: PRESERVATION OF MOTION PICTURE FILM

Meaning different things to different people, film preservation has transitioned "from a fringe activity [...] to one that has become fully integrated into both commercial business models and public policy".[38] As the popularity of cinema grew over time, so too did the nascent movement dedicated to preserving films, providing exhibition space, and encouraging the care and study of moving images as art. Following the formation of the International Federation of Film Archives (known by its French-language acronym, FIAF) in 1938, the number of publicly-

[38] Leo Enticknap, *Film Restoration: The Culture and Science of Audiovisual Heritage* (New York: Palgrave Macmillan, 2013), 46.

funded national archives grew globally, and it was from within this sector that "the set of practices that would now be recognized as film preservation activity effectively emerged".[39] Distinct from all other cultural heritage fields, "where a tradition is already established" and involves work on an original artefact, creating motion-picture preservation elements involves the process of duplication: "the output is always a duplicate or surrogate".[40]

5.1 Photochemical Duplication of Motion Picture Film

Photochemical duplication has historically been the standard approach for both the production of preservation elements, and for the restoration of motion picture film. Photochemical duplication of motion picture film is accomplished with a printer, a "device that re-photographs the image from an existing processed film element onto unexposed, raw filmstock".[41] Simply put, the printer copies the element to another roll of film, and in some circumstances changes its visual characteristics in the process.[42]

There are two main types of film printer, both of which use a combination of optics and mechanics to duplicate source elements to destination. In a standard optical printer, an image of a source element is *projected* through a lens onto the adjacent emulsion of the destination film, without either element coming in contact with the other. This is a process of re-photographing processed film. Modifying aperture and depth of field is done in similar fashion to other cameras and projectors, enabling (among many things) the duplication of one film gauge to another, with the disadvantage of inevitable loss of definition and contrast.[43] Using a contact printer, however, the source and destination film elements are placed in direct contact, emulsion-to-emulsion, and

---

[39] Ibid 58
[40] Ibid 71
[41] Ibid 96
[42] Ibid
[43] Ibid 97

exposed to a light beam of controlled intensity, temperature and duration. While contact printing offers significant advantage in reducing generational loss, it comes with the drawback that duplication is impossible between different gauges, and shrunken source elements are troublesome to copy.[44]

Photochemical printers are further subdivided by their mechanical action, which may be either stepped or continuous. In continuous motion printing, both the source and destination elements proceed continuously past the illuminated aperture to be exposed, enabling rapid duplication in a single pass. This method has the disadvantages of potential stability loss, “without the ability to mitigate even slight shrinkage”.[45] In a step printer, on the other hand, the source and destination elements are passed *intermittently* before the light source “with each frame being duplicated as a discreet exposure”.[46] This process, while time-consuming, nonetheless enables exposure settings to be modified shot by shot, and frame by frame.[47] Whichever method is used, the result of successful photochemical preservation is a duplicate of the source image on film.

5.2 Digital Duplication of Motion Picture Film

In its essence, the duplication of film images by digital means consists of capturing an *electronic* representation of the source image, modifying it (if desired) using computer software, then outputting the resulting digital file(s) onto whichever media formats are sought for access purposes.[48] “The first stage in the process is the creation of the initial representation which is done with a motion picture film scanner”.[49] The scanner can be understood as the digital

---

[44] Ibid
[45] Ibid
[46] Ibid
[47] Ibid
[48] Ibid 105
[49] Ibid

equivalent of an analog motion picture film printer, and captures information using a digital sensor, most frequently a Charge Coupled Device, or CCD, not unlike those used in digital cameras. CCDs "generate an electrical signal that varies in power" according to their exposure to light[50] and, like destination stock in a printer, record an image based on the characteristics of the light received.

Compared to its photochemical counterparts, the modern film scanner has "a vastly simplified film transport mechanism", enabling the duplication of film elements with defects that would either require extensive repairs prior to printing, or be so severe that they made photochemical duplication impossible. For this reason, the majority of physical film repair and master element assembly required for photochemical duplication is unnecessary in a digital workflow. Images are captured frame by frame, and "the source elements from which the restored film will be constructed can be scanned separately".[51] The scanning process itself is essentially determined by two variables: the color and resolution characteristics, and whether image control will be performed during the scan, "or as a software function afterwards".[52]

The file format most often used in digital film preservation is the Digital Picture Exchange (DPX) format, "a specification that began life as the proprietary format for the Kodak Cineon system, and was then later adopted and developed further by other scanner and software manufacturers".[53] Designed with a number of features specifically tailored to restoration, DPX has the capacity to encode the specific light-sensitivity characteristics of the emulsion scanned (gamma), and is compatible with the application of a Look Up Table (LUT), a type of calibration

---

[50] Ibid
[51] Ibid 106
[52] Ibid 107
[53] Ibid 111

data that allows consistent appearance across various displays.[54] DPX moreover enables the creation of information about each one-frame file, for example, the title of the film, the reel number, the record number, and color space. Known as 'metadata' this information can be embedded within the DPX file header itself, to assist with project management and validation checks.[55] A moving image preserved in the DPX file format will be represented as a lengthy sequence of still images and will, unless treated, exhibit most of the defects present in the source film.

5.3 Automated Restoration Tools

A number of automated digital tools exist to mitigate common defects in degraded motion picture film without human supervision. These tools look 'across frames' for similar defects and, as their name implies, automatically apply a solution to any detected errors.[56] Despite the significant gains offered by such technologies in terms of error-per-second detection and correction, the electronic algorithms (sequences of rules applied by the machine to identify defects) are hardly infallible.[57] The process of "comparing the suspect artifact being analyzed with information about known types of defect and the photographic information surrounding it"[58] can reduce work-time in eliminating unwanted artifacts, but can also erroneously remove key imagery when left to perform its task without human supervision. While automated tools are attractive from an economic standpoint, promise a faster, less-involved restoration process, and grow more accurate with each new generation of hardware and software, a better result is still obtained by using tools individually and interactively. Human intuition, and experimentation

[54] Ibid
[55] Ibid
[56] Ibid 111;112
[57] Ibid 112
[58] Ibid

with different tools, offers a more precise correction, tailored to the film at hand and to the tastes of the filmmaker.[59] For these and other reasons, discourse within cultural heritage professions on the use of digital restoration tools, and indeed, whether digital capture of motion picture film constitutes preservation at all, remains contentious.

PART VI: ETHICS

Writing in 2002, Jon Gartenberg examines the technical and ethical challenges unique to the preservation and restoration of experimental motion picture film "such as the precarious process of restoring images which contain both intentional and unintentional damage".[60] Gartenberg describes "five guiding principles" to bear in mind while preserving and/or restoring experimental films, such as Miron's. First, he says, anyone preserving an experimental film has a responsibility to know the genre's history, especially "in relation to the dominant mode of commercial narrative cinema".[61] Understanding this history makes possible a deeper appreciation of the techniques of production, and informs future preservation decisions. "First and foremost is the fact that these films resemble the work of fine artists, paintings for example".[62]

Second, it is crucial to establish a working collaboration between the archivist, the laboratory personnel, and the filmmaker, whenever possible.[63] Working in dialogue with the creator of the works leads to valuable insights into the circumstances surrounding their creation. Certain aesthetic choices made in production may have been deliberate, or based on the artist's living arrangements or financial situation at the time, and such factors ought to be considered and

---

[59] Ibid 113
[60] Jeffrey Lauber, *History and Ethics of Film Restoration,* (MA Thesis, New York University, 2019), 38.
[61] Jon Gartenberg, "The Fragile Emulsion," *The Moving Image*, no. 2 (2002): 143.
[62] Ibid
[63] Ibid 144

discussed as part of the preservation work.[64] In short, it is important that the preservationist consider the artist's "life and career as part of a unique culture".[65]

Third, says Gartenberg, the preservationist needs to focus on the filmmaker's artistic process. "In approaching the preservation of experimental works, decisions must be tailored in harmony with the artist's creative process and intent, not just with the product", i.e., the finished film.[66] It is essential that no alterations be made to the source material that would dislocate the piece from its creator's working process.

Next, the preservation staff should document the specific version of the work produced. Unlike commercial cinema, where "the film is set in a fixed form that allows the object to be massively distributed in order to generate maximum profits", experimental works are not infrequently exhibited in more than one version, and the potential for such evolution should be determined and considered before initiating restoration.[67] "We are working not only to preserve the physical materiality of experimental film, but also to inscribe the circumstances surrounding its exhibition".[68]

Finally, and despite the experimental genre's characteristic opposition to the commercial mainstream, efforts should be made to imitate the economic models of the commercial film industry. Experimental films are too often "lost between the profit potential of the commercial film industry and the museum-gallery-collector fine art industry".[69] To reintegrate these works into the broader culture, it is necessary to address legal issues, such as determining copyright issues related to the artist's estate; storage concerns, such as relocating original source elements

[64] Ibid
[65] Ibid
[66] Ibid
[67] Ibid 145
[68] Ibid
[69] Ibid 147

from personal possession and film labs to qualified archives; cataloging processes, to help assemble a definitive filmography; preservation programs, to create either photochemical master elements, or digital surrogates; distribution concerns such as the creation of DCPs and/or new release prints; and finally, exhibition questions such as how to curate screenings and establish a system of study and research.[70] These six aspects of management, adopted by the commercial film industry to increase intellectual control, ensure compliance with intellectual property laws, and maximize profitability, are no less essential in the preservation of marginal genres like experimental film.

While Gartenberg's cultural and aesthetic approaches apply to experimental works generally, his writing (from 2002) is primarily concerned with photochemical duplication. Great strides have since been made in the digital restoration of motion picture films, and in light of these new developments, it is worthwhile to reexamine the ethics of film preservation from a more current perspective. One recent and thorough examination of the ethical discourse surrounding film restoration is by New York University Moving Image Archiving and Preservation (MIAP) alum Jeffrey Lauber. In *History and Ethics of Film Restoration,* Lauber offers a review of theoretical conversations on the subject, from the 1980s until more recently, uses case studies to demonstrate how various challenges have been addressed, and proposes a framework for the future discussion of ethical film restoration practices. Most relevant to this thesis is Lauber's discussion of digital film restoration, which, in this project, has informed a number of the practical decisions made to preserve and restore Miron's work ethically.

According to Lauber, "the era of digital film restoration begins in earnest in 1993", with the development of Kodak's *Cineon* system - a monolithic system including a film scanner,

[70] Ibid

computer workstation, and film recorder for production purposes".[71] Due to the enormous cost of such systems, digital restoration of film remained out of reach for most studios, not to mention non-profit archives, until well into the 2000s. "It was around the mid-2000s that digital restoration tools began to reach a level of affordability suitable for non-profit contexts, though still restricted" to only the most prestigious projects.[72] By the second half of the decade, however, an ever-growing demand for digital restoration tools catalyzed the development of "various products designed for and marketed to film archives".[73] Since approximately 2010, the digital restoration of motion picture film has become "practical, affordable, and visible enough to be undertaken widely and frequently".[74] While this increased accessibility to high-quality digital film scanners has made possible an enormous number of otherwise-unaffordable film preservation and restoration projects, it has likewise catalyzed renewed ethical debates.

Central to the ethical discussion of digital film restoration is the contested notion of authenticity. As Lauber explains: "digital possibilities for film preservation at large sparked apprehension over whether a digital rendering of celluloid born moving images represents an authentic reproduction of the image both technically and philosophically".[75] A common complaint about restoration software is that the "tools used, and in particular, film grain reduction, change the overall subjective aesthetic of the viewing experience from that of an analogue image to that of a digital one".[76] When restoring digital representations of motion picture film, it is common practice to correct damage accrued over time, while preserving defects

[71] Jeffrey Lauber, *History and Ethics of Film Restoration,* (MA Thesis, New York University, 2019), 16.
[72] Ibid 18
[73] Ibid 18
[74] Ibid 20
[75] Ibid 13
[76] Leo Enticknap, *Film Restoration: The Culture and Science of Audiovisual Heritage* (New York: Palgrave Macmillan, 2013), 116.

inherent to the original production.[77] In the case of experimental films, however, such distinctions are not so easily drawn. For example, Miron's optical printing collages make use of many found-footage elements in various states of degradation. Not only do the defects and damage vary from one element to the next, it is difficult if not impossible to determine how much damage and generational loss were introduced in the montage and optical printing processes. In the context of this project, most artifacts will be considered "defects" rather than damage, and will not be removed digitally.

In those cases when defective and/or damaged elements form an integral part of the original production, some restorers opt not to eliminate damage or defects at all. For example, in dir. Nicolas Ray's 2011 restoration of *We Can't Go Home Again* (1973) "scratches, fingerprints, bad splices, and other signs of defect were left on the footage used to make the negative of the Cannes version. These defects might have been unintentional at the time, but have nonetheless become part of the film's history and aesthetics".[78] Such concerns are of particular importance to experimental films, which pose unique challenges in terms of accurate color representation; in the case of Miron's collages, sequences exhibit an unavoidable imbalance of color, exposure, and framing due to the mixed provenance and use history of the source elements. Because the scanned films were photochemically-graded, positive release or work prints, individual scenes were neither captured nor graded shot-by-shot; instead, one consistent temperature and intensity of light was determined as ideal for each film and used throughout the scanning of each reel, as would be done in a projection setting. Whether the imbalances of exposure, temperature and

---

[77] Jeffrey Lauber, *History and Ethics of Film Restoration,* (MA Thesis, New York University, 2019), 69.
[78] Ibid 72

framing were intentional or not, they represent "important manifestations of the film's original production and its physical state of being"[79], and will therefore be preserved.

Considerations such as these pertain not only to the preservation and restoration of motion picture films, but to their exhibition also, and "the ethical implications of presenting restored moving images should be given the same consideration as those of the restoration process itself".[80] Archival philosophy insists that only by providing access can a preservation project be said to have been completed. "By this logic, no restoration is complete without distribution and/or exhibition".[81] The manner in which a moving image is presented technically (frame rate, format, aspect ratio etc.) is no less important than how it is presented contextually.[82] In spite of the sincere desire to minimize intervention, it is sometimes necessary to modify original specifications in order to conform to current exhibition standards. For example, Digital Cinema Initiatives (DCI) standards stipulate a resolution of 1998x1080 for 2K exhibition, which requires modification of the raw scanner output resolution of 2160x1702. Moreover, DCP demands a frame rate of precisely 24 fps, which, while ideal for most of the works selected, does not allow for the correct 18 fps presentation of *Gap in the Curtain*.

In accordance with the principles put forth by Gartenberg and Lauber, the post-production component of this project will likewise take a minimalist approach to image correction, preserving defects inherent to the source materials, and seek only to optimize the representation of the digital exhibition duplicates. No alterations to the original specifications were made to any Preservation files, be they master or mezzanine. Specifications of exhibition deliverables were modified only when strictly necessary to comply with modern exhibition

---

[79] Ibid 75
[80] Ibid 79
[81] Ibid
[82] Ibid

standards. Preservation Masters were captured full frame, and were not subjected to image modification of any kind; Production Masters were subjected only to data compression and are visually lossless, with no other adjustment applied; access derivatives were subjected to further data compression, presenting a mild reduction in visual detail necessary to reduce online streaming bandwidth demands, and were downscaled to 1920x1080 HD resolution, but were not graded. Finally, exhibition copies, prepared for BluRay and DCP release, were digitally graded, cropped, and otherwise modified to conform to the standards of their respective formats. Different deliverables are intended for different use cases, and each must be prepared according to a specific method if it is to function as intended upon delivery. Using open-source software facilitates this customization.

PART VII: METHODOLOGY

7.1 Proprietary vs. Open-source Software

Whenever possible, this project uses open-source software tools. The term software is a generic name for programs, or sequences of instructions "understandable by a computer's central processing unit" that indicate "which operations the computer should perform".[83] Software is distinguished from the physical media systems on which it runs, known as hardware, and refers instead to programs and data stored in electronic form.[84] The terms open-source and proprietary (often closed-source), when used to describe software, refer to the intellectual property licensing of the source code. Source code is "the version of a software as it is originally written (i.e., typed into a computer) by a human in plain text (i.e., human readable alphanumeric characters)"[85] Where commercial software is almost always closed-source, preventing users from accessing,

---

[83] "Program Definition," *Linux Information Project,* June 8, 2005.
[84] "Software Definition," *Linux Information Project,* November 26, 2005.
[85] Ibid

modifying, or sharing the proprietary code, open-source code is freely available "for anyone to use for any purpose, including studying, modifying, extending, giving away, or even selling".[86] As James Corbly explains:

> Open-source software carries the concept of freeware to its ultimate conclusion. With open-source products, the copyright holder gives others the right to study, modify, and distribute the software free of charge to anyone for any purpose. Quite often, open-source products result from the collaborative efforts of contributors living in numerous locations around the world. Raw program code, along with the compiled program, is available to anyone who is willing to obtain it, scrutinize it, and make additions or improvements to it in the expectation that the combined efforts of many people will result in a product increasingly useful and reliable to end users. Although some open-source products lack documentation, many (if not most) have active user groups or communities which serve as sources of assistance to users.[87]

To be classified as open-source, a piece of software must therefore be freely available, without fees or royalties of any kind; the software may only be distributed as source code for programmers, or as compiled binaries for end users; all users must be permitted to modify the program's code, and all modifications to the source code must be "redistributed under the same conditions as the license for the original version of the software".[88]

The most common license used for open-source tools is the General Public License, first developed by former MIT researcher Richard Stallman in 1989.[89] The GPL license has been repeatedly modified over the years, but remains based on four basic principles:

1. The right of individuals to use software for any purpose;
2. The right of individuals to alter software to meet individual needs;
3. The right of individuals to alter software to share software with others; and

---

[86] "Source Code Definition," *Linux Information Project,* May 23, 2004.
[87] James Edward Corbly, "The Free Software Alternative: Freeware, Open Source Software, and Libraries," *Information Technology and Libraries* 33 (3), 66.
[88] Ibid 66;67
[89] Ibid 67

4. The right of individuals to freely distribute the changes one makes to software.[90]

In accordance with these principles, GPL grants users the privilege to reproduce and distribute copies of a software's code, provided that "each copy displays a copyright notice, a disclaimer of warranty, a copy of the GPL, and GPL notices".[91]

Open-source software development is characterized in large part by its collaborative nature, its community of likeminded developers, and its affordability for small, and otherwise under-funded archives. Transparent, and always being refined, open-source tools offer a level of autonomy and adaptability unrivaled by their proprietary counterparts, and, for this reason, are especially helpful when designing microservice architectures for audiovisual preservation.

7.2 Monolithic vs Microservice Architectures

This project uses a microservice model when selecting appropriate digital preservation tools. As Annie Schweikert and Dave Rice explain in their 2019 publication *Microservices in Audiovisual Archives,* the proper management of archival audiovisual collections demands that appropriate tools be identified and employed to suit the specific needs of the archive and its unique preservation objectives.[92] Any individual or team seeking to locate and utilize the correct tools for their needs may either decide to use a complex all-in-one system, which promises simple efficiency under a single, proprietary model, or instead consider a customized approach in which discrete tools are selected independently for their own focused objectives and "combined into a loosely coupled system" tailored to the archive's needs.[93] These descriptions illustrate the distinction between monolithic and microservice preservation architectures.

---

[90] Ibid 68
[91] Ibid
[92] Dave Rice and Annie Schweikert, "Microservices in Audiovisual Archives: An Exploration of Constructing Microservices for Archival Audiovisual Information," *IASA* 50 (August): 53.
[93] Ibid

Where a monolithic system "may suggest reliability and efficiency, as control of each task is integrated under a single company's umbrella", it may present obstacles when trying to "adapt the architecture to an archive's preferred workflow, or remix the monolith with other, preferred tools".[94] A microservice architecture, by contrast, involves the use of "many tools that accomplish discrete, bounded tasks - each one a 'microservice' - [that] are combined into archival workflows like links in a chain".[95] The customizable nature of microservice architectures requires knowledge of each independent tool and its functions, as well as a "ground-up construction of an archive's workflow".[96] While this approach necessitates greater involvement, a microservice environment "may be easier to independently evolve over time, and may be easier to steer or customize to the unique needs of its collections or its organization".[97] Microservice architectures frequently make use of open-source tools because of the versatility and adaptability of such programs to the archive's unique and evolving needs. In both monolithic and microservice architectures, users interact with computer programs in one of two ways.

7.3 Command Line vs. Graphical User Interface

This project uses both command line and graphical user interfaces to operate software. Most consumer software, and a great many professional programs, are operated using a graphical user interface (GUI), which simplifies and standardizes the use of computer programs, allowing users to manipulate content displayed graphically on a screen.[98] Traditionally, this has been done with a keyboard and mouse, and is the most common manner computers are used in day-to-day settings. DaVinci Resolve, for example, is given instructions by the user through a GUI, but the

---

[94] Ibid 54
[95] Ibid
[96] Ibid
[97] Ibid
[98] "Graphical User Interface," Dictionary.com, accessed February 20, 2022.

actual processes being performed remain opaque. Operating software using a GUI offers predictable functionality according to a standardized set of variables, but limits the user's capacity to customize their workflow.

Operating software with a command line interface (CLI) instead, promises much greater flexibility by allowing the user to interact with the computer using text. The user types specific commands into a terminal window, and the computer executes those commands. The text environment into which the commands are entered is called the shell, which is a program that sends requests to the "core" of the operating system, called the kernel. The kernel is "responsible for allocating time and memory to each program" as requested by the user through the shell.[99] Where operating software with a GUI provides convenience at the expense of control, operating in the command line offers control at the expense of convenience. Using both GUI and command line tools, this project will identify and apply appropriate microservices to process and preserve the digital representations of Miron's films.

PART VIII: PROJECT DETAILS

This preservation plan entails processing the scanned image sequences from their native format into a number of derivative file types, each dedicated to a specific use case. The six films were chosen by the filmmaker in 2018 to compile a BluRay retrospective, and were scanned at Concordia University's Global Emergent Media Lab in Montreal, QC, using a BlackMagic Cintel motion picture film scanner. The Cintel scanner is compatible only with DaVinci Resolve editing software, and the highest quality digital master elements were captured in the proprietary Cintel Raw Image (CRI) format.

---

[99] Kevin Skoglund, "UNIX Essential Training," LinkedIn Learning, accessed February 20, 2022.

8.1: CRI to DPX Conversion

The CRI format, developed by the BlackMagic comapny, is a 12-bit image sequence format in a linear RGB color space and is compressed with neither mathematical nor visual loss.[100] The first process is to encode the CRI sequences into DPX sequences, which are totally uncompressed, and can be processed outside the DaVinci Resolve software environment. Only DaVinci Resolve can perform this microservice, due to the proprietary specifications of the CRI format. Fortunately, the free version of DaVinci Resolve can perform this function.

To convert CRI to DPX, CRI sequences are imported to the Resolve media pool and a timeline is created using the selected sequence.

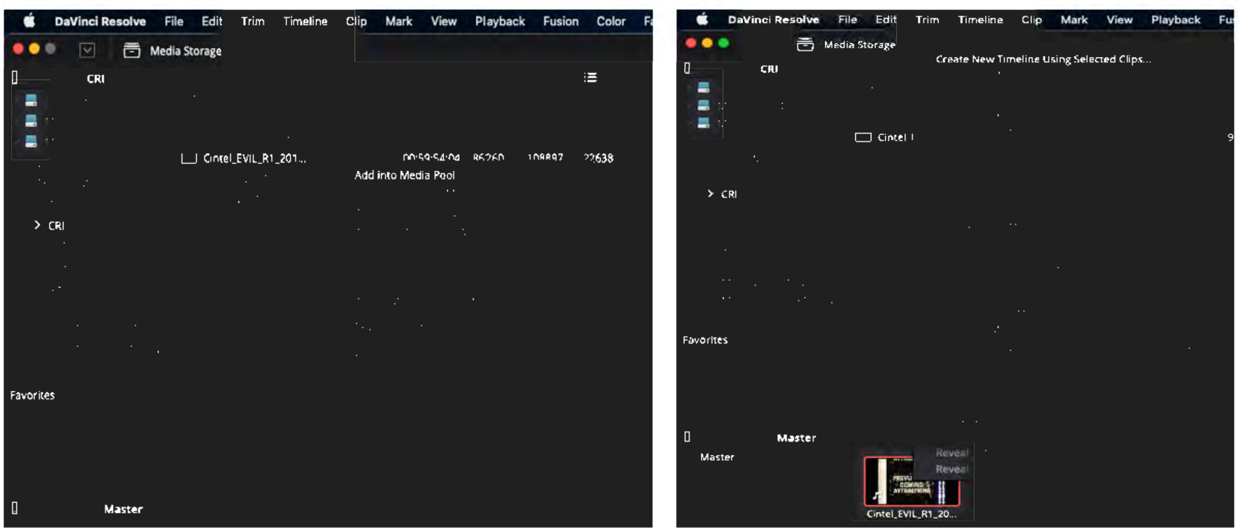


Figure 3. BlackMagic DaVinci Resolve Media Pool and Timeline Setup (Screenshot)

Without making any changes to the image, the sequences are output as DPX according to the desired specifications of 12-bit color depth, in an RGB color space at native resolution of 2160x1702, with a square pixel aspect ratio.

[100] See Appendix I

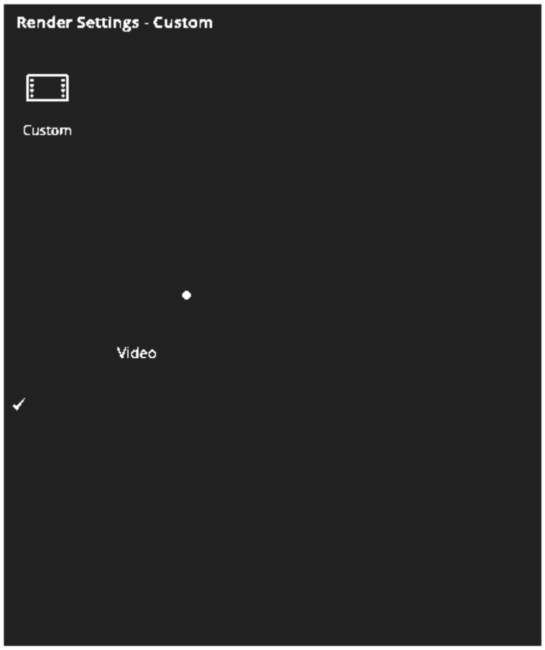


Figure 4. BlackMagic DaVinci Resolve Deliver Settings (Screenshot)

Additionally, options to force data levels, sizing, and debayering to full quality are selected in the software's Deliver pane, to ensure zero loss of information during the render operation.

Figure 5. BlackMagic DaVInci Resolve Force Quality Settings (Screenshot)

The process was repeated for all six films, with each sequence stored in a dedicated folder on a dedicated project drive. Outputting DPX files directly from Resolve, instead of CRI files, makes this step unnecessary, and the process was performed only to retrace initial steps and broaden the range of preservation options. The scanned films have thus been duplicated with zero compression, and can be used in a wide variety of software environments; most importantly, they can be processed using open-source technologies. DPX sequences are, however, enormous in file size, and troublesome to manage, as they put heavy demands on computer processing capacity.

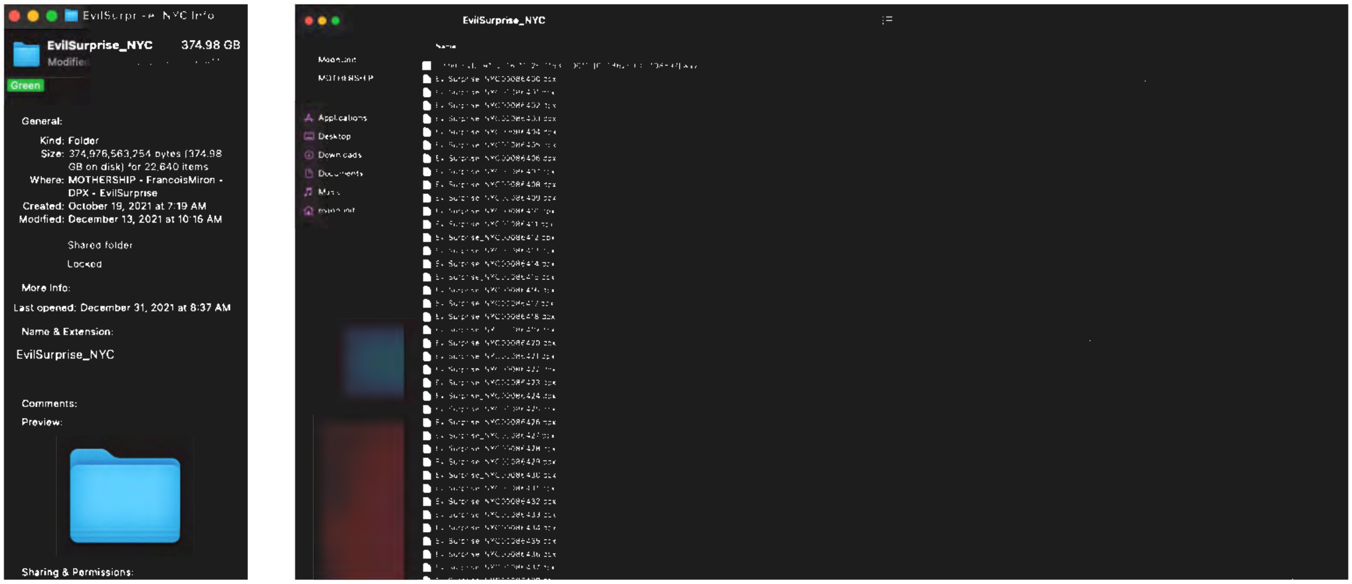


Figure 6. DPX Sequence File Size and Source Folder Item-count (Screenshot)

8.2: DPX to FFV1/MKV Conversion

The solution to this problem is an open-source tool called RAWcooked, which uses another open-source software, FFmpeg, to compress and manage archival image sequences. Developed by the open-source software company MediaArea, RAWcooked encodes uncompressed image sequences into a lossless video stream using FFmpeg; "FFmpeg encodes the audio-visual data into a Matroska container (MKV) using the video codec FFV1, and audio codec FLAC".[101]

FFmpeg is an audio and video conversion software operated through a computer's command line interface, and is able to decode, encode, transcode, multiplex, demultiplex,

[101] "RAWcooked," accessed February 20, 2022, https://mediaarea.net/RAWcooked.

stream, filter, and play a wide variety of audio-visual formats.[102] The basic outline of an FFmpeg operation is illustrated in the following diagram.

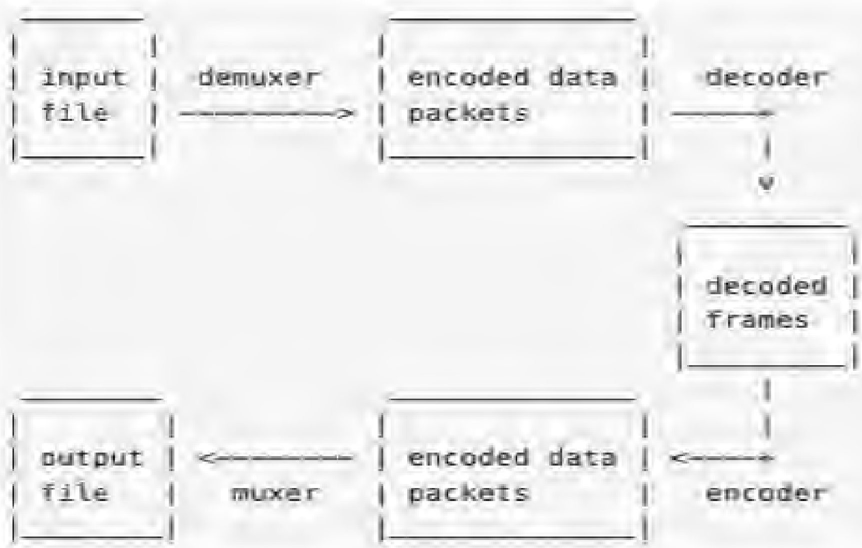


Figure 7. FFmpeg Encode/Decode Operation (ffmpeg.org)

FFmpeg reads any number of input files, which may be modified according to a number of options, and writes any number of output files according to the options specified. In its most basic form, an FFmpeg command may be typed into the terminal as follows:

```
ffmpeg -i input_file.abc -option output_file.xyz
```

In this command, `ffmpeg` launches the program; the `-i` flag instructs the program to anticipate an input file, represented by `input_file.abc;` the `input_file.abc` is encoded or decoded according to the `-option` flag, which determines what operation(s) will be performed before writing the modified `output_file.xyz` according to the operation(s) specified in the option(s). FFmpeg provides the function libraries and encoding/decoding engines that RAWcooked uses to compress image sequences into a lossless video stream, and to reverse that process.

102

Using RAWcooked to convert DPX (or TIFF) sequences into FFV1/Matroska offers a number of benefits for digital preservation. As Kieran O'Leary explains in *Introduction to FFV1 and Matroska for Film Scans,* these are "open formats [...] driven by the advocacy of archivists who have put preservation-friendly features to the top of the agenda".[103] For example, FFV1 is able to store CR32 checksums "for every slice of a frame".[104] Also, the single resulting single file demands "less file system overhead than a large sequence of files", enabling quicker fixity checks.[105]

Unlike raw image sequence formats, FFV1/Matroska streams can be played with free, open-source playback software such as VLC and El Media players, and can accommodate one or more audio streams.[106] FFV1 is a "lossless intra-frame only codec", and can compress material to roughly 40% of the uncompressed storage space without mathematical loss.[107] The FFV1 codec offers "a similar compression rate to that achieved by the JPEG2000 video codec, but FFV1's compression time is less than that of JPEG 2000 because of its much simpler compression algorithm".[108] FFV1/Matroska is an ideal choice of Preservation Master format for film archives because it enables viewing, decreases file size, and reduces file transfer times.[109] Additionally, all processes run by the RAWcooked software are fully reversible.

If desired, RAWcooked is able to decode the Matroska video stream back into the original DPX image sequence, and restore the original metadata and sidecar files.[110] Any raw

---

103 Kieran O'Leary, "Introduction to FFVI and Matroska for Film Scans" *Digital Preservation Scripts* (blog), 2016, https://kieranjol.wordpress.com/2016/10/07/introduction-to-ffv1-and-matroska-for-film-scans/
104 Ibid
105 Ibid
106 Reto Kromer, "Matroska and FFV1: One File Format for Film and Video Archiving?" *Journal of Film Preservation* 96, (April, 2017).
107 Ibid
108 Ibid
109 Kieran O'Leary, "Introduction to FFVI and Matroska for Film Scans" *Digital Preservation Scripts* (blog), 2016, https://kieranjol.wordpress.com/2016/10/07/introduction-to-ffv1-and-matroska-for-film-scans/
110 "RAWcooked," accessed February 20, 2022, https://mediaarea.net/RAWcooked.

image sequence encoded to Matroska can be fully decoded, creating files identical to the originals, bit by bit. “Not only is the image and/or sound content fully preserved, but also all enclosed metadata and all the file’s characteristics”.[111] Therefore, an image sequence encoded to Matroska, then decoded back to its raw format is indistinguishable from its original in every way.[112]

RAWcooked supports a limited number of input file specifications, or ‘flavors’ of image sequence formats. Some flavors are supported by default, some require a license key, and others remain in development. The DPX sequences output by Resolve are 12-bit, RGB, packed files, big-endian in sequence, and are not supported by default. RAWcooked, when installed using the binary executable files available for download, will not process unsupported flavors.

Supported input flavors

D = Supported by default / K = Supported with a key, please contact us / N = Need file & development if interest, please contact us

Video format	Components	Bit depth	Packing	Endianness	Support
DPX left to right top to bottom 1 image element unsigned without encoding	RGB	8-bit			D
		10-bit	Filled A	BE	D
				LE	D
		12-bit	Packed	BE	K
				LE	N
			Filled A	BE	K
				LE	K
		16-bit		BE	K
				LE	K
		16-bit Float (out of FFV1 specs)		BE	N
				LE	N
	RGBA	8-bit			K
		10-bit	Filled A	BE	K
				LE	K
		12-bit	Packed	BE	K
				LE	N
			Filled A	BE	K
				LE	K
		16-bit		BE	K
				LE	K

Figure 8. RAWcooked Supported Input 'Flavors' (MediaArea)

111 Ibid

112

The solution to this problem is to install the program from source code. Installing RAWcooked from source enables free access to all flavors of input files that are compatible with the program.

Installing RAWcooked from source requires the use of a package manager, which is a collection of software tools, each one a package, that automates the installation of programs to a computer. The package manager *Homebrew* offers a wide variety of packages through its core *tap*, or library of available tools. Running the command

```
/bin/bash   curl   https://raw.githubusercontent.com/Homebrew/install/HEAD/install.sh
```

in the terminal installs the *Homebrew* package manager, giving access to all programs available on the core tap. To install Program X from the core tap, for example, the user instructs Homebrew to do so with the command `brew install programx.`

In this command, `brew` launches the program, and `install` instructs homebrew to anticipate a program name, obtain the code from the tap, and install the `program` using that `code.` Because RAWcooked is not included in the default *Homebrew* core tap, the package manager must be instructed to seek the software elsewhere. Running the command `brew tap mediaarea/mediaarea` instructs *Homebrew* to locate all packages on the MediaArea tap. With MediaArea packages available in *Homebrew,* RAWcooked can then be installed from source, with the command `brew install rawcooked.`

As mentioned, the primary functions of RAWcooked are to convert image sequences to FFV1/Matroska video streams and to reverse that process if desired. The software reads an input image sequence, compresses it according to a number of options, and outputs an FFV1/MKV video stream according to the options specified. Alternatively, the program is able to read an FFV1/MKV input video stream, decode it according to a number of options, and deliver it back into the raw image sequence format. In its simplest form, a RAWcooked command to convert DPX to FFV1/MKV would read as follows:

```
rawcooked input_file.dpx
```

In this command, `rawcooked` launches the program, and instructs it to anticipate an input file, represented by `input_file.dpx.` When dealing with image sequence inputs, RAWcooked will accept either a folder, containing the sequence, or a single file from that folder; whether a single file or a folder is input, all files in that sequence folder will be encoded to FFV1/MKV. If an audio file accompanies the image sequence, it will be encoded using the Free Lossless Audio Codec (FLAC) and multiplexed with the video stream. Reversing the process, and decoding the FFV1/MKV back to the raw sequence is done in much the same manner. In its simplest form, the command to decode FFV1/MKV back to DPX would read as follows:

```
rawcooked input_file.mkv
```

In this command, `rawcooked` launches the program and instructs it to anticipate an input file, represented by `input_file.mkv,` and decodes the video stream to an image sequence folder. While these descriptions outline the basic functionality and purpose of RAWcooked, the example commands do not make use of the software's various options. Including options in the encode or decode commands ensures the creation of both embedded and sidecar metadata files needed for archival validation, long-term data integrity, and reversibility.

Most of RAWcooked's core functions are included in the `--all` command, which instructs the program to execute the encode or decode operation according to the following options, without the user needing to type each option independently: `--info` "provides extra information about the compressed file, for example, the presence of hashes for the raw data" (Manual); `--conch` performs a conformance check, verifying whether the delivered file conforms to the correct specifications; `--hash` calculates the hash value of raw sequence files: "during encoding it computes a hash for each file within a source folder and stores this within the RAWcooked reversibility metadata".[113] When decoding a Matroska with hash values included in the metadata, "the file is decoded and new hashes generated which are then tested against the source file hashes stored in the metadata".[114] `--coherency` determines whether or not package contents are coherent "for example, is the audio file duration the same as the image sequence duration";[115] `--check-padding` is used to determine whether there are extraneous bits, or "padding" in the file relative to the bit depth of the scanner's sensor; any data found in the padding is "stored in the RAWcooked reversibility file" and guarantees full reversibility to original scanned bit depth.[116] `--check` verifies that the encoded file can be correctly decoded. Finally, in the case of missing frames; `--accept-gaps` instructs the program to create "a concatenated list of all files ensuring the sequence can be encoded".[117]

```
ACTIONS
    --all  Same as --info --conch --decode --encode --hash --coherency
           --check-padding --check --accept-gaps (see below)

    --none Same as --no-info --no-conch --no-decode --no-encode --no-hash
           --no-coherency --quick-check-padding --quick-check (see below)
```

The `--all` action performs these core checks, without the need to include each option manually. The above operation is repeated for each film to produce a lossless Preservation Master file in the FFV1/MKV format, thereby reducing overall file size, and enabling playback. [118] This master file will be used to create all subsequent derivatives.

---

113 "RAWcooked Manual," *MediaArea,* 2018-2021.
114 Ibid
115 Ibid
116 Ibid
117 Ibid
118 See Appendix III

8.3: FFV1/MKV to ProRes 422 HQ

In addition to its role supporting the operations performed by RAWcooked, FFmpeg will also be used to produce derivative files from the FFV1/MKV Preservation Master files. The first derivatives to be produced from the Preservation Masters are high-quality Apple ProRes 422 HQ mezzanine copies in a Quicktime (.mov) wrapper for production use. This standardized encoding specification achieves a compression ratio of approximately 5:1 compared to the MKV, without visual loss, and is intended for post-production work or the creation of later deliverables, if desired. “With widespread adoption across the video post-production industry, Apple ProRes 422 HQ offers visually lossless preservation of the highest-quality professional HD video that a single-link HD-SDI signal can carry”.[119] Efficient, versatile, and widely used in both archival and post-production environments, Apple ProRes is often cited as an ideal choice of format when preserving mezzanine Production Masters. Though it was originally closed-source and proprietary, this format can now be encoded and decoded with open-source CLI tools. To produce an Apple ProRes 422 HQ Production Master from the FFV1/MKV Preservation Master, the following command is run:

```
ffmpeg -i input.mkv -c:v prores -profile:v 3 -c:a pcm_s24le
-pix_fmt yuv422p10le output.mov
```

In the above command, `ffmpeg` launches the program; `-i` instructs the program to anticipate an input file; `input.mkv` represents the input file; `-c:` instructs the program to anticipate a codec type; `v` indicates the codec type is video and instructs the program to anticipate a video codec name; `prores` indicates the video codec name; `-profile:` instructs the program to anticipate a profile type compatible with the chosen codec; `v 3` indicates the third profile (422

[119] “About Apple ProRes,” *Apple*, April 9, 2018, https://support.apple.com/en-us/HT202410.

HQ) of the chosen codec has been selected for output ; `-c:` again instructs the program to anticipate a codec type; `a` indicates the codec type is audio, and instructs the program to anticipate an audio codec name; `pcm_s24le` is the audio code name, and indicates the audio track to be output is a pulse-code modulated, signed, 24-bit audio stream, little-endian in sequence; `-pix_fmt` instructs the program to anticipate a pixel format compatible with the chosen codec; `yuv422p10le` indicates the pixel format chosen for output is in a YUV color space, with 4:2:2 chroma subsampling, progressively scanned at 10-bit color depth, and little-endian in sequence; `output.mov` represents the output file, rendered according to the options specified above. These FFmpeg parameters ensure that the file is encoded according to the specifications of the Apple ProRes 422 HQ format, enabling widespread compatibility at a greatly reduced file size, with no visual loss.[120]

8.4: FFV1/MKV to H.264/MP4

The next derivatives produced are the access copies, which are encoded with Advanced Video Coding, also known as H.264, in the MPEG-4 (.mp4) container format. Like Apple ProRes, this video stream format is compatible with a wide variety of both open-source and closed-source software applications, and offers enormous savings in terms of storage space relative to the master and mezzanine files. H.264/MP4 files are more heavily compressed than the other formats mentioned, and are therefore more likely to exhibit loss of visual detail; while these access copies cannot be considered to be without visual loss entirely, the H.264 Advanced Video Coding is efficient enough to produce results more than satisfactory for casual viewing, and/or online streaming access. The overall subjectively-perceived visual ‘quality’ of an H.264/MP4 access derivative depends largely on the chosen video bitrate, or number of bits

[120] See Appendix IV

sampled each second, measured in Megabits per second, or Mb/s. Increasing the video bitrate raises overall perceived quality, with the highest bitrates approaching zero perceived loss; decreasing the video bitrate diminishes the overall perceived quality in proportion to the decrease in bitrate.

Either the FFV1/MKV Preservation Master or the ProRes/MOV Production Master may be used to create the access copies, and, for experimental purposes, both of these operations were performed. Creating access copies from the compressed ProRes/MOV files did not significantly reduce file size of the resulting access copies relative to those produced from master files, and so it was decided to produce access copies from the FFV1/MKV Preservation Master files instead. Derivatives produced from a lossless video stream are less likely to exhibit visual loss, as no mathematical information was discarded prior to further encoding. Running the following command will produce an H.264/MP4 access derivative from the FFV1/MKV Preservation Master:

```
ffmpeg -i input.mkv -movflags faststart -crf 18 -c:v
libx264 -pix_fmt yuv420p output.mp4
```

In this command, `ffmpeg` launches the program; `-i` instructs the program to anticipate an input file; `input.mkv` represents the input file; `-movflags faststart` instructs the program to "move some information to the beginning of your file and allow the video to begin playing before it is completely downloaded by the viewer" and will facilitate online streaming; this information is known as the *moov atom,* and is stored in the MP4 container data; `-crf` instructs the program to anticipate a Constant Rate Factor (CRF) value, or "default quality (and rate control) setting for the x264 and x265 encoders"; this is "the recommended rate control mode for most cases"; `18` indicates a CRF of 18, considered "to be visually lossless or nearly so”;[121] `-c:` instructs the program to anticipate a codec type; `v` indicates the codec type is video, and instructs the program to anticipate a video codec name; `libx264` indicates the video codec chosen for output is from the x264 library of encoders/decoders; `-pix_fmt` instructs the program to anticipate a pixel format name; the pixel format chosen for output is `yuv420p,` and indicates the file will be output in a YUV color space, with 4:2:0 chroma subsampling, progressively scanned; `output.mp4` represents the file name of the derivative file produced, with appropriate .mp4 extension.

While running the above command produces H.264/MP4 derivatives with the correct specifications, file sizes proved needlessly large for simple access purposes, and this would likely cause problems for online viewing. File sizes can be reduced by lowering the video bitrate and/or display resolution until a satisfactory compromise of compression and performance is achieved. In the context of this project, 1920x1080 HD resolution, at 10 Mb/s is adequate for access purposes.[122] Adjusting resolution is a very simple operation and involves only the `-s` argument, which instructs the program to anticipate a display *size,* or width/height ratio, measured in pixels; 1920x1080 indicates HD resolution.

Adjusting video bitrate is slightly more complicated, and there are several ways to perform this operation. One method of keeping bitrate within an acceptable range is to combine the arguments `-maxrate` and `-bufsize` with the `-crf` option, thereby *targeting* a visually-lossless constant rate factor of 18, while *limiting* bitrate to within the range specified. To produce an H.264/MP4 access derivative with bitrate suitable for online streaming, the following command is run:

---

[121] “H.264 Video Encoding Guide,” *Trac*, accessed February 20, 2022, https://trac.ffmpeg.org/wiki/Encode/H.264.
[122] “Recommended upload encoding settings,” YouTube Help, accessed February 20, 2022, https://support.google.com/youtube/answer/1722171?hl=en#zippy=%2Cbitrate.

```
ffmpeg -i input.mkv -movflags faststart -crf 18 -c:v
libx264 -pix_fmt yuv420p -s 1920x1080 -maxrate 12M -bufsize
2M output.mp4
```

All arguments previously included in this command function as described earlier, but are accompanied in this example by options to adjust resolution and limit video bitrate. Where the option `-crf 18` again instructs the program to target a visually-lossless constant rate factor of 18, the subsequent option `-maxrate` now instructs the program to also anticipate a maximum bitrate; `12M` represents a maximum bitrate of 12 Mb/s; if the output exceeds that maximum bitrate, "the encoder would increase the CRF to prevent bitrate spikes" thus limiting the bitrate to within the chosen range; the argument `-bufsize` instructs the program to anticipate a buffer rate of `2M`, and enforce the chosen `-maxrate` value across every 2 Mb worth of video.[123] The above command string reduces file size with only marginal loss of perceived quality, thus reducing storage needs and optimizing online performance across a variety of consumer displays.[124]

8.5: FFV1/MKV to AVID/MXF

Together, the FFV1/MKV masters, ProRes/MOV mezzanine files, and H.264/MP4 access derivatives align with or exceed Libraries and Archives Canada Standards,[125] and would be sufficient for most use cases.[126] However, because the filmmaker works primarily in AVID Media Composer, it was decided to also produce production master files to AVID specifications.

[123] "H.264 Video Encoding Guide," *Trac* online, accessed February 20, 2022, https://trac.ffmpeg.org/wiki/Encode/H.264.
[124] See Appendix VI
[125] "Recommendations on Preservation Files for Use in the Digitization of Analog Audio and Video Recordings and Motion Picture Films," *Libraries and Archives Canada,* accessed March 19, 2022, https://www.bac-lac.gc.ca/eng/about-us/publications/Documents/preservation-file-formats.pdf#search=%2Cfilm%20preservation%20standards.
[126] RAWcooked decodes back to DPX

Like Apple ProRes, there are a number of AVID codecs with various compression schemes. The AVID DNxHR HQX profile was selected because of its capacity for 10-bit color depth at 4:2:2 chroma subsampling, and for its 5:1 compression ratio.[127] To produce AVID DNxHR HQX production masters, the following command may be run:

```
ffmpeg -i input.mkv -c:v dnxhd -vf "scale=2160x1702,
fps=24, format=yuv42210le" -profile:v dnxhr_hqx -c:a
pcm_s24le output.mxf
```

In the above command, `ffmpeg` launches the program `-i` instructs the program to anticipate an input file; `input.mkv`represents the input file; `-c`instructs the program to anticipate a codec type; `v`indicates the codec type is video and instructs the program to anticipate a video codec name; `dnxhd`indicates the video codec name; `-vf`indicates filter graph, and instructs the program to anticipate one or more video filter options, separated by commas, and listed together between quotation marks; `scale`indicates frame size, in width by height, measured in pixels; `2160x1702`indicates the native frame size in pixels; `fps`indicates frames per second, and instructs the program to anticipate a frame rate value of `24`; `format`instructs the program to anticipate a color format; `yuv42210le`indicates the color format is YUV with 4:2:2 chroma subsampling, at a bit depth of 10, little endian in sequence; `-profile`instructs the program to anticipate a compression profile compatible with the codec and format chosen; `dnxhr_hqx` indicates the "high quality" 12-bit compression scheme with 4:2:2 chroma subsampling, which is padded to preserve the desired 10-bit output, and is suitable for 2K resolution (AVID); `-c:` again instructs the program to anticipate a codec type; `a`indicates the codec type is audio, and

---

[127] "DNxHR Codec Bandwidth Specifications," *AVID Knowledge Base,* accessed February 20, 2022. https://avid.secure.force.com/pkb/articles/en_US/White_Paper/DNxHR-Codec-Bandwidth-Specifications.

instructs the program to anticipate an audio codec name; `pcm_s24le`is the audio codec name, and indicates the audio track is a pulse-code modulated, signed, 24-bit broadcast wave file, little-endian in sequence; `output.mxf`indicates the output file name, delivered in an MXF container format, according to standard AVID specifications.[128] The AVID DNxHQ Production Master files are the last digital image elements needed for preservation.

PART IX: QUALITY CONTROL AND METADATA GENERATION

The first program used for quality control is MediaArea's MediaConch. This software consists of "an implementation checker, policy checker, reporter, and fixer that targets preservation level audiovisual files".[129] Intended for use in cultural heritage institutions, MediaConch provides "detailed and batch-level conformance checking via an adaptable and flexible application program interface accessible by the command line, a graphical user interface, or a web interface".[130] Users create a policy stipulating the desired file specifications for a given preservation element type, and compare the files to the specifications stipulated in the policy; MediaConch analyzes each file in relation to the policy, and either confirms that the file has passed the conformance check, or marks it as having failed.

---

[128] "Avid Supported Video File Formats," *Avid Technologies, Inc.,* accessed February 20, 2022, https://resources.avid.com/SupportFiles/attach/Avid_Supported_Video_File_Formats.pdf, 4.
[129] "MediaConch," *MediaArea,* accessed February 20, 2022, https://mediaarea.net/MediaConch.
[130] Ibid

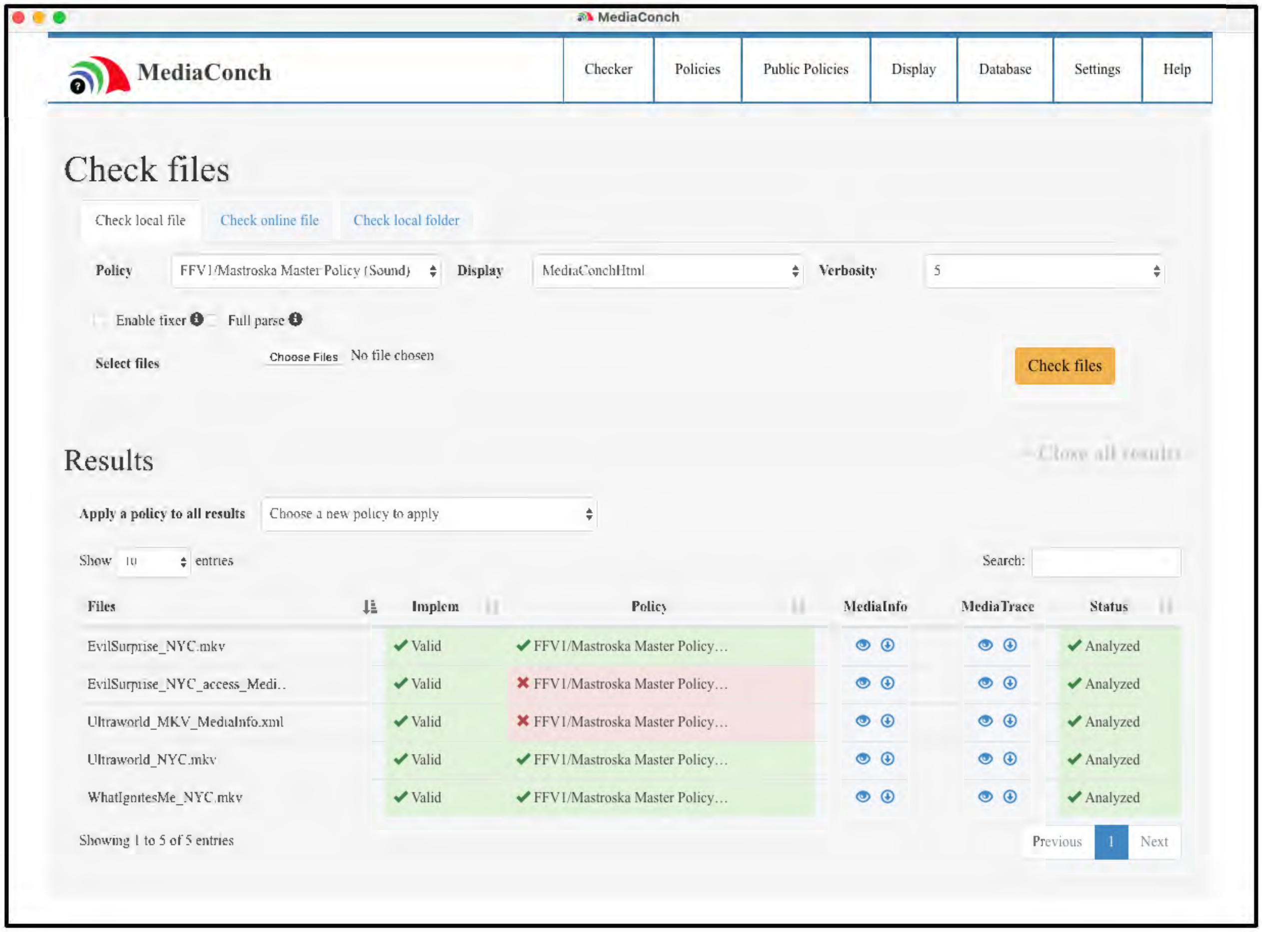


Figure 9. MediaConch GUI (MediaArea)

MediaConch was used in this project to check the conformance of each audiovisual file to the policy of its respective element type, and to produce detailed reports on each file following conformance verification. Any files that did not pass conformance check were re-encoded to comply with the requirements of their respective policies.

MediaConch offers a variety of reports, which can be exported in a number of different file formats; one of these is a MediaInfo report. MediaConch (and/or MediaInfo alone) can produce sidecar metadata files in plain text, HTML, XML and CSV formats, to name a few. MediaInfo reports offer a detailed breakdown of key file characteristics, including color space, bitrate, bit depth, codec name and version, and container format. MediaInfo reports were produced for each preservation element in human-readable PDF documents, for quick reference to file specifications, and in the Extensible Markup Language (XML), for ingest into a wide variety of archival metadata schema.

General

Unique ID :	56686297832701971164063295677858282375 (0x2AA562438D09C8178008B9642C7F7B87)
Complete name :	/Volumes/MOTHERSHIP/FrancoisMiron/MIRON_PRESERVATION/Master/SquareRoot/SquareRoot_Master.mkv
Format :	Matroska
Format version :	Version 4
File size :	95.3 GiB
Duration :	6 min 17 s
Overall bit rate mode :	Variable
Overall bit rate :	2 169 Mb/s
Writing application :	Lavf58.76.100
Writing library :	Lavf58.76.100
ErrorDetectionType :	Per level 1
Attachments :	RAWcooked reversibility data

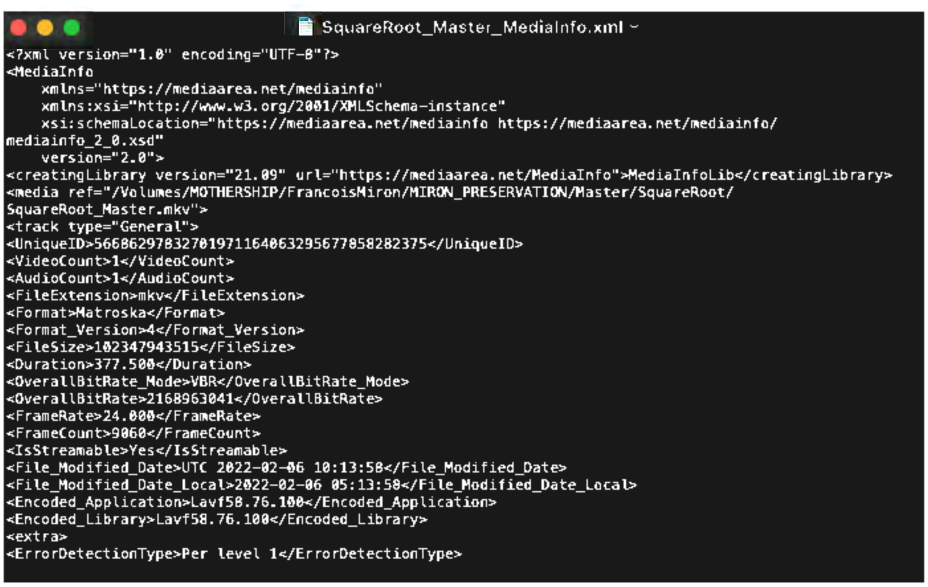
Video

ID :	1
Format :	FFV1
Format version :	Version 3.4
Format settings, GOP :	N=1
Codec ID :	V_MS/VFW/FOURCC / FFV1
Duration :	6 min 17 s
Bit rate mode :	Variable
Width :	2 160 pixels
Height :	1 702 pixels
Display aspect ratio :	5:4
Frame rate mode :	Constant
Frame rate :	24.000 FPS
Color space :	RGB
Bit depth :	12 bits
Scan type :	Progressive
Compression mode :	Lossless
Writing library :	Lavc58.134.100 ffv1
Default :	Yes
Forced :	No
Matrix coefficients :	Identity
coder_type :	Range Coder
MaxSlicesCount :	100
ErrorDetectionType :	Per slice

Audio

ID :	2
Format :	FLAC
Format/Info :	Free Lossless Audio Codec
Codec ID :	A_FLAC
Duration :	6 min 17 s
Bit rate mode :	Variable
Channel(s) :	2 channels
Channel layout :	L R
Sampling rate :	48.0 kHz
Bit depth :	24 bits
Compression mode :	Lossless
Writing library :	Lavc58.134.100 flac
Default :	Yes
Forced :	No

Figure 10. Sample MediaInfo PDF (Screenshot)



SquareRoot_Master_MediaInfo.xml

```
<?xml version="1.0" encoding="UTF-8"?>
<MediaInfo
    xmlns="https://mediaarea.net/mediainfo"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="https://mediaarea.net/mediainfo https://mediaarea.net/mediainfo/
mediainfo_2_0.xsd"
    version="2.0">
<creatingLibrary version="21.09" url="https://mediaarea.net/MediaInfo">MediaInfoLib</creatingLibrary>
<media ref="/Volumes/MOTHERSHIP/FrancoisMiron/MIRON_PRESERVATION/Master/SquareRoot/
SquareRoot_Master.mkv">
<track type="General">
<UniqueID>56686297832701971164063295677858282375</UniqueID>
<VideoCount>1</VideoCount>
<AudioCount>1</AudioCount>
<FileExtension>mkv</FileExtension>
<Format>Matroska</Format>
<Format_Version>4</Format_Version>
<FileSize>102347943515</FileSize>
<Duration>377.500</Duration>
<OverallBitRate_Mode>VBR</OverallBitRate_Mode>
<OverallBitRate>2168963041</OverallBitRate>
<FrameRate>24.000</FrameRate>
<FrameCount>9060</FrameCount>
<IsStreamable>Yes</IsStreamable>
<File_Modified_Date>UTC 2022-02-06 10:13:58</File_Modified_Date>
<File_Modified_Date_Local>2022-02-06 05:13:58</File_Modified_Date_Local>
<Encoded_Application>Lavf58.76.100</Encoded_Application>
<Encoded_Library>Lavf58.76.100</Encoded_Library>
<extra>
<ErrorDetectionType>Per level 1</ErrorDetectionType>
```

Figure 11. Sample MediaInfo XML (Screenshot)

Another program used for quality control is QCTools, a free and open-source software that "helps users analyze and understand their digitized video files through the use of audiovisual analytics and filtering".[131] The program may be operated using a GUI, which prompts the user to provide an input video file for analysis. QCTools parses the file, frame by frame, returns a variety of data about the file, and displays these data graphically.

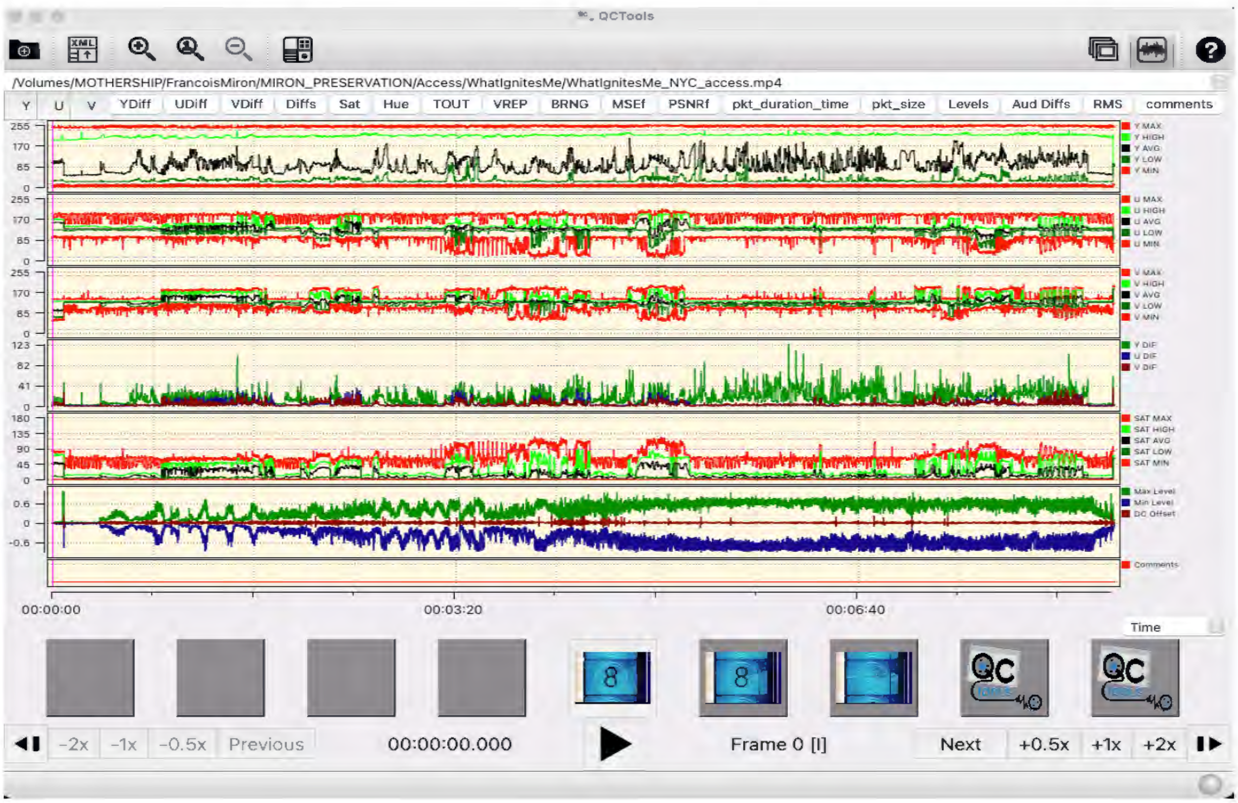


Figure 12. QCTools GUI Showing Levels (Screenshot)

The software analyzes and displays a number of key image characteristics including YUV values, crop width-by-height, and broadcast range compliance, among many others. QCTools is equipped with a playback environment "that allows the user to review video through multiple filters simultaneously".[132] Intended for "analytical playback", the window "may be set to different combinations of filters" including histogram, waveform, vectorscope, and value

---

[131] "QCTools," *MediaArea,* accessed February 20, 2022, https://mediaarea.net/QCTools.
[132] Ibid

highlight.[133] QCTools outputs reports in a compressed xml.gz file format, which may be imported into the software for analysis in lieu of the element itself, enabling remote analysis of files too large for online sharing.

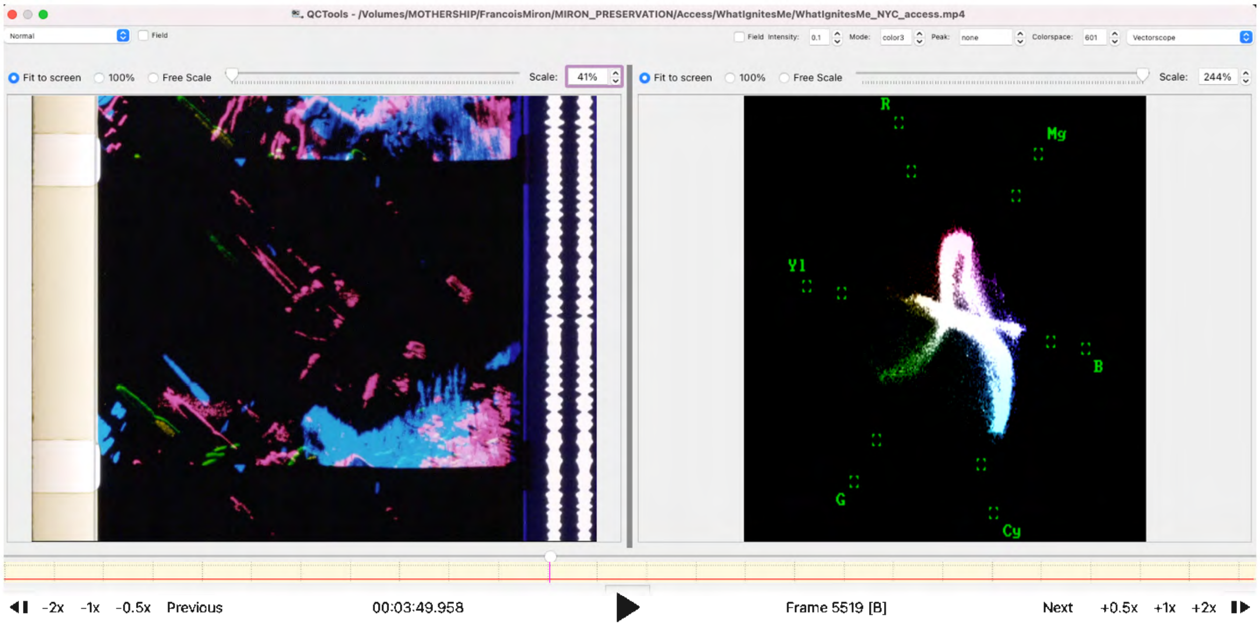


Figure 13. QCTools GUI Analytical Playback (Screenshot)

Item-level MD5 checksums were also produced for each preservation element, and are included to validate fixity following backup or migration; after each file is transferred from one location to another, a second checksum is generated and compared to the hash value of the MD5 sidecar file submitted. A mismatch of the original and duplicate checksums indicates that the transfer operation was compromised. To produce an item-level MD5 checksum for any file, the following command is run:

```
ffmpeg -i input_file.ext -f md5 output_file.md5
```

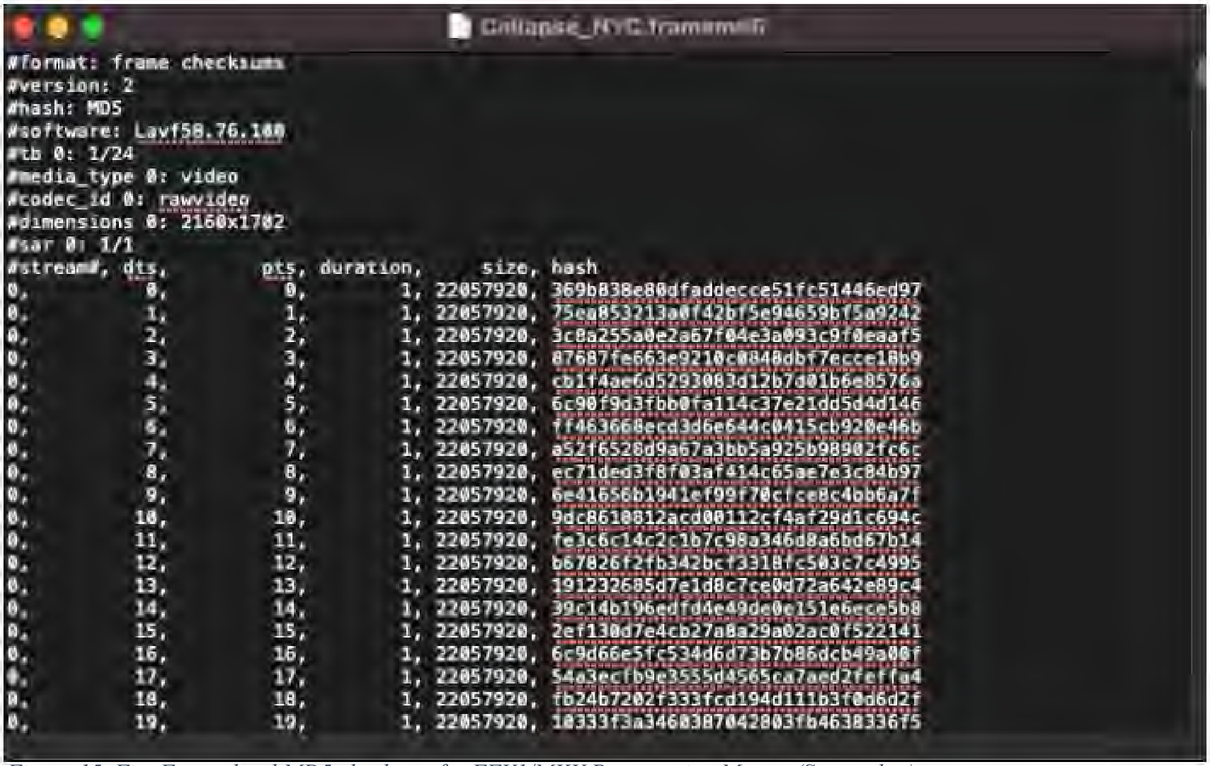
In this command, `ffmpeg` launches the program; `-i` instructs the program to anticipate an input file name; `input_file.ext` represents the input filename, with any extension; `-f` represents

133

'force format' and instructs the program to anticipate a format type; `md5`represents the output format type is md5; `output_file.md5`represents the output file name, with appropriate .md5 extension.

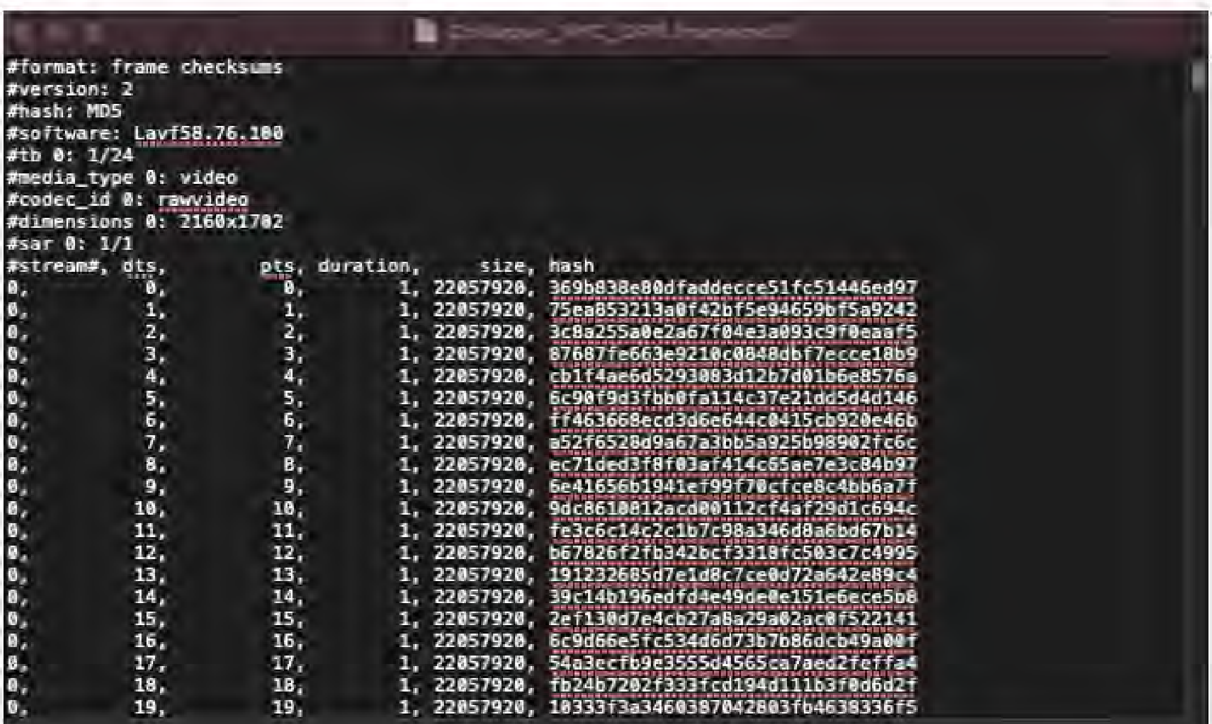
Figure 14. Item-level MD5 Checksum (Screenshot)

In addition to the item-level MD5 checksums produced for all preservation elements, frame-level MD5 checksums were produced for the FFV1/MKV Preservation Masters, and for the DPX sequences. Frame-level MD5 sidecar files are included to verify the encoding and decoding processes performed by RAWcooked. The frame-level checksums produce one MD5 hash value for every frame in the video stream, and deliver these data in a sidecar text file. Comparing this checksum with the checksum of the original DPX sequences confirms the success of encoding and decoding at the frame level.



```
#format: frame checksums
#version: 2
#hash: MD5
#software: Lavf58.76.100
#tb 0: 1/24
#media_type 0: video
#codec_id 0: rawvideo
#dimensions 0: 2160x1702
#sar 0: 1/1
#stream#, dts,        pts, duration,     size, hash
0,          0,          0,        1, 22057920, 369b838e80dfaddecce51fc51446ed97
0,          1,          1,        1, 22057920, 75ea853213a0f42bf5e94659bf5a9242
0,          2,          2,        1, 22057920, 3c8a255a0e2a67f04e3a093c9f0eaaf5
0,          3,          3,        1, 22057920, 87687fe663e9210c0840dbf7ecce18b9
0,          4,          4,        1, 22057920, cb1f4ae6d5293083d12b7d01b6e8576a
0,          5,          5,        1, 22057920, 6c90f9d3fbb0fa114c37e21dd5d4d146
0,          6,          6,        1, 22057920, ff463668ecd3d6e644c0415cb920e46b
0,          7,          7,        1, 22057920, a52f6528d9a67a3bb5a925b98902fc6c
0,          8,          8,        1, 22057920, ec71ded3f8f03af414c65ae7e3c84b97
0,          9,          9,        1, 22057920, 6e41656b1941ef99f70cfce8c4bb6a7f
0,         10,         10,        1, 22057920, 9dc8610812acd00112cf4af29d1c694c
0,         11,         11,        1, 22057920, fe3c6c14c2c1b7c98a346d8a6bd67b14
0,         12,         12,        1, 22057920, b67826f2fb342bcf3318fc503c7c4995
0,         13,         13,        1, 22057920, 191232685d7e1d8c7ce0d72a642e89c4
0,         14,         14,        1, 22057920, 39c14b196edfd4e49de0e151e6ece5b8
0,         15,         15,        1, 22057920, 2ef130d7e4cb27a8a29a02ac0f522141
0,         16,         16,        1, 22057920, 6c9d66e5fc534d6d73b7b86dcb49a00f
0,         17,         17,        1, 22057920, 54a3ecfb9e3555d4565ca7aed2feffa4
0,         18,         18,        1, 22057920, fb24b7202f333fcd194d111b3f0d6d2f
0,         19,         19,        1, 22057920, 10333f3a3460387042803fb4638336f5
```

Figure 15. Fig. Frame-level MD5 checksum for FFV1/MKV Preservation Master (Screenshot)



```
#format: frame checksums
#version: 2
#hash: MD5
#software: Lavf58.76.100
#tb 0: 1/24
#media_type 0: video
#codec_id 0: rawvideo
#dimensions 0: 2160x1702
#sar 0: 1/1
#stream#, dts,        pts, duration,     size, hash
0,          0,          0,        1, 22057920, 369b838e80dfaddecce51fc51446ed97
0,          1,          1,        1, 22057920, 75ea853213a0f42bf5e94659bf5a9242
0,          2,          2,        1, 22057920, 3c8a255a0e2a67f04e3a093c9f0eaaf5
0,          3,          3,        1, 22057920, 87687fe663e9210c0840dbf7ecce18b9
0,          4,          4,        1, 22057920, cb1f4ae6d5293083d12b7d01b6e8576a
0,          5,          5,        1, 22057920, 6c90f9d3fbb0fa114c37e21dd5d4d146
0,          6,          6,        1, 22057920, ff463668ecd3d6e644c0415cb920e46b
0,          7,          7,        1, 22057920, a52f6528d9a67a3bb5a925b98902fc6c
0,          8,          8,        1, 22057920, ec71ded3f8f03af414c65ae7e3c84b97
0,          9,          9,        1, 22057920, 6e41656b1941ef99f70cfce8c4bb6a7f
0,         10,         10,        1, 22057920, 9dc8610812acd00112cf4af29d1c694c
0,         11,         11,        1, 22057920, fe3c6c14c2c1b7c98a346d8a6bd67b14
0,         12,         12,        1, 22057920, b67826f2fb342bcf3318fc503c7c4995
0,         13,         13,        1, 22057920, 191232685d7e1d8c7ce0d72a642e89c4
0,         14,         14,        1, 22057920, 39c14b196edfd4e49de0e151e6ece5b8
0,         15,         15,        1, 22057920, 2ef130d7e4cb27a8a29a02ac0f522141
0,         16,         16,        1, 22057920, 6c9d66e5fc534d6d73b7b86dcb49a00f
0,         17,         17,        1, 22057920, 54a3ecfb9e3555d4565ca7aed2feffa4
0,         18,         18,        1, 22057920, fb24b7202f333fcd194d111b3f0d6d2f
0,         19,         19,        1, 22057920, 10333f3a3460387042803fb4638336f5
```

Figure 16. Fig. Frame-level MD5 checksum for raw DPX sequence (Screenshot)

PART X: ARCHIVAL PACKAGING AND STORAGE

All digital preservation elements will be assembled into archival information packages, each one suited to a particular preservation context. All preservation packages created in this project are stored as a project folder at root level on a dedicated external storage volume, each volume to be delivered to its respective destination. Each preservation element format is assigned a folder containing one subfolder for each title; inside each subfolder is the preservation element and its associated metadata. Each individual preservation element in the package is accompanied by its own set of metadata sidecar files. All packages, regardless of their destination, include appropriate documentation, and each file is accompanied by metadata in both human, and machine-readable languages. A total of three preservation packages will be prepared.

The simplest, and most standard preservation package is the one created for submission to a collecting institution, and includes only three digital preservation element types. First are the FFV1/MKV Preservation Masters, in lieu of the much larger and more cumbersome DPX sequences; these master files are unlikely to be used for viewing or production work, and are included to enable decoding back to DPX, or to produce higher-quality production derivatives as archival standards evolve. Next are the Apple ProRes Mezzanine files, which are included as the current standard for production delivery; the ProRes files remain "visually lossless through many generations of decoding and reencoding", making them ideal for post-production work such as color-grading, or for the creation of any number of further derivatives.[134] Third are the access derivatives, ready for viewing, and tailored to suit the requirements of web streaming, should the collecting institution wish to present the works as a virtual exhibit.

[134] "About Apple ProRes," *Apple* online, April 9, 2018, https://support.apple.com/en-us/HT202410.

The archival information package submitted for institutional collection therefore consists of a volume, named MIRON_COLLECT, containing a project folder at root level, inside which are subfolders arranged by element type; these subfolders contain the digital objects and their accessory files, which will enable the institution to validate file backups, check reversibility, and perform fixity checks.

Each digital preservation element will be delivered along with three metadata files:

1. A QCTools report in the xml.gz format.
2. A machine-readable MediaInfo document in the Extensible Markup Language (XML).
3. An item-level md5 checksum.

FFV1/MKV Preservation Masters are also accompanied by:

4. A frame-level md5 checksum.

The preservation package created for delivery to the filmmaker, named MIRON_ARTIST, resembles the one given to the collecting institution, but also includes PDF versions of all MediaInfo reports, as well as AVID DNxHQ Production Masters, as per the client's request. This package will therefore consist of a volume, with a project folder at root level; inside the project folder are four subfolders, one for each preservation element type; as before, each preservation element subfolder contains another subfolder for each title, which itself contains the digital object and its associated sidecar files.

The primary project storage volume, named MOTHERSHIP, contains every element type produced, including the CRI and DPX image sequences, and is periodically archived on a backup volume any time a change is made. Once the archival information packages are successfully submitted to the client and the collecting archive, the cumbersome image sequence files may be deleted from the project drive and its backup, as they can be regenerated from the FFV1/MKV Preservation Masters if desired. Discarding the original CRI and DPX image sequences will reduce overall storage demands by over 2 TB, and is possible because the reversibility data generated by RAWcooked and stored within the Matroska container file enables full and verifiable decoding back to DPX. Should the need arise, DPX files can be imported to Resolve and re-encoded back to CRI. Indeed, any file type desired can be produced from the FFV1/MKV Preservation Master. All metadata files will be preserved on the main project volume and its backup.

PART XI: DIGITAL POST-PRODUCTION

Minor digital post-production was performed in DaVinci Resolve before creating exhibition copies. First, the images were cropped to eliminate all perforations and frame lines from view, leaving only the main image content visible:

Figure 17. Full-frame as Scanned vs. Cropped Frame (Screenshot)

Next, slight increases were made to contrast and saturation, in order to maximize dynamic range and chrominance intensity without exceeding broadcast limits. These subjective adjustments were minor, and impart a subtly more vivid image:

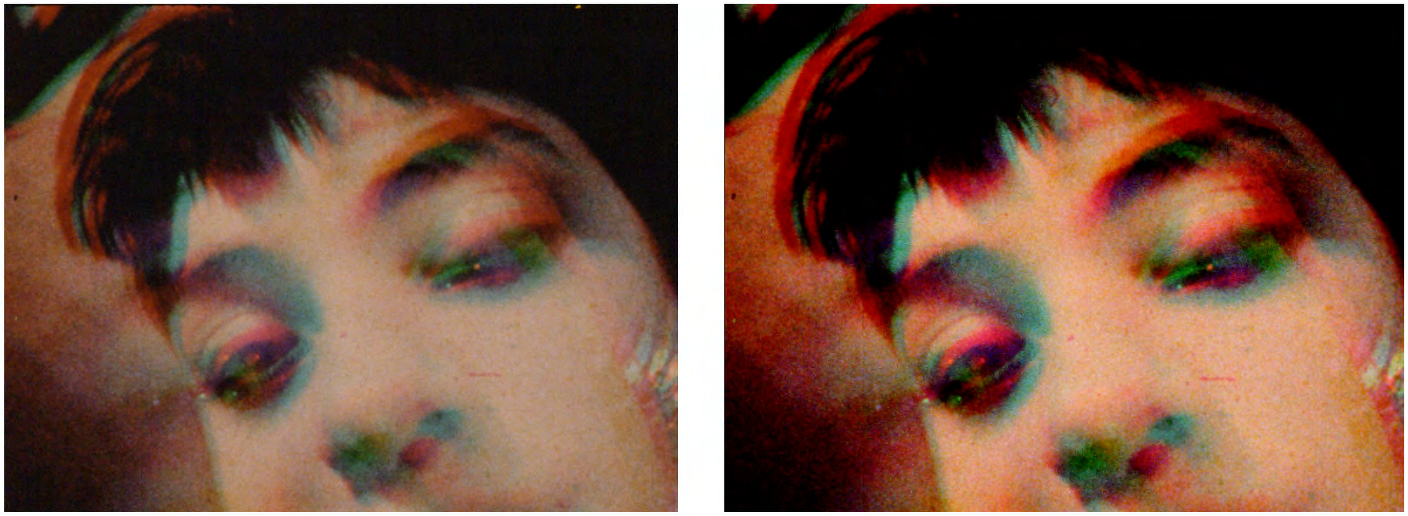


Figure 18. Color as Captured vs. Color Enhanced Screenshot

Also, video lift was lowered to darken shadows, and eliminate unwanted video interference or ‘noise’ introduced during the digital capture process. Bringing the lowest end of the light spectrum just outside of broadcast range eliminates video noise without appreciable loss of visual information:

Figure 19. Blacks as Captured vs. Blacks with Video Lift Adjusted (Screenshot)

Finally, audio tracks for restored images were gently treated with the *iZotope RX* noise reduction filter plugin in AVID ProTools. This filter samples the audio track for ‘clicks’ and ‘pops’ caused by adhering particles or other damage, and applies a digital algorithm to remove or quiet these unwanted sounds. This was the only automated tool used, and no other audio restoration was performed:

Figure 20. RX De-click Automated Audio Noise-reduction Plugin (Screenshot)

All digital image correction was performed manually using DaVinci Resolve, and no automated tools were used to correct the image. Modifications to the source image were minor, and made with consideration to the films’ original production and exhibition context. The filmmaker was consulted as to the final aesthetic quality of each restored deliverable, and these restored duplicate files will be used as Digital Source Masters (DSM) for creating Digital Cinema Packages (DCP) and collectible optical media copies.

PART XII: DISTRIBUTION AND EXHIBITION

12.1 Digital Cinema Package

All selected films were compiled together as a Digital Cinema Package (DCP) for theatrical exhibition. A DCP can be understood as the digital equivalent of a photochemical release print, and consists of a “discrete ensemble” of compressed audiovisual, and package information files.[135] As stated by the FIAF Technical Commission, “the main intention of the DCP is to serve as a flexible and secure format for delivery and projection of digital movies on a very high quality level”.[136]

The first element required to create a DCP is the Digital Source Master (DSM). The term DSM refers to “any content coming out of a digital post-production environment that will be eventually converted into a DCP”.[137] The DSM files used to produce the DCP in this project were the digitally restored Restoration Masters described above, though any high-quality master format may be used as the DSM.

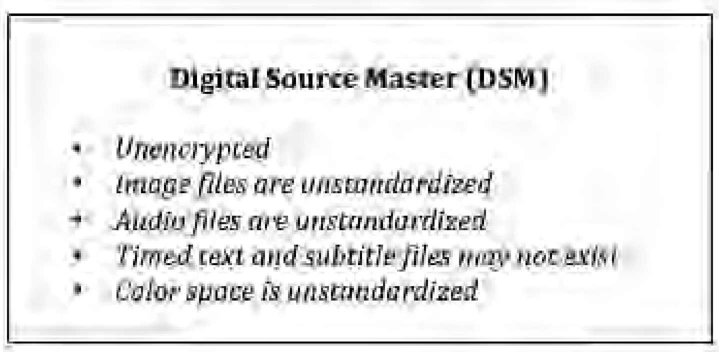


Figure 21. DSM File List (Peltzman, 2013)

Producing a DCP from a DSM requires the creation of an intermediate set of master files called the Digital Cinema Distribution Master (DCDM). The purpose of the DCDM is to organize all of

[135] Shira Peltzman, *Unlocking the DCP: Evaluating the Risks, Preservation, and Long-Term Management of Digital Cinema Packages in Audiovisual Archives,* (MA Thesis, New York University, 2013), 4.
[136] Ibid 14
[137] Ibid 15

the various components of the DSM into a standardized file structure, equip all files with metadata, and to format these files according to DCDM specifications in preparation for compression and packaging as a DCP. The DCDM provides "a complete and standardized way to communicate movies […] between studio, post-production and exhibition".[138] For delivery to an offsite production environment, the DCDM should be prepared according to the following specifications:

Digital Cinema Distribution Master (DCDM)

- *Unencrypted*
- *Image files are TIFF Revision 6.0 files*
- *Audio files are uncompressed 24 bit 48kHz or 96kHz Broadcast Wave (.WAV) files*
- *Timed text files are either XML-based documents or a set of Portable Network Graphic (.PNG) images mastered at the same resolution as the image files*
- *Color space is XYZ*

Figure 22. DCDM File List (Peltzman, 2013)

To become a DCDM, DSM files should be transcoded and arranged with standardized image, sound, and title files according to DCI specifications. DCI standards demand that DCDM image files be in the TIFF revision 6.0 format, and be scaled to 2048x858 (2K scope), 1998x1080 (2k flat), 4906x1716 (4K scope), or 3998x2160 (4K flat). All films were scaled to 2k flat resolution to match as best as possible the original resolution of 2160x1702.[139] DCDM specifications also standardize colorimetry characteristics, and the DSM files should be converted from their native

[138] Ibid 15;16
[139] Ibid 17

RGB color space to the DCI-approved XYZ color space.[140] The DCDM requires audio bit depth of 24, with a sample rate of either 48kHz or 96kHz, at a frame rate of exactly 24fps. If subtitles are to be included, they must be formatted as timed text files in a .xml file, or as a sequence of lossless .png image files, mastered at identical resolution to the image essence files. The DCDM ensures compliance with DCI specifications prior to creating a DCP.

This project used FFmpeg to convert DSM files as closely as possible to DCDM requirements using the following command:

```
ffmpeg -i input_file.mov -compression_algo raw –pix_fmt
rgba -s 1998x1080 output_file%8d.tiff
```

In this command, `ffmpeg` launches the program; `-i` instructs the program to anticipate an input file; `input_file.mov`represents the input video file to be processed; `-compression_algo` indicates compression algorithm and instructs the program to anticipate a compression value; `raw` indicates the algorithm will apply no compression during transcode; `output_file%8d.tiff` represents the output sequence name, with eight digits of frame count, and delivered with the appropriate .tiff extension. Running this command converts the ProRes/MOV files to TIFF sequences, but does not convert to an XYZ color space. Other software is able to convert RGB to XYZ, so it is not strictly necessary to produce TIFF sequences in XYZ.[141]

---

[140] Ibid 17

[141] OpenDCP, as described below, will perform the RGB to XYZ conversion. Alternatively, DaVinci Resolve is able to output TIFF sequences in a DCI-compliant XYZ color space. While MediaInfo misidentifies XYZ TIFF files output by Resolve as RGB, a frame-by-frame A/B comparison reveals the RGB to XYZ conversion was indeed successful.

As an intermediate product between the DSM and DCP, the DCDM is useful only for delivering standardized content from one production environment to another. When producing a DCP in a single, dedicated environment, "a complete DCDM of the work might not actually exist", and it is now common practice to omit the DCDM completely.[142] To reduce processing time, this project used RGB TIFFS as the DCDM. Indeed, the DCDM is "not even produced. It's virtually produced in the machine but then it doesn't exist anymore.".[143] Ultimately, the DCP itself is the only product which must meet DCI specifications in order to play.

Digital Cinema Package (DCP)

- *May be either encrypted or unencrypted*
- *Image files are sequentially numbered, lossy JPEG 2000 files in an MXF wrapper*
- *Audio files are uncompressed 24 bit 48kHz or 96kHz Broadcast Wave (.WAV) files*
- *Timed text files are either XML-based documents or a set of Portable Network Graphic (.PNG) images mastered at the same resolution as the image files*
- *Color space is XYZ*
- *Packing List, Composition Playlist, AssetMap, and VolumeIndex are added*

Figure 23. DCP File List (Peltzman, 2013)

The Digital Cinema Package is "a complex group of files whose structure must be maintained in order for the information to be understood and played back as its creators intended".[144] To become a DCP, this set of files must be compressed and packaged, and may be encrypted if desired. To reduce the enormous file size of the DCDM, each TIFF file in each

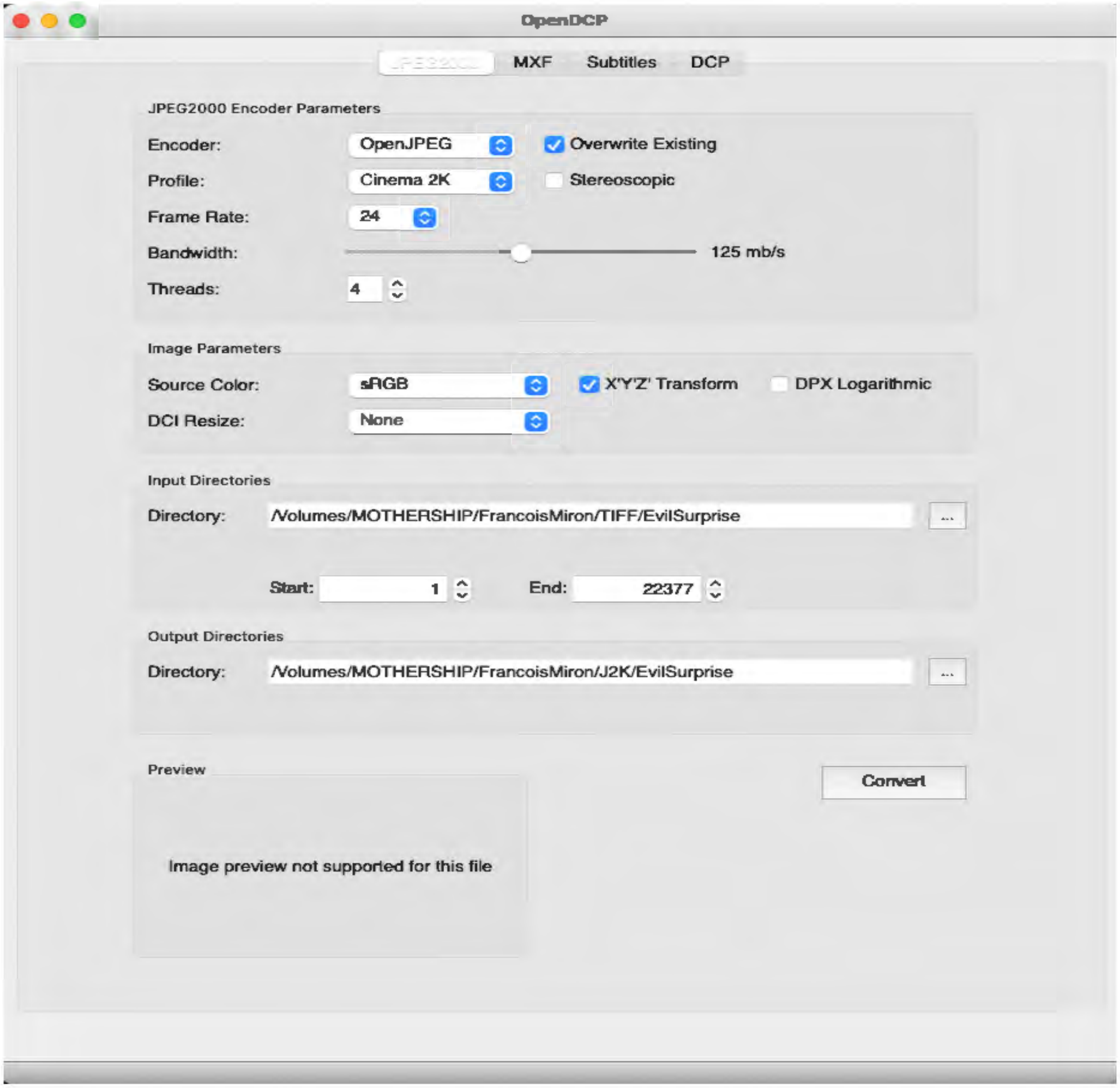
[142] Ibid 19
[143] Ibid
[144] Ibid 21

sequence must be compressed using the JPEG2000 standard.[145] Audio tracks are uncompressed, 24-bit linear PCM files with a sample rate of either 48kHz or 96kHz, and image and sound are packaged separately in the MXF container format. A vestigial concept carried over from analog projection, DCPs are divided by digital 'reels'; "Each reel is set up as a distinct folder that contains a set of track files – one for image, one for sound, and one for subtitles".[146] Reels are then packaged together with a Composition Playlist, Asset Map, Packing List and Volume Index, in the XML format, to create the final DCP.

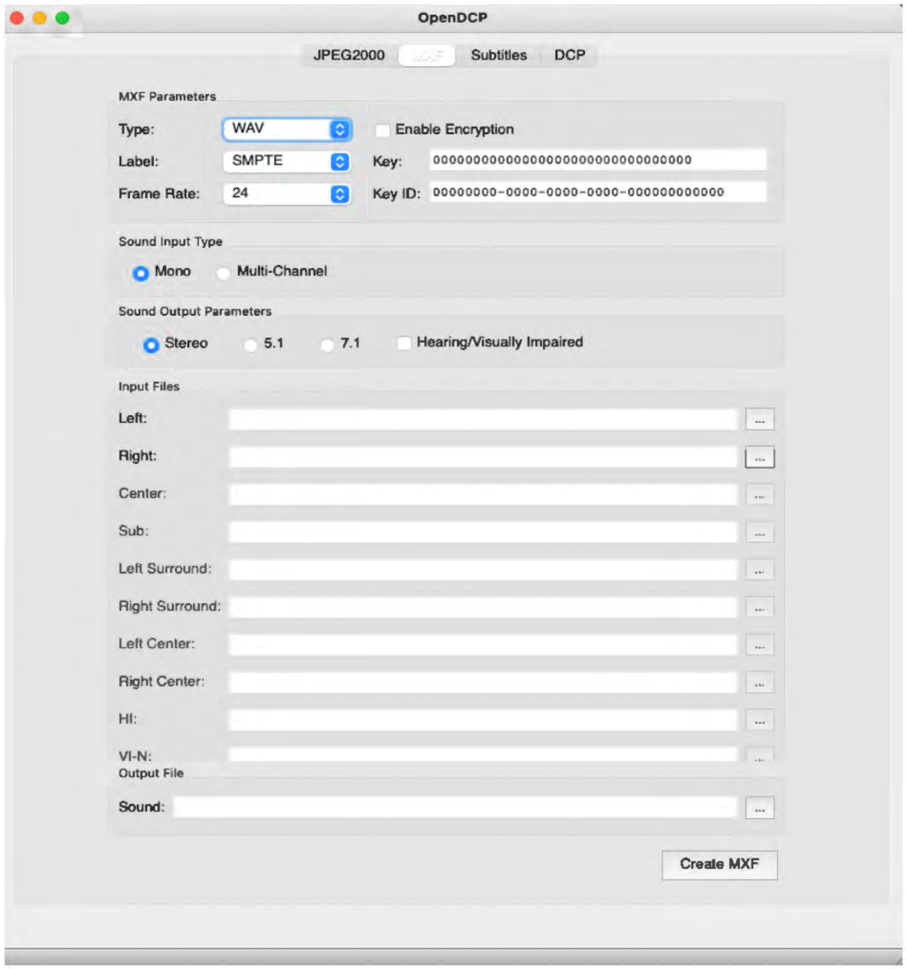
This project used OpenDCP to compile the Digital Cinema Package. OpenDCP is a free, open-source program that converts and packages input sequences to DCI standards, while producing the necessary XML documents needed for playback. The program accepts input files in TIFF, DPX, or BMP formats in RGB, YUV, or YCbCr color spaces, and converts these to JPEG2000 sequences in an XYZ color space using the OpenJPEG encoder. This project used both the command line and graphical user interface features of OpenDCP to create the DCP as desired.

First, each TIFF sequence from the DCDM is converted to JPEG2000. The OpenDCP GUI enables the user to customize the JPEG encoder parameters, specify the characteristics of the source sequence, and to select input and output directories. This process converts the RGB TIFF sequences to JPEG2000 files in an XYZ color space.

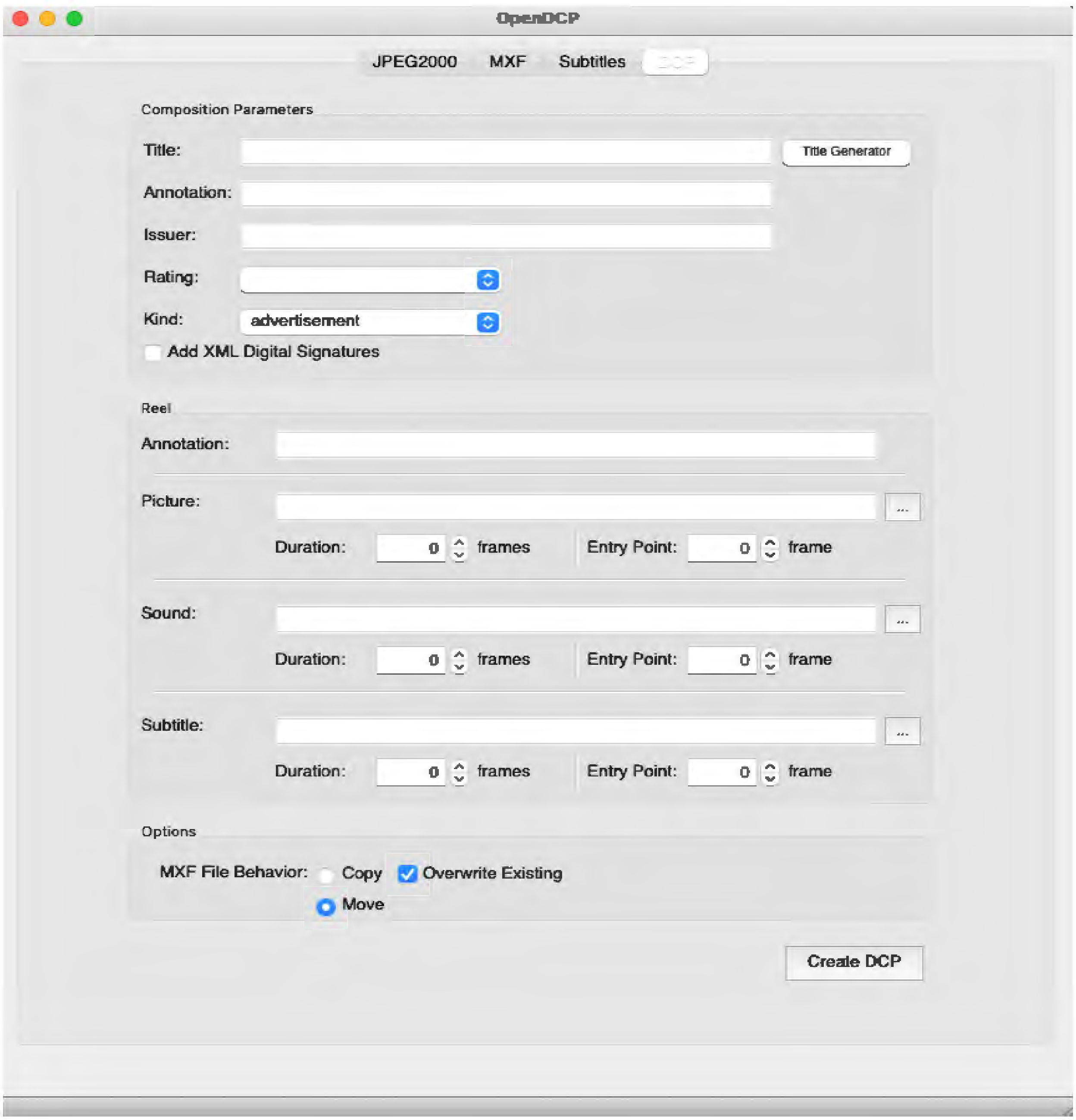
[145] Ibid 19
[146] Ibid 20


OpenDCP
JPEG2000
MXF
Subtitles
DCP
JPEG2000 Encoder Parameters
Encoder:
OpenJPEG
Overwrite Existing
Profile:
Cinema 2K
Stereoscopic
Frame Rate:
24
Bandwidth:
125 mb/s
Threads:
4
Image Parameters
Source Color:
sRGB
X'Y'Z' Transform
DPX Logarithmic
DCI Resize:
None
Input Directories
Directory:
/Volumes/MOTHERSHIP/FrancoisMiron/TIFF/EvilSurprise
Start:
1
End:
22377
Output Directories
Directory:
/Volumes/MOTHERSHIP/FrancoisMiron/J2K/EvilSurprise
Preview
Convert
Image preview not supported for this file


OpenDCP
JPEG2000
Subtitles
DCP
MXF Parameters
Type:
JPEG2000
Enable Encryption
Label:
SMPTE
Key:
00000000000000000000000000000000
Frame Rate:
24
Key ID:
00000000-0000-0000-0000-000000000000
Picture Parameters
Stereoscopic
Slideshow
1s
duration per slide
Picture Input
Directory:
Output Files
Picture:


OpenDCP
JPEG2000
Subtitles
DCP
MXF Parameters
Type:
WAV
Enable Encryption
Label:
SMPTE
Key:
00000000000000000000000000000000
Frame Rate:
24
Key ID:
00000000-0000-0000-0000-000000000000
Sound Input Type
Mono
Multi-Channel
Sound Output Parameters
Stereo
5.1
7.1
Hearing/Visually Impaired
Input Files
Left:
Right:
Center:
Sub:
Left Surround:
Right Surround:
Left Center:
Right Center:
HI:
VI-N:
Output File
Sound:
Create MXF


OpenDCP
JPEG2000
MXF
DCP
Subtitles and Closed Captions
Type:
SMPTE (Timed Text)
Label:
SMPTE
Subtitle
Input:
Output:
Create


OpenDCP
JPEG2000
MXF
Subtitles
Composition Parameters
Title:
Title Generator
Annotation:
Issuer:
Rating:
Kind:
advertisement
Add XML Digital Signatures
Reel
Annotation:
Picture:
Duration:
0
frames
Entry Point:
0
frame
Sound:
Duration:
0
frames
Entry Point:
0
frame
Subtitle:
Duration:
0
frames
Entry Point:
0
frame
Options
MXF File Behavior:
Copy
Overwrite Existing
Move
Create DCP

While the GUI allows for straightforward creation of a single-reel cinema package, it does not support the compiling of multiple reels into a single DCP. To compile a DCP with multiple reels, it is necessary to use the command-line interface. Video and audio tracks, already packaged as XML files, were assembled as a DCP, one reel per title. The DCP contains six reels. To compile a number of reels using the command line interface of OpenDCP, the following command is run in terminal:

```
opendcp_xml --reel video01.mxf sound01.mxf --reel
video02.mxf sound02.mxf --reel video03.mxf sound03.mxf --
digest --sign
```

In this example command, `opendcp_xml` launches the program's DCP generator, which creates an Asset Map, Volume Index, Packing List, and Composition Playlist, in XML format, according to DCI standards; `--reel` instructs the program to anticipate a set of video, audio, and subtitle track files as applicable for each reel; `video01.mxf` represents the image essence file of the first reel; `audio01.mxf` represents the audio essence file of the first reel; `--reel` terminates the previous reel, and instructs the program to anticipate a second reel; `video02.mxf` represents the image essence of the second reel, and so on. The `opendcp_xml` command functions exactly like the DCP tab in the OpenDCP GUI, but is capable of compiling multiple reels.

Once all reels are listed, the command may be concluded with the `--digest` option (which compares SHA256 validation digests and notifies the user of any errors during encoding), and the `--sign` option, which generates an XML digital signature. These final options help secure the files, if desired, and verify the integrity of the encoding operation. The XML files will be output to the user’s home folder, and should then be included with the image and sound essence tracks in a dedicated folder; the files in this dedicated folder are thus arranged to DCI standards, and are accompanied by the metadata files required for playback on DCP servers.

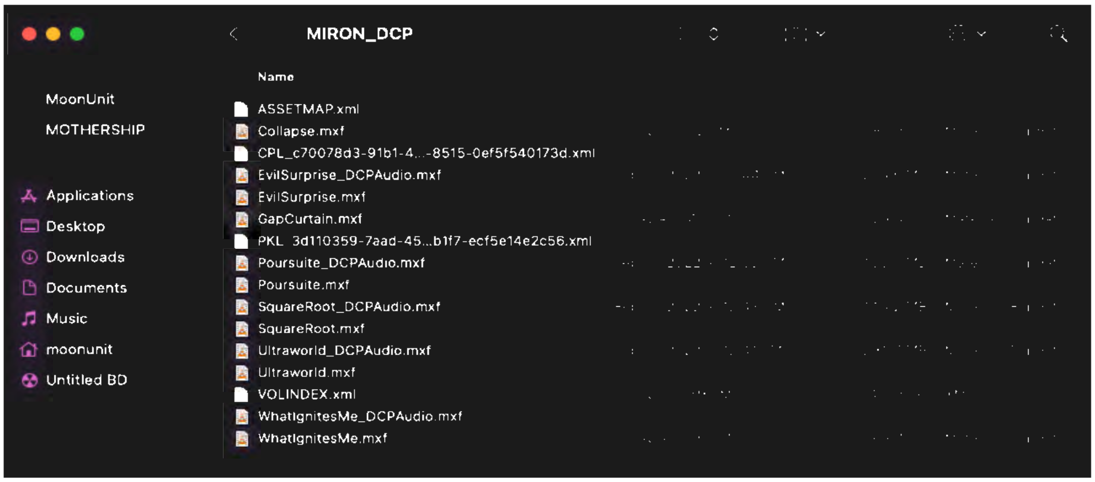


Figure 29. DCP File Structure (Screenshot)

In the Composition Playlist (CPL), for example, each reel is assigned a Universal Unique Identifier (UUID) and listed along with its title, entry point, and duration, expressed in frames.[147]

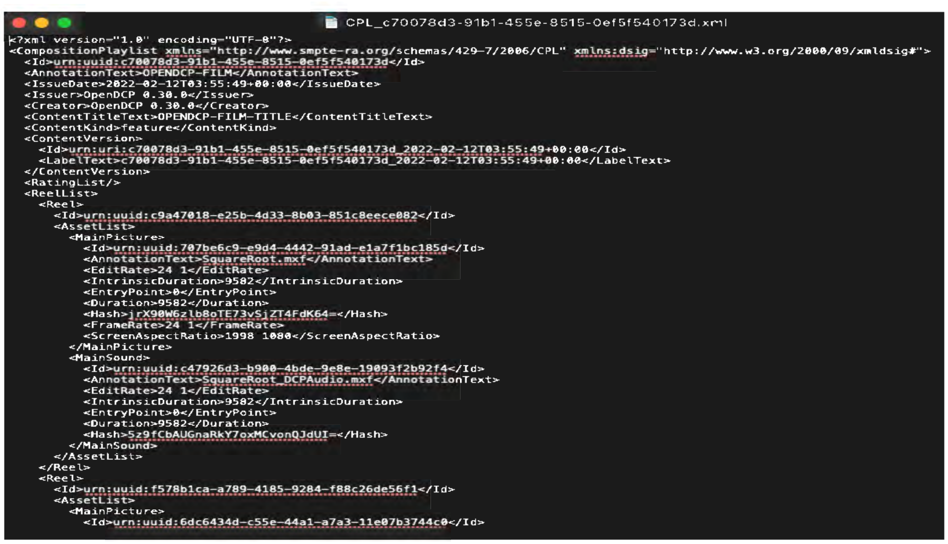


Figure 30. Composition Playlist (Screenshot)

[147] For a detailed breakdown of DCP file structures, see Peltzman, 2013.

12.2 BluRay Disc

In addition to the DCP, video files were compiled on BluRay disc for collecting and home-viewing. The BluRay disc is an optical media format, and supports video encoded in MPEG-2, MPEG-4 (AVC), and VC-1 specifications. Audio and video tracks are multiplexed using the BluRay Disc Audio/Video (BDAV) transport stream, also known as M2TS.[148] To produce a BluRay disc compatible with consumer players, it is necessary to produce an ISO disc image, then copy this image to a disc. The ISO image file format is an "archive file containing the content from (or destined for) an optical disc", and is "typically used to package or bundle software, databases, authored DVD video programs and the like".[149] This project used the free software program tsMuxeR to create a disc image containing all selected films.

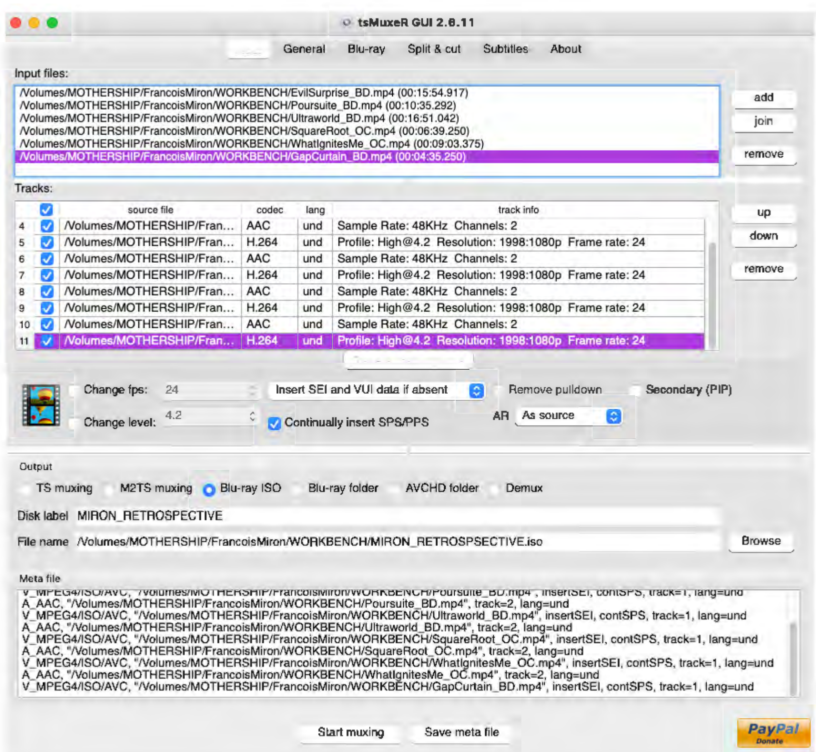


Figure 31. tsMuxer GUI (Screenshot)

[148] "BDMV" *Afterdawn,* accessed February 20, 2022. https://www.afterdawn.com/glossary/term.cfm/bd-mv.
[149]

The tsMuxeR program reads any number of input audiovisual files, multiplexes video and audio tracks according to BluRay specifications, and produces an ISO disc image which can then be written to an optical disc.

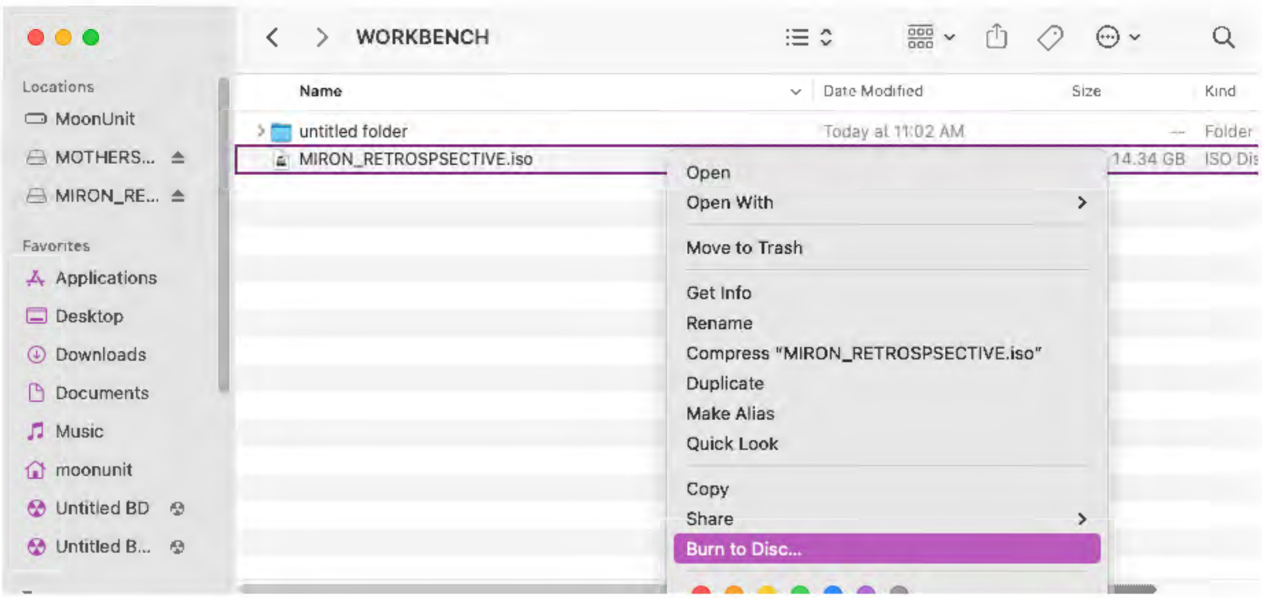


Figure 32. Using Finder to Write BluRay ISO to Disc (Screenshot)

Unlike typical files, disc images are not opened, but are rather *mounted*.[150] Once written to the disc, the ISO image is mounted as a collection of AVCHD video files in the BluRay Disc Movie (BDMV) format, enabling playback on standard consumer BluRay players.

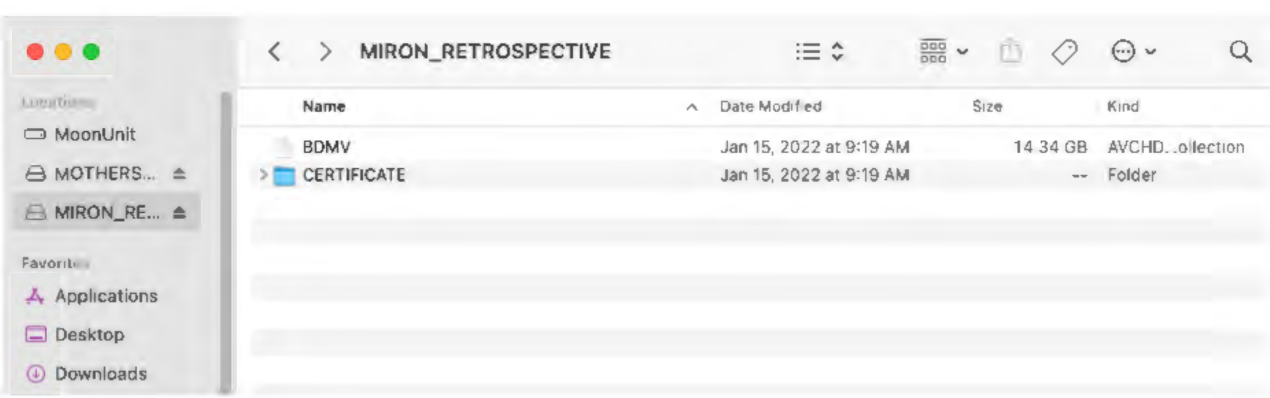


Figure 33. BDMV Written to Disc (Screenshot)

150

CONCLUSION:

As described herein, this project has digitally preserved a ten-year artist's retrospective of François Miron's optical printing films. Preservation packages were prepared for submission to a collecting institution, and for delivery to the filmmaker. Proprietary source files were converted without loss to open-source Preservation Master files using the FFV1 codec in a Matroska container format, thereby reducing file size relative to DPX, and enabling playback. Master files were then duplicated and compressed to ProRes 422 HQ Production Masters, and H.264/MP4 access derivatives as per Libraries and Archives Canada standards for the digital preservation of 16mm film. All preservation files are accompanied by relevant metadata, including MediaInfo reports in XML format, QCTools reports, and MD5 checksums to facilitate ingest to institutional digital asset management systems and to enable fixity checks following file migration. Configured as such, these files can be processed using open-source tools, are compatible with a wide range of software programs, and will integrate into any number of monolithic or microservice preservation architectures.

Limited edition BluRay discs will be donated to archives, cinemas, and collectors, as chosen by the filmmaker, and a complete Digital Cinema Package was prepared for international festival distribution. Remastered copies of *The Evil Surprise, What Ignites Me, Extinguishes Me,* and *The Square Root of Negative Three* have already been programmed in the *Optronica* film series at Other Cinema in San Francisco, and it is hoped that Anthology Film Archives will agree to preserve the files and include them in future exhibits. Through the "diversity of techniques and references they suggest", Miron's films of this period "form a hysterical compendium of the history of experimental cinema",[151] and for this reason alone deserve preservation as valuable documents of Canadian film heritage. More importantly, though, the films epitomize a forgotten,

---

[151] Etienne Desrosiers, *François Miron: Films Experimentaux,* (Montreal: Filmgrafix, 2010), 9.

laborious, and truly singular production style. Simply put, they are outstanding examples of their genre, but be forewarned: as you are watching these films "a brain probe is being inserted inside your head, through the light beam".[152]

[152] The Evil Surprise (Miron, 1994).

Appendix I: Cintel Raw Image (CRI) MediaInfo Report

General

Complete name :	/Volumes/MOTHERSHIP/FrancoisMiron/CRI/Cintel_EVIL_R1_2018-10-25_1153_C0011/Cintel_EVIL_R1_2018-10-25_1153_C0011_00086266.cri
File size :	5.27 MiB

Appendix II: Digital Picture Exchange (DPX) MediaInfo Report

General

Complete name :	/Volumes/MOTHERSHIP/FrancoisMiron/DPX/EvilSurprise/EvilSurprise_NYC/EvilSurprise_NYC00095372.dpx
CompleteName_Last :	/Volumes/MOTHERSHIP/FrancoisMiron/DPX/EvilSurprise/EvilSurprise_NYC/EvilSurprise_NYC00109037.dpx
Format :	DPX
Format version :	Version 1.0
File size :	15.8 MiB
Duration :	9 min 29 s
Overall bit rate :	233 kb/s
Encoded date :	2021-10-19T08:32:39EDT
Writing library :	daVinci

Video

Format :	DPX
Format version :	Version 1.0
Compression :	Raw
Format settings :	Big / Packed
Duration :	9 min 29 s
Bit rate :	233 kb/s
Width :	2 160 pixels
Height :	1 702 pixels
Display aspect ratio :	5:4
Frame rate :	24.000 FPS
Color space :	RGB
Bit depth :	12 bits
Scan type :	Progressive
Compression mode :	Lossless
*Bits/(Pixel*Frame) :*	0.003
Stream size :	15.8 MiB (100%)
Writing library :	daVinci
Encoded date :	2021-10-19T08:32:39EDT
Transfer characteristics :	Printing density

Appendix III: FFV1/MKV Preservation Master MediaInfo Reports

General

Unique ID :	241531148381143067018577487354947021267 (0xB5B535059DC6240DB6466BB8CDCDA9D3)
Complete name :	/Volumes/MOTHERSHIP/FrancoisMiron/MIRON_PRESERVATION/Master/EvilSurprise/EvilSurprise_NYC.mkv
Format :	Matroska
Format version :	Version 4
File size :	273 GiB
Duration :	15 min 43 s
Overall bit rate mode :	Variable
Overall bit rate :	2 487 Mb/s
Encoded by :	DaVinci Resolve
Writing application :	Lavf58.76.100
Writing library :	Lavf58.76.100
ErrorDetectionType :	Per level 1
Attachments :	RAWcooked reversibility data
DATE :	2018:10:25
TIME_REFERENCE :	172520000

Video

ID :	2
Format :	FFV1
Format version :	Version 3.4
Format settings, GOP :	N=1
Codec ID :	V_MS/VFW/FOURCC / FFV1
Duration :	15 min 43 s
Bit rate mode :	Variable
Width :	2 160 pixels
Height :	1 702 pixels
Display aspect ratio :	5:4
Frame rate mode :	Constant
Frame rate :	24.000 FPS
Color space :	RGB
Bit depth :	12 bits
Scan type :	Progressive
Compression mode :	Lossless
Writing library :	Lavc58.134.100 ffv1
Default :	Yes
Forced :	No
Matrix coefficients :	Identity
coder_type :	Range Coder
MaxSlicesCount :	100
ErrorDetectionType :	Per slice

Audio

ID :	1
Format :	FLAC
Format/Info :	Free Lossless Audio Codec
Codec ID :	A_FLAC
Duration :	15 min 43 s
Bit rate mode :	Variable
Channel(s) :	2 channels
Channel layout :	L R
Sampling rate :	48.0 kHz
Bit depth :	16 bits
Compression mode :	Lossless
Writing library :	Lavc58.134.100 flac
Default :	Yes
Forced :	No

General

Complete name :	/Volumes/MOTHERSHIP/FrancoisMiron/MIRON_PRESERVATION/Master/GapCurtain/GapCurtain_NYC_18fps.mkv
Format :	Matroska
Format version :	Version 4
File size :	73.9 GiB
Duration :	5 min 39 s
Overall bit rate mode :	Variable
Overall bit rate :	1 870 Mb/s
Writing application :	Lavf58.76.100
Writing library :	Lavf58.76.100
ErrorDetectionType :	Per level 1
Attachments :	RAWcooked reversibility data

Video

ID :	1
Format :	FFV1
Format version :	Version 3.4
Format settings, GOP :	N=1
Codec ID :	V_MS/VFW/FOURCC / FFV1
Duration :	5 min 39 s
Bit rate mode :	Variable
Bit rate :	1 833 Mb/s
Width :	2 160 pixels
Height :	1 702 pixels
Display aspect ratio :	5:4
Frame rate mode :	Constant
Frame rate :	18.000 FPS
Color space :	RGB
Bit depth :	12 bits
Scan type :	Progressive
Compression mode :	Lossless
*Bits/(Pixel*Frame) :*	27.697
Stream size :	72.4 GiB (98%)
Writing library :	Lavc58.134.100 ffv1
Default :	Yes
Forced :	No
Matrix coefficients :	Identity
coder_type :	Range Coder
MaxSlicesCount :	100
ErrorDetectionType :	Per slice

General

Unique ID :	281847271558939555373808295356495940364 (0xD409CF5C6ABB282063646E13A21DCB0C)
Complete name :	/Volumes/MOTHERSHIP/FrancoisMiron/MIRON_PRESERVATION/Master/GapCurtain/GapCurtain_NYC_24fps.mkv
Format :	Matroska
Format version :	Version 4
File size :	73.9 GiB
Duration :	4 min 14 s
Overall bit rate mode :	Variable
Overall bit rate :	2 493 Mb/s
Writing application :	Lavf58.76.100
Writing library :	Lavf58.76.100
ErrorDetectionType :	Per level 1
Attachments :	RAWcooked reversibility data

Video

ID :	1
Format :	FFV1
Format version :	Version 3.4
Format settings, GOP :	N=1
Codec ID :	V_MS/VFW/FOURCC / FFV1
Duration :	4 min 14 s
Bit rate mode :	Variable
Bit rate :	2 444 Mb/s
Width :	2 160 pixels
Height :	1 702 pixels
Display aspect ratio :	5:4
Frame rate mode :	Constant
Frame rate :	24.000 FPS
Color space :	RGB
Bit depth :	12 bits
Scan type :	Progressive
Compression mode :	Lossless
*Bits/(Pixel*Frame) :*	27.697
Stream size :	72.4 GiB (98%)
Writing library :	Lavc58.134.100 ffv1
Default :	Yes
Forced :	No
Matrix coefficients :	Identity
coder_type :	Range Coder
MaxSlicesCount :	100
ErrorDetectionType :	Per slice

General

Unique ID :	194903182650088676245621801353199159638 (0x92A0FCD1886AFCABD832A8BC437F0956)
Complete name :	/Volumes/MOTHERSHIP/FrancoisMiron/MIRON_PRESERVATION/Master/Ultraworld/Ultraworld_NYC.mkv
Format :	Matroska
Format version :	Version 4
File size :	299 GiB
Duration :	16 min 58 s
Overall bit rate mode :	Variable
Overall bit rate :	2 523 Mb/s
Encoded by :	DaVinci Resolve
Writing application :	Lavf58.76.100
Writing library :	Lavf58.76.100
ErrorDetectionType :	Per level 1
Attachments :	RAWcooked reversibility data
DATE :	2018:11:03
TIME_REFERENCE :	172522000

Video

ID :	2
Format :	FFV1
Format version :	Version 3.4
Format settings, GOP :	N=1
Codec ID :	V_MS/VFW/FOURCC / FFV1
Duration :	16 min 58 s
Bit rate mode :	Variable
Width :	2 160 pixels
Height :	1 702 pixels
Display aspect ratio :	5:4
Frame rate mode :	Constant
Frame rate :	24.000 FPS
Color space :	RGB
Bit depth :	12 bits
Scan type :	Progressive
Compression mode :	Lossless
Writing library :	Lavc58.134.100 ffv1
Default :	Yes
Forced :	No
Matrix coefficients :	Identity
coder_type :	Range Coder
MaxSlicesCount :	100
ErrorDetectionType :	Per slice

Audio

ID :	1
Format :	FLAC
Format/Info :	Free Lossless Audio Codec
Codec ID :	A_FLAC
Duration :	16 min 58 s
Bit rate mode :	Variable
Channel(s) :	2 channels
Channel layout :	L R
Sampling rate :	48.0 kHz
Bit depth :	16 bits
Compression mode :	Lossless
Writing library :	Lavc58.134.100 flac
Default :	Yes
Forced :	No

General

Unique ID :	286248993434055162746863714713039357704 (0xD7598D01438D58B004B3143263A54708)
Complete name :	/Volumes/MOTHERSHIP/FrancoisMiron/MIRON_PRESERVATION/Master/WhatIgnitesMe/WhatIgnitesMe_NYC.mkv
Format :	Matroska
Format version :	Version 4
File size :	146 GiB
Duration :	8 min 47 s
Overall bit rate mode :	Variable
Overall bit rate :	2 376 Mb/s
Encoded by :	DaVinci Resolve
Writing application :	Lavf58.76.100
Writing library :	Lavf58.76.100
ErrorDetectionType :	Per level 1
Attachments :	RAWcooked reversibility data
DATE :	2018:10:21
TIME_REFERENCE :	172520000

Video

ID :	2
Format :	FFV1
Format version :	Version 3.4
Format settings, GOP :	N=1
Codec ID :	V_MS/VFW/FOURCC / FFV1
Duration :	8 min 47 s
Bit rate mode :	Variable
Width :	2 160 pixels
Height :	1 702 pixels
Display aspect ratio :	5:4
Frame rate mode :	Constant
Frame rate :	24.000 FPS
Color space :	RGB
Bit depth :	12 bits
Scan type :	Progressive
Compression mode :	Lossless
Writing library :	Lavc58.134.100 ffv1
Default :	Yes
Forced :	No
Matrix coefficients :	Identity
coder_type :	Range Coder
MaxSlicesCount :	100
ErrorDetectionType :	Per slice

Audio

ID :	1
Format :	FLAC
Format/Info :	Free Lossless Audio Codec
Codec ID :	A_FLAC
Duration :	8 min 47 s
Bit rate mode :	Variable
Channel(s) :	2 channels
Channel layout :	L R
Sampling rate :	48.0 kHz
Bit depth :	16 bits
Compression mode :	Lossless
Writing library :	Lavc58.134.100 flac
Default :	Yes
Forced :	No

General

Unique ID :	270257549572635326699210696811835558586 (0x1454F898516145F210473117FC280BBA)
Complete name :	/Volumes/MOTHERSHIP/FrancoisMiron/MIRON_PRESERVATION/Master/Poursuite/Poursuite_Master.mkv
Format :	Matroska
Format version :	Version 4
File size :	159 GiB
Duration :	10 min 14 s
Overall bit rate mode :	Variable
Overall bit rate :	2 224 Mb/s
Writing application :	Lavf58.76.100
Writing library :	Lavf58.76.100
ErrorDetectionType :	Per level 1
Attachments :	RAWcooked reversibility data

Video

ID :	1
Format :	FFV1
Format version :	Version 3.4
Format settings, GOP :	N=1
Codec ID :	V_MS/VFW/FOURCC / FFV1
Duration :	10 min 14 s
Bit rate mode :	Variable
Width :	2 160 pixels
Height :	1 702 pixels
Display aspect ratio :	5:4
Frame rate mode :	Constant
Frame rate :	24.000 FPS
Color space :	RGB
Bit depth :	12 bits
Scan type :	Progressive
Compression mode :	Lossless
Writing library :	Lavc58.134.100 ffv1
Default :	Yes
Forced :	No
Matrix coefficients :	Identity
coder_type :	Range Coder
MaxSlicesCount :	100
ErrorDetectionType :	Per slice

Audio

ID :	2
Format :	FLAC
Format/Info :	Free Lossless Audio Codec
Codec ID :	A_FLAC
Duration :	10 min 14 s
Bit rate mode :	Variable
Channel(s) :	2 channels
Channel layout :	L R
Sampling rate :	48.0 kHz
Bit depth :	24 bits
Compression mode :	Lossless
Writing library :	Lavc58.134.100 flac
Default :	Yes
Forced :	No

General

Unique ID :	56686297832701971164063295677858282375 (0x2AA562438D09C8178008B9642C7F7B87)
Complete name :	/Volumes/MOTHERSHIP/FrancoisMiron/MIRON_PRESERVATION/Master/SquareRoot/SquareRoot_Master.mkv
Format :	Matroska
Format version :	Version 4
File size :	95.3 GiB
Duration :	6 min 17 s
Overall bit rate mode :	Variable
Overall bit rate :	2 169 Mb/s
Writing application :	Lavf58.76.100
Writing library :	Lavf58.76.100
ErrorDetectionType :	Per level 1
Attachments :	RAWcooked reversibility data

Video

ID :	1
Format :	FFV1
Format version :	Version 3.4
Format settings, GOP :	N=1
Codec ID :	V_MS/VFW/FOURCC / FFV1
Duration :	6 min 17 s
Bit rate mode :	Variable
Width :	2 160 pixels
Height :	1 702 pixels
Display aspect ratio :	5:4
Frame rate mode :	Constant
Frame rate :	24.000 FPS
Color space :	RGB
Bit depth :	12 bits
Scan type :	Progressive
Compression mode :	Lossless
Writing library :	Lavc58.134.100 ffv1
Default :	Yes
Forced :	No
Matrix coefficients :	Identity
coder_type :	Range Coder
MaxSlicesCount :	100
ErrorDetectionType :	Per slice

Audio

ID :	2
Format :	FLAC
Format/Info :	Free Lossless Audio Codec
Codec ID :	A_FLAC
Duration :	6 min 17 s
Bit rate mode :	Variable
Channel(s) :	2 channels
Channel layout :	L R
Sampling rate :	48.0 kHz
Bit depth :	24 bits
Compression mode :	Lossless
Writing library :	Lavc58.134.100 flac
Default :	Yes
Forced :	No

Appendix IV: ProRes/MOV Mezzanine MediaInfo Reports

General

Complete name :	/Volumes/MOTHERSHIP/FrancoisMiron/MIRON_PRESERVATION/Mezzanine/EvilSurprise/EvilSurprise_NYC_mezzanine.mov
Format :	MPEG-4
Format profile :	QuickTime
Codec ID :	qt 0000.02 (qt)
File size :	55.0 GiB
Duration :	15 min 43 s
Overall bit rate mode :	Variable
Overall bit rate :	501 Mb/s
Recorded date :	2018:10:25
Writing application :	Lavf58.76.100

Video

ID :	1
Format :	ProRes
Format version :	Version 0
Format profile :	422 HQ
Codec ID :	apch
Duration :	15 min 43 s
Bit rate mode :	Variable
Bit rate :	499 Mb/s
Width :	2 160 pixels
Height :	1 702 pixels
Display aspect ratio :	5:4
Frame rate mode :	Constant
Frame rate :	24.000 FPS
Color space :	RGB
Chroma subsampling :	4:2:2
Scan type :	Progressive
*Bits/(Pixel*Frame) :*	5.654
Stream size :	54.8 GiB (100%)
Writing library :	fmpg
Matrix coefficients :	Identity

Audio

ID :	2
Format :	PCM
Format settings :	Little / Signed
Codec ID :	in24
Duration :	15 min 43 s
Bit rate mode :	Constant
Bit rate :	2 304 kb/s
Channel(s) :	2 channels
Channel layout :	L R
Sampling rate :	48.0 kHz
Bit depth :	24 bits
Stream size :	259 MiB (0%)
Default :	Yes
Alternate group :	1

General

Complete name :	/Volumes/MOTHERSHIP/FrancoisMiron/MIRON_PRESERVATION/Mezzanine/GapCurtain/GapCurtain_NYC_18fps_mezzanine.mov
Format :	MPEG-4
Format profile :	QuickTime
Codec ID :	qt 0000.02 (qt)
File size :	15.5 GiB
Duration :	5 min 39 s
Overall bit rate mode :	Variable
Overall bit rate :	391 Mb/s
Writing application :	Lavf58.76.100

Video

ID :	1
Format :	ProRes
Format version :	Version 0
Format profile :	422 HQ
Codec ID :	apch
Duration :	5 min 39 s
Bit rate mode :	Variable
Bit rate :	391 Mb/s
Width :	2 160 pixels
Height :	1 702 pixels
Display aspect ratio :	5:4
Frame rate mode :	Constant
Frame rate :	18.000 FPS
Color space :	RGB
Chroma subsampling :	4:2:2
Scan type :	Progressive
*Bits/(Pixel*Frame) :*	5.912
Stream size :	15.5 GiB (100%)
Writing library :	fmpg
Matrix coefficients :	Identity

General

Complete name :	/Volumes/MOTHERSHIP/FrancoisMiron/MIRON_PRESERVATION/Mezzanine/GapCurtain/GapCurtain_NYC_24fps_mezzanine.mov
Format :	MPEG-4
Format profile :	QuickTime
Codec ID :	qt 0000.02 (qt)
File size :	15.5 GiB
Duration :	4 min 14 s
Overall bit rate mode :	Variable
Overall bit rate :	522 Mb/s
Writing application :	Lavf58.76.100

Video

ID :	1
Format :	ProRes
Format version :	Version 0
Format profile :	422 HQ
Codec ID :	apch
Duration :	4 min 14 s
Bit rate mode :	Variable
Bit rate :	522 Mb/s
Width :	2 160 pixels
Height :	1 702 pixels
Display aspect ratio :	5:4
Frame rate mode :	Constant
Frame rate :	24.000 FPS
Color space :	RGB
Chroma subsampling :	4:2:2
Scan type :	Progressive
*Bits/(Pixel*Frame) :*	5.912
Stream size :	15.5 GiB (100%)
Writing library :	fmpg
Matrix coefficients :	Identity

General

Complete name :	/Volumes/MOTHERSHIP/FrancoisMiron/MIRON_PRESERVATION/Mezzanine/Ultraworld/Ultraworld_NYC_mezzanine.mov
Format :	MPEG-4
Format profile :	QuickTime
Codec ID :	qt 0000.02 (qt)
File size :	58.9 GiB
Duration :	16 min 58 s
Overall bit rate mode :	Variable
Overall bit rate :	497 Mb/s
Recorded date :	2018:11:03
Writing application :	Lavf58.76.100

Video

ID :	1
Format :	ProRes
Format version :	Version 0
Format profile :	422 HQ
Codec ID :	apch
Duration :	16 min 58 s
Bit rate mode :	Variable
Bit rate :	495 Mb/s
Width :	2 160 pixels
Height :	1 702 pixels
Display aspect ratio :	5:4
Frame rate mode :	Constant
Frame rate :	24.000 FPS
Color space :	RGB
Chroma subsampling :	4:2:2
Scan type :	Progressive
*Bits/(Pixel*Frame) :*	5.606
Stream size :	58.7 GiB (100%)
Writing library :	fmpg
Matrix coefficients :	Identity

Audio

ID :	2
Format :	PCM
Format settings :	Little / Signed
Codec ID :	in24
Duration :	16 min 58 s
Bit rate mode :	Constant
Bit rate :	2 304 kb/s
Channel(s) :	2 channels
Channel layout :	L R
Sampling rate :	48.0 kHz
Bit depth :	24 bits
Stream size :	280 MiB (0%)
Default :	Yes
Alternate group :	1

General

Complete name :	/Volumes/MOTHERSHIP/FrancoisMiron/MIRON_PRESERVATION/Mezzanine/WhatIgnitesMe/WhatIgnitesMe_NYC_mezzanine.mov
Format :	MPEG-4
Format profile :	QuickTime
Codec ID :	qt 0000.02 (qt)
File size :	30.8 GiB
Duration :	8 min 47 s
Overall bit rate mode :	Variable
Overall bit rate :	502 Mb/s
Recorded date :	2018:10:21
Writing application :	Lavf58.76.100

Video

ID :	1
Format :	ProRes
Format version :	Version 0
Format profile :	422 HQ
Codec ID :	apch
Duration :	8 min 47 s
Bit rate mode :	Variable
Bit rate :	499 Mb/s
Width :	2 160 pixels
Height :	1 702 pixels
Display aspect ratio :	5:4
Frame rate mode :	Constant
Frame rate :	24.000 FPS
Color space :	RGB
Chroma subsampling :	4:2:2
Scan type :	Progressive
*Bits/(Pixel*Frame) :*	5.660
Stream size :	30.6 GiB (100%)
Writing library :	fmpg
Matrix coefficients :	Identity

Audio

ID :	2
Format :	PCM
Format settings :	Little / Signed
Codec ID :	in24
Duration :	8 min 47 s
Bit rate mode :	Constant
Bit rate :	2 304 kb/s
Channel(s) :	2 channels
Channel layout :	L R
Sampling rate :	48.0 kHz
Bit depth :	24 bits
Stream size :	145 MiB (0%)
Default :	Yes
Alternate group :	1

General

Complete name :	/Volumes/MOTHERSHIP/FrancoisMiron/MIRON_PRESERVATION/Mezzanine/Poursuite/Poursuite_Mezzanine.mov
Format :	MPEG-4
Format profile :	QuickTime
Codec ID :	qt 0000.02 (qt)
File size :	31.2 GiB
Duration :	10 min 14 s
Overall bit rate mode :	Variable
Overall bit rate :	437 Mb/s
Writing application :	Lavf58.76.100

Video

ID :	1
Format :	ProRes
Format version :	Version 0
Format profile :	422 HQ
Codec ID :	apch
Duration :	10 min 14 s
Bit rate mode :	Variable
Bit rate :	435 Mb/s
Width :	2 160 pixels
Height :	1 702 pixels
Display aspect ratio :	5:4
Frame rate mode :	Constant
Frame rate :	24.000 FPS
Color space :	YUV
Chroma subsampling :	4:2:2
Scan type :	Progressive
*Bits/(Pixel*Frame) :*	4.928
Stream size :	31.1 GiB (99%)
Writing library :	fmpg

Audio

ID :	2
Format :	PCM
Format settings :	Little / Signed
Codec ID :	in24
Duration :	10 min 14 s
Bit rate mode :	Constant
Bit rate :	2 304 kb/s
Channel(s) :	2 channels
Channel layout :	L R
Sampling rate :	48.0 kHz
Bit depth :	24 bits
Stream size :	169 MiB (1%)
Default :	Yes
Alternate group :	1

General

Complete name :	/Volumes/MOTHERSHIP/FrancoisMiron/MIRON_PRESERVATION/Mezzanine/SquareRoot/SquareRoot_Mezzanine.mov
Format :	MPEG-4
Format profile :	QuickTime
Codec ID :	qt 0000.02 (qt)
File size :	19.2 GiB
Duration :	6 min 17 s
Overall bit rate mode :	Variable
Overall bit rate :	437 Mb/s
Writing application :	Lavf58.76.100

Video

ID :	1
Format :	ProRes
Format version :	Version 0
Format profile :	422 HQ
Codec ID :	apch
Duration :	6 min 17 s
Bit rate mode :	Variable
Bit rate :	435 Mb/s
Width :	2 160 pixels
Height :	1 702 pixels
Display aspect ratio :	5:4
Frame rate mode :	Constant
Frame rate :	24.000 FPS
Color space :	YUV
Chroma subsampling :	4:2:2
Scan type :	Progressive
*Bits/(Pixel*Frame) :*	4.928
Stream size :	19.1 GiB (99%)
Writing library :	fmpg

Audio

ID :	2
Format :	PCM
Format settings :	Little / Signed
Codec ID :	in24
Duration :	6 min 17 s
Bit rate mode :	Constant
Bit rate :	2 304 kb/s
Channel(s) :	2 channels
Channel layout :	L R
Sampling rate :	48.0 kHz
Bit depth :	24 bits
Stream size :	104 MiB (1%)
Default :	Yes
Alternate group :	1

Appendix V: AVID DNxHR/MXF Production Masters MediaInfo Reports

General

Complete name :	/Volumes/MOTHERSHIP/FrancoisMiron/MIRON_PRESERVATION /AVID/Collapse/Collapse_NYC_AVID.mxf
Format :	MXF
Commercial name :	DNxHR HQX
Format version :	1.3
Format profile :	OP-1a
Format settings :	Closed / Complete
File size :	21.2 GiB
Duration :	9 min 42 s
Overall bit rate :	312 Mb/s
Encoded date :	0-00-00 00:00:00.000
Writing application :	FFmpeg OP1a Muxer 58.76.100.0.0
Writing library :	Lavf (darwin) 58.76.100.0.0

Video

ID :	2
Format :	VC-3
Commercial name :	DNxHR HQX
Format version :	Version 3
Format profile :	RI@HQX
Format settings, wrapping mode :	Frame
Codec ID :	0D01030102110100-0401020271250000
Duration :	9 min 42 s
Bit rate mode :	Constant
Bit rate :	312 Mb/s
Width :	2 160 pixels
Height :	1 702 pixels
Display aspect ratio :	5:4
Frame rate :	24.000 FPS
Color space :	YUV
Chroma subsampling :	4:2:2
Bit depth :	10 bits
Scan type :	Progressive
*Bits/(Pixel*Frame) :*	3.539
Stream size :	21.2 GiB (100%)
Color range :	Limited

General

Complete name :	/Volumes/MOTHERSHIP/FrancoisMiron/MIRON_PRESERVATION /AVID/EvilSurprise/EvilSurprise_NYC_AVID.mxf
Format :	MXF
Commercial name :	DNxHR HQX
Format version :	Version 1.3
Format profile :	OP-1a
Format settings :	Closed / Complete
File size :	34.5 GiB
Duration :	15 min 43 s
Overall bit rate :	314 Mb/s
Encoded date :	0-00-00 00:00:00.000
Writing application :	FFmpeg OP1a Muxer 58.76.100.0.0
Writing library :	Lavf (darwin) 58.76.100.0.0

Video

ID :	2
Format :	VC-3
Commercial name :	DNxHR HQX
Format version :	Version 3
Format profile :	RI
Format level :	HQX
Format settings, wrapping mode :	Frame
Codec ID :	0D01030102110100-0401020271250000
Duration :	15 min 43 s
Bit rate mode :	Constant
Bit rate :	312 Mb/s
Width :	2 160 pixels
Height :	1 702 pixels
Display aspect ratio :	5:4
Frame rate :	24.000 FPS
Color space :	YUV
Chroma subsampling :	4:2:2
Bit depth :	10 bits
Scan type :	Progressive
*Bits/(Pixel*Frame) :*	3.539
Stream size :	34.3 GiB (99%)

General

Complete name :	/Volumes/MOTHERSHIP/FrancoisMiron/MIRON_PRESERVATION /AVID/GapCurtain/GapCurtain_NYC_24fps_AVID.mxf
Format :	MXF
Commercial name :	DNxHR HQX
Format version :	1.3
Format profile :	OP-1a
Format settings :	Closed / Complete
File size :	9.26 GiB
Duration :	4 min 14 s
Overall bit rate :	312 Mb/s
Encoded date :	0-00-00 00:00:00.000
Writing application :	FFmpeg OP1a Muxer 58.76.100.0.0
Writing library :	Lavf (darwin) 58.76.100.0.0

Video

ID :	2
Format :	VC-3
Commercial name :	DNxHR HQX
Format version :	Version 3
Format profile :	RI@HQX
Format settings, wrapping mode :	Frame
Codec ID :	0D01030102110100-0401020271250000
Duration :	4 min 14 s
Bit rate mode :	Constant
Bit rate :	312 Mb/s
Width :	2 160 pixels
Height :	1 702 pixels
Display aspect ratio :	5:4
Frame rate :	24.000 FPS
Color space :	YUV
Chroma subsampling :	4:2:2
Bit depth :	10 bits
Scan type :	Progressive
*Bits/(Pixel*Frame) :*	3.539
Stream size :	9.25 GiB (100%)
Color range :	Limited

General

Complete name :	/Volumes/MOTHERSHIP/FrancoisMiron/MIRON_PRESERVATION /AVID/Ultraworld/Ultraworld_NYC_AVID.mxf
Format :	MXF
Commercial name :	DNxHR HQX
Format version :	1.3
Format profile :	OP-1a
Format settings :	Closed / Complete
File size :	37.2 GiB
Duration :	16 min 58 s
Overall bit rate :	314 Mb/s
Encoded date :	0-00-00 00:00:00.000
Writing application :	FFmpeg OP1a Muxer 58.76.100.0.0
Writing library :	Lavf (darwin) 58.76.100.0.0

Video

ID :	2
Format :	VC-3
Commercial name :	DNxHR HQX
Format version :	Version 3
Format profile :	RI@HQX
Format settings, wrapping mode :	Frame
Codec ID :	0D01030102110100-0401020271250000
Duration :	16 min 58 s
Bit rate mode :	Constant
Bit rate :	312 Mb/s
Width :	2 160 pixels
Height :	1 702 pixels
Display aspect ratio :	5:4
Frame rate :	24.000 FPS
Color space :	YUV
Chroma subsampling :	4:2:2
Bit depth :	10 bits
Scan type :	Progressive
*Bits/(Pixel*Frame) :*	3.539
Stream size :	37.0 GiB (99%)
Color range :	Limited

General

Complete name :	/Volumes/MOTHERSHIP/FrancoisMiron/MIRON_PRESERVATION /AVID/WhatIgnitesMe/WhatIgnitesMe_NYC_AVID.mxf
Format :	MXF
Commercial name :	DNxHR HQX
Format version :	1.3
Format profile :	OP-1a
Format settings :	Closed / Complete
File size :	19.3 GiB
Duration :	8 min 47 s
Overall bit rate :	314 Mb/s
Encoded date :	0-00-00 00:00:00.000
Writing application :	FFmpeg OP1a Muxer 58.76.100.0.0
Writing library :	Lavf (darwin) 58.76.100.0.0

Video

ID :	2
Format :	VC-3
Commercial name :	DNxHR HQX
Format version :	Version 3
Format profile :	RI@HQX
Format settings, wrapping mode :	Frame
Codec ID :	0D01030102110100-0401020271250000
Duration :	8 min 47 s
Bit rate mode :	Constant
Bit rate :	312 Mb/s
Width :	2 160 pixels
Height :	1 702 pixels
Display aspect ratio :	5:4
Frame rate :	24.000 FPS
Color space :	YUV
Chroma subsampling :	4:2:2
Bit depth :	10 bits
Scan type :	Progressive
*Bits/(Pixel*Frame) :*	3.539
Stream size :	19.2 GiB (99%)
Color range :	Limited

General

Complete name :	/Volumes/MOTHERSHIP/FrancoisMiron/MIRON_PRESERVATION/AVID/Poursuite/Poursuite_AVID.mxf
Format :	MXF
Commercial name :	DNxHR HQX
Format version :	1.3
Format profile :	OP-1a
Format settings :	Closed / Complete
File size :	22.4 GiB
Duration :	10 min 14 s
Overall bit rate :	314 Mb/s
Encoded date :	0-00-00 00:00:00.000
Writing application :	FFmpeg OP1a Muxer 58.76.100.0.0
Writing library :	Lavf (darwin) 58.76.100.0.0

Video

ID :	2
Format :	VC-3
Commercial name :	DNxHR HQX
Format version :	Version 3
Format profile :	RI@HQX
Format settings, wrapping mode :	Frame
Codec ID :	0D01030102110100-0401020271250000
Duration :	10 min 14 s
Bit rate mode :	Constant
Bit rate :	312 Mb/s
Width :	2 160 pixels
Height :	1 702 pixels
Display aspect ratio :	5:4
Frame rate :	24.000 FPS
Color space :	YUV
Chroma subsampling :	4:2:2
Bit depth :	10 bits
Scan type :	Progressive
*Bits/(Pixel*Frame) :*	3.539
Stream size :	22.3 GiB (99%)
Color range :	Limited

Audio

ID :	3
Format :	PCM
Format settings :	Little
Format settings, wrapping mode :	Frame (AES)
Codec ID :	0D01030102060300
Duration :	10 min 14 s
Bit rate mode :	Constant
Bit rate :	1 536 kb/s
Channel(s) :	2 channels
Sampling rate :	48.0 kHz
Frame rate :	24.000 FPS (2000 SPF)
Bit depth :	16 bits
Stream size :	112 MiB (0%)
Locked :	Yes

Other #1

ID :	1-Material
Type :	Time code
Format :	MXF TC
Frame rate :	24.000 FPS
Time code of first frame :	00:00:00:00
Time code settings :	Material Package
Time code, striped :	Yes

Other #2

ID :	1-Source
Type :	Time code
Format :	MXF TC
Frame rate :	24.000 FPS
Time code of first frame :	00:00:00:00
Time code settings :	Source Package
Time code, striped :	Yes

Other #3

Type :	Time code
Format :	SMPTE TC
Muxing mode :	SDTI
Frame rate :	24.000 FPS
Time code of first frame :	00:00:00:00

General

Complete name :	/Volumes/MOTHERSHIP/FrancoisMiron/MIRON_PRESERVATION/AVID/SquareRoot/SquareRoot_AVID.mxf
Format :	MXF
Commercial name :	DNxHR HQX
Format version :	1.3
Format profile :	OP-1a
Format settings :	Closed / Complete
File size :	13.8 GiB
Duration :	6 min 17 s
Overall bit rate :	314 Mb/s
Encoded date :	0-00-00 00:00:00.000
Writing application :	FFmpeg OP1a Muxer 58.76.100.0.0
Writing library :	Lavf (darwin) 58.76.100.0.0

Video

ID :	2
Format :	VC-3
Commercial name :	DNxHR HQX
Format version :	Version 3
Format profile :	RI@HQX
Format settings, wrapping mode :	Frame
Codec ID :	0D01030102110100-0401020271250000
Duration :	6 min 17 s
Bit rate mode :	Constant
Bit rate :	312 Mb/s
Width :	2 160 pixels
Height :	1 702 pixels
Display aspect ratio :	5:4
Frame rate :	24.000 FPS
Color space :	YUV
Chroma subsampling :	4:2:2
Bit depth :	10 bits
Scan type :	Progressive
*Bits/(Pixel*Frame) :*	3.539
Stream size :	13.7 GiB (99%)
Color range :	Limited

Audio

ID :	3
Format :	PCM
Format settings :	Little
Format settings, wrapping mode :	Frame (AES)
Codec ID :	0D01030102060300
Duration :	6 min 17 s
Bit rate mode :	Constant
Bit rate :	1 536 kb/s
Channel(s) :	2 channels
Sampling rate :	48.0 kHz
Frame rate :	24.000 FPS (2000 SPF)
Bit depth :	16 bits
Stream size :	69.1 MiB (0%)
Locked :	Yes

Other #1

ID :	1-Material
Type :	Time code
Format :	MXF TC
Frame rate :	24.000 FPS
Time code of first frame :	00:00:00:00
Time code settings :	Material Package
Time code, striped :	Yes

Other #2

ID :	1-Source
Type :	Time code
Format :	MXF TC
Frame rate :	24.000 FPS
Time code of first frame :	00:00:00:00
Time code settings :	Source Package
Time code, striped :	Yes

Other #3

Type :	Time code
Format :	SMPTE TC
Muxing mode :	SDTI
Frame rate :	24.000 FPS
Time code of first frame :	00:00:00:00

Appendix VI: H.264/MP4 Access Derivatives MediaInfoReports

General

Complete name :	/Volumes/MOTHERSHIP/FrancoisMiron/MIRON_PRESERVATION/Derivatives/Access/Collapse/Collapse_NYC_access.mp4
Format :	MPEG-4
Format profile :	Base Media
File size :	710 MiB
Duration :	9 min 42 s
Overall bit rate :	10.2 Mb/s
Writing application :	Lavf58.76.100

Video

ID :	1
Format :	AVC
Format/Info :	Advanced Video Codec
Format profile :	High
Format level :	4
Format settings, CABAC :	Yes
Format settings, Reference frames :	4 frames
Codec ID :	avc1
Duration :	9 min 42 s
Bit rate :	10.2 Mb/s
Maximum bit rate :	12.0 Mb/s
Width :	1 920 pixels
Height :	1 080 pixels
Display aspect ratio :	5:4
Frame rate mode :	Constant
Frame rate :	24.000 FPS
Color space :	RGB
Chroma subsampling :	4:2:0
Bit depth :	8 bits
Scan type :	Progressive
*Bits/(Pixel*Frame) :*	0.205
Stream size :	709 MiB (100%)
Writing library :	x264 core 163 r3060 5db6aa6

General

Complete name :	/Volumes/MOTHERSHIP/FrancoisMiron/MIRON_PRESERVATION/Access/EvilSurprise/EvilSurprise_NYC_access.mp4
Format :	MPEG-4
Format profile :	Base Media
Codec ID :	isom (isom/iso2/avc1/mp41)
File size :	1.09 GiB
Duration :	15 min 43 s
Overall bit rate :	9 900 kb/s
Recorded date :	2018:10:25
Writing application :	Lavf58.76.100

Video

ID :	1
Format :	AVC
Format/Info :	Advanced Video Codec
Format profile :	High@L4
Format settings :	CABAC / 4 Ref Frames
Format settings, CABAC :	Yes
Format settings, Reference frames :	4 frames
Codec ID :	avc1
Codec ID/Info :	Advanced Video Coding
Duration :	15 min 43 s
Bit rate :	9 766 kb/s
Maximum bit rate :	12.0 Mb/s
Width :	1 920 pixels
Height :	1 080 pixels
Display aspect ratio :	5:4
Frame rate mode :	Constant
Frame rate :	24.000 FPS
Color space :	RGB
Chroma subsampling :	4:2:0
Bit depth :	8 bits
Scan type :	Progressive
*Bits/(Pixel*Frame) :*	0.196
Stream size :	1.07 GiB (99%)

General

Complete name :	/Volumes/MOTHERSHIP/FrancoisMiron/MIRON_PRESERVATION/Access /GapCurtain/GapCurtain_NYC_18fps_access.mp4
Format :	MPEG-4
Format profile :	Base Media
Codec ID :	isom (isom/iso2/avc1/mp41)
File size :	416 MiB
Duration :	5 min 39 s
Overall bit rate :	10.3 Mb/s
Writing application :	Lavf58.76.100

Video

ID :	1
Format :	AVC
Format/Info :	Advanced Video Codec
Format profile :	High@L4
Format settings :	CABAC / 4 Ref Frames
Format settings, CABAC :	Yes
Format settings, Reference frames :	4 frames
Codec ID :	avc1
Codec ID/Info :	Advanced Video Coding
Duration :	5 min 39 s
Bit rate :	10.3 Mb/s
Maximum bit rate :	12.0 Mb/s
Width :	1 920 pixels
Height :	1 080 pixels
Display aspect ratio :	5:4
Frame rate mode :	Constant
Frame rate :	18.000 FPS
Color space :	RGB
Chroma subsampling :	4:2:0
Bit depth :	8 bits
Scan type :	Progressive
*Bits/(Pixel*Frame) :*	0.275
Stream size :	415 MiB (100%)
Writing library :	x264 core 163 r3060 5db6aa6

General

Complete name :	/Volumes/MOTHERSHIP/FrancoisMiron/MIRON_PRESERVATION/Access /GapCurtain/GapCurtain_NYC_24fps_access.mp4
Format :	MPEG-4
Format profile :	Base Media
Codec ID :	isom (isom/iso2/avc1/mp41)
File size :	312 MiB
Duration :	4 min 14 s
Overall bit rate :	10.3 Mb/s
Writing application :	Lavf58.76.100

Video

ID :	1
Format :	AVC
Format/Info :	Advanced Video Codec
Format profile :	High@L4
Format settings :	CABAC / 4 Ref Frames
Format settings, CABAC :	Yes
Format settings, Reference frames :	4 frames
Codec ID :	avc1
Codec ID/Info :	Advanced Video Coding
Duration :	4 min 14 s
Bit rate :	10.3 Mb/s
Maximum bit rate :	12.0 Mb/s
Width :	1 920 pixels
Height :	1 080 pixels
Display aspect ratio :	5:4
Frame rate mode :	Constant
Frame rate :	24.000 FPS
Color space :	RGB
Chroma subsampling :	4:2:0
Bit depth :	8 bits
Scan type :	Progressive
*Bits/(Pixel*Frame) :*	0.207
Stream size :	312 MiB (100%)
Writing library :	x264 core 163 r3060 5db6aa6

General

Complete name :	/Volumes/MOTHERSHIP/FrancoisMiron/MIRON PRESERVATION/Access/Ultraworld/Ultraworld_NYC_access.mp4
Format :	MPEG-4
Format profile :	Base Media
Codec ID :	isom (isom/iso2/avc1/mp41)
File size :	1.23 GiB
Duration :	16 min 58 s
Overall bit rate :	10.4 Mb/s
Recorded date :	2018:11:03
Writing application :	Lavf58.76.100

Video

ID :	1
Format :	AVC
Format/Info :	Advanced Video Codec
Format profile :	High@L4
Format settings :	CABAC / 4 Ref Frames
Format settings, CABAC :	Yes
Format settings, Reference frames :	4 frames
Codec ID :	avc1
Codec ID/Info :	Advanced Video Coding
Duration :	16 min 58 s
Bit rate :	10.2 Mb/s
Maximum bit rate :	12.0 Mb/s
Width :	1 920 pixels
Height :	1 080 pixels
Display aspect ratio :	5:4
Frame rate mode :	Constant
Frame rate :	24.000 FPS
Color space :	RGB
Chroma subsampling :	4:2:0
Bit depth :	8 bits
Scan type :	Progressive
*Bits/(Pixel*Frame) :*	0.206
Stream size :	1.21 GiB (99%)

General

Complete name :	/Volumes/MOTHERSHIP/FrancoisMiron/MIRON_PRESERVATION/Access /WhatIgnitesMe/WhatIgnitesMe_NYC_access.mp4
Format :	MPEG-4
Format profile :	Base Media
Codec ID :	isom (isom/iso2/avc1/mp41)
File size :	641 MiB
Duration :	8 min 47 s
Overall bit rate :	10.2 Mb/s
Recorded date :	2018:10:21
Writing application :	Lavf58.76.100

Video

ID :	1
Format :	AVC
Format/Info :	Advanced Video Codec
Format profile :	High@L4
Format settings :	CABAC / 4 Ref Frames
Format settings, CABAC :	Yes
Format settings, Reference frames :	4 frames
Codec ID :	avc1
Codec ID/Info :	Advanced Video Coding
Duration :	8 min 47 s
Bit rate :	10.1 Mb/s
Maximum bit rate :	12.0 Mb/s
Width :	1 920 pixels
Height :	1 080 pixels
Display aspect ratio :	5:4
Frame rate mode :	Constant
Frame rate :	24.000 FPS
Color space :	RGB
Chroma subsampling :	4:2:0
Bit depth :	8 bits
Scan type :	Progressive
*Bits/(Pixel*Frame) :*	0.202
Stream size :	632 MiB (99%)

General

Complete name :	/Volumes/MOTHERSHIP/FrancoisMiron/MIRON_PRESERVATION/Access/Poursuite/Poursuite_Access.mp4
Format :	MPEG-4
Format profile :	Base Media
Codec ID :	isom (isom/iso2/avc1/mp41)
File size :	715 MiB
Duration :	10 min 14 s
Overall bit rate :	9 765 kb/s
Writing application :	Lavf58.76.100

Video

ID :	1
Format :	AVC
Format/Info :	Advanced Video Codec
Format profile :	High@L4
Format settings :	CABAC / 4 Ref Frames
Format settings, CABAC :	Yes
Format settings, Reference frames :	4 frames
Codec ID :	avc1
Codec ID/Info :	Advanced Video Coding
Duration :	10 min 14 s
Bit rate :	9 631 kb/s
Maximum bit rate :	12.0 Mb/s
Width :	1 920 pixels
Height :	1 080 pixels
Display aspect ratio :	5:4
Frame rate mode :	Constant
Frame rate :	24.000 FPS
Color space :	YUV
Chroma subsampling :	4:2:0
Bit depth :	8 bits
Scan type :	Progressive
*Bits/(Pixel*Frame) :*	0.194
Stream size :	705 MiB (99%)
Writing library :	x264 core 163 r3060 5db6aa6
Encoding settings :	cabac=1 / ref=3 / deblock=1:0:0 / analyse=0x3:0x113 / me=hex / subme=7 / psy=1 / psy_rd=1.00:0.00 / mixed_ref=1 / me_range=16 / chroma_me=1 / trellis=1 / 8x8dct=1 / cqm=0 / deadzone=21,11 / fast_pskip=1 / chroma_qp_offset=-2 / threads=6 / lookahead_threads=1 / sliced_threads=0 / nr=0 / decimate=1 / interlaced=0 / bluray_compat=0 / constrained_intra=0 / bframes=3 / b_pyramid=2 / b_adapt=1 / b_bias=0 / direct=1 / weightb=1 / open_gop=0 / weightp=2 / keyint=250 / keyint_min=24 / scenecut=40 / intra_refresh=0 / rc_lookahead=40 / rc=crf / mbtree=1 / crf=18.0 / qcomp=0.60 / qpmin=0 / qpmax=69 / qpstep=4 / vbv_maxrate=12000 / vbv_bufsize=2000 / crf_max=0.0 / nal_hrd=none / filler=0 / ip_ratio=1.40 / aq=1:1.00
Codec configuration box :	avcC

Audio

ID :	2
Format :	AAC LC
Format/Info :	Advanced Audio Codec Low Complexity
Codec ID :	mp4a-40-2
Duration :	10 min 14 s
Source duration :	10 min 14 s
Source_Duration_LastFrame :	-17 ms
Bit rate mode :	Constant
Bit rate :	128 kb/s
Channel(s) :	2 channels
Channel layout :	L R
Sampling rate :	48.0 kHz
Frame rate :	46.875 FPS (1024 SPF)
Compression mode :	Lossy
Stream size :	9.40 MiB (1%)
Source stream size :	9.40 MiB (1%)
Default :	Yes
Alternate group :	1
mdhd_Duration :	614042

General

Complete name :	/Volumes/MOTHERSHIP/FrancoisMiron/MIRON_PRESERVATION/Access/SquareRoot/SquareRoot_Access.mp4
Format :	MPEG-4
Format profile :	Base Media
Codec ID :	isom (isom/iso2/avc1/mp41)
File size :	445 MiB
Duration :	6 min 17 s
Overall bit rate :	9 892 kb/s
Writing application :	Lavf58.76.100

Video

ID :	1
Format :	AVC
Format/Info :	Advanced Video Codec
Format profile :	High@L4
Format settings :	CABAC / 4 Ref Frames
Format settings, CABAC :	Yes
Format settings, Reference frames :	4 frames
Codec ID :	avc1
Codec ID/Info :	Advanced Video Coding
Duration :	6 min 17 s
Bit rate :	9 759 kb/s
Maximum bit rate :	12.0 Mb/s
Width :	1 920 pixels
Height :	1 080 pixels
Display aspect ratio :	5:4
Frame rate mode :	Constant
Frame rate :	24.000 FPS
Color space :	YUV
Chroma subsampling :	4:2:0
Bit depth :	8 bits
Scan type :	Progressive
*Bits/(Pixel*Frame) :*	0.196
Stream size :	439 MiB (99%)
Writing library :	x264 core 163 r3060 5db6aa6
Encoding settings :	cabac=1 / ref=3 / deblock=1:0:0 / analyse=0x3:0x113 / me=hex / subme=7 / psy=1 / psy_rd=1.00:0.00 / mixed_ref=1 / me_range=16 / chroma_me=1 / trellis=1 / 8x8dct=1 / cqm=0 / deadzone=21,11 / fast_pskip=1 / chroma_qp_offset=-2 / threads=6 / lookahead_threads=1 / sliced_threads=0 / nr=0 / decimate=1 / interlaced=0 / bluray_compat=0 / constrained_intra=0 / bframes=3 / b_pyramid=2 / b_adapt=1 / b_bias=0 / direct=1 / weightb=1 / open_gop=0 / weightp=2 / keyint=250 / keyint_min=24 / scenecut=40 / intra_refresh=0 / rc_lookahead=40 / rc=crf / mbtree=1 / crf=18.0 / qcomp=0.60 / qpmin=0 / qpmax=69 / qpstep=4 / vbv_maxrate=12000 / vbv_bufsize=2000 / crf_max=0.0 / nal_hrd=none / filler=0 / ip_ratio=1.40 / aq=1:1.00
Codec configuration box :	avcC

Audio

ID :	2
Format :	AAC LC
Format/Info :	Advanced Audio Codec Low Complexity
Codec ID :	mp4a-40-2
Duration :	6 min 17 s
Source duration :	6 min 17 s
Source_Duration_LastFrame :	-15 ms
Bit rate mode :	Constant
Bit rate :	129 kb/s
Channel(s) :	2 channels
Channel layout :	L R
Sampling rate :	48.0 kHz
Frame rate :	46.875 FPS (1024 SPF)
Compression mode :	Lossy
Stream size :	5.79 MiB (1%)
Source stream size :	5.79 MiB (1%)
Default :	Yes
Alternate group :	1
mdhd_Duration :	377500

Works Cited:

"About Apple ProRes." *Apple,* April 19, 2018. https://support.apple.com/en-us/HT202410.

"Arthur Lipsett Biography." *National Film Board of Canada,* accessed February 20, 2022. https://web.archive.org/web/20120307223030/http://www3.nfb.ca/animation/objanim/en/filmmakers/Arthur-Lipsett/biography.php.

"Avid Supported Video File Formats." *Avid Technologies Inc.,* accessed February 20, 2022. https://resources.avid.com/SupportFiles/attach/Avid_Supported_Video_File_Formats.pdf

"BDMV." *Afterdawn,* accessed February 20, 2022. https://www.afterdawn.com/glossary/term.cfm/bd-mv.

Cole, David R. and Joff P.N. Bradley. 2016. *A Pedagogy of Cinema.* Rotterdam: Sense Publishers.

Corbly, James Edward. 2014. "The Free Software Alternative: Freeware, Open Source Software, and Libraries". *Information Technology and Libraries* 33 (3), 65-75. https://doi.org/10.6017/ital.v33i3.5105.

Desrosiers, Etienne. 2010. *François Miron: Films Experimentaux.* Montreal: Filmgrafix.

"DNxHR Codec Bandwidth Specifications." *AVID Knowledge Base,* accessed February 20, 2022. https://avid.secure.force.com/pkb/articles/en_US/White_Paper/DNxHR-Codec-Bandwidth-Specifications.

Enticknap, Leo. 2013. *Film Preservation: The Culture and Science of Audiovisual Heritage.* New York: Palgrave Macmillan.

Enticknap, Leo. 2005. *Moving Image Technology: From Zoetrope to Digital.* London: Wallflower Press.

"FFmpeg General Documentation." FFmpeg.org. November 21, 2021. https://ffmpeg.org/general.html#SEC6.

Gartenberg, Jon. "The Fragile Emulsion." *The Moving Image: The Journal of the Association of Moving ImageArchivists* 2, no. 2 (2002): 142–53. http://www.jstor.org/stable/41167089.

"H.264 Video Encoding Guide." *Trac*, accessed February 20, 2022. https://trac.ffmpeg.org/wiki/Encode/H.264.

Kromer, Reto. "Matroska and FFV1: One File Format for Film and Video Archiving?" *Journal of Film Preservation* 96, (April, 2017): 41-45.

Lauber, Jeffrey. 2019. *History and Ethics of Film Restoration.* MA Thesis, New York University, Moving Image Archiving and Preservation.

Peltzman, Shira. 2013. *Unlocking the DCP: Evaluating the Risks, Preservation, and Long-Term Management of Digital Cinema Packages in Audiovisual Archives.* MA Thesis, New York University, Moving Image Archiving and Preservation.

MediaConch." *MediaArea,* accessed February 20, 2022. https://mediaarea.net/MediaConch.

Miron, François. *Flake.* By Jack Johnson. KSLO Radio, 2002.

Miron, François. Interview on KHUM Radio, 2002.

"Norman McLaren Biography." *National Film Board of Canada,* accessed February 20, 2022. https://web.archive.org/web/20120428054648/http://www3.nfb.ca/animation/objanim/en/filmmakers/Norman-McLaren/overview.php.

O'Leary, Kieran. "Introduction to FFV1 and Matroska for Film Scans." *Digital Preservation Scripts* (blog), 2016. https://kieranjol.wordpress.com/2016/10/07/introduction-to-ffv1-and matroska-for-film-scans/.

"Program Definition." *Linux Information Project,* June 8, 2005. http://www.linfo.org/program.html.

"QCTools." *MediaArea,* accessed February 20, 2022. https://mediaarea.net/qctools.

"RAWcooked." *MediaArea,* 2022. https://mediaarea.net/rawcooked.

"RAWcooked Manual." *MediaArea,* 2018-2021.

"Recommendations on Preservation Files for Use in the Digitization of Analog Audio and Video Recordings and Motion Picture Films." *Libraries and Archives Canada,* accessed March 19, 2022. https://www.bac-lac.gc.ca/eng/about-us/publications/Documents/preservation-file-formats.pdf#search=%2Cfilm%20preservation%20standards

"Recommended upload encoding settings." *YouTube Help*, accessed February 20, 2022. https://support.google.com/youtube/answer/1722171?hl=en#zippy=%2Cbitrate.

Rees, A. L. A History of Experimental Film and Video: From the Canonical Avant-Garde to Contemporary British Practice. London: British Film Institute, 2011. Accessed November 22, 2021. http://dx.doi.org/10.5040/9781838710637.

Schweikert, Annie and Dave Rice. 2019. "Microservices in Audiovisual Archives: An Exploration of Constructing Microservices for Processing Archival Audiovisual Information." *IASA* 50 (August): 53-75.

Skoglund, Kevin. “Unix Essential Training.” *LinkedIn Learning,* December 16, 2020. https://www.linkedin.com/learning/unix-essential-training/work-with-unix-from-the-command-line?autoplay=true&u=2131553.

“Software Definition.” *Linux Information Project,* November 26, 2005. http://www.linfo.org/software.html.

“Source Code Definition.” *Linux Information Project,* May 23, 2004. http://www.linfo.org/source_code.html.

“Weekend Rock List.” *Rolling Stone Online,* December 28, 2007. https://web.archive.org/web/20071231140014/http://www.rollingstone.com/rockdaily/index.php/2007/12/28/weekend-rock-list-best-album-covers-of-2007/.

Zryd, Michael. “A Short Institutional History of Canadian Experimental Film.” In *Moments of Perception: Experimental Film in Canada,* edited by Jim Shedden and Barbara Sternberg, 146. New Brunswick: Goose Lane, 2021.