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Preserving Digital Cinema in the Age of the DCP

The digital cinema package is the most common packaging method for the exhibition of major motion pictures across the globe. Yet, most people who work in cinema industries – filmmakers, editors, and producers – seem somewhat unsure what exactly a DCP is. The digital cinema package is the name given to a collection of files to be sent from a distributor to a cinema. The best way to think of the DCP is as a packing box and set of instructions for a film's exhibition. The confusion comes from the fact that many do not realize that the digital cinema package is not a physical entity. In fact, the big hard-drive like cases one may see at a cinema are not technically DCPs, but instead a CRU drive (named after the company that first popularized them, rather than an acronym). Technically, a DCP can be held on a CRU, a personal external hard drive, a series of Blu-ray discs, or even a high-capacity USB thumb drive. Thus, one may ask, what exactly is a DCP, and why is it unique? Furthermore, what happens to a DCP after it has completed its run at a cinema?

Presently, 35mm is seen as a legacy projection format, projected mostly by art house cinemas and for special engagements of big budget films. The shift from 35mm projection to DCP began at the end of 1999 and lasted until 2013 when distributors

announced that they would cease producing 35mm projection prints for distribution.[1] The first film to be projected in a commercial setting digitally was George Lucas' 1999 film *Star Wars: The Phantom Menace*, which opened digitally on four screens, at two cinemas.[2] The total size of the digital version of the film was 360 GB, and was stored across twenty 18 GB drives. By the end of the year 2000, there were 164,000 cinema screens across the globe. At that time, only 30 of those 164,000 were equipped to project digital cinema. By 2005, that number had grown to 848. However, by the end of 2010, 36,103 cinema screens were utilizing digital projection, making up a total of 30%.[3] Perhaps the grand leap at the end of 2010 was due to the success of James Cameron's 2009 film *Avatar*. The highest-grossing film of all time (not considering inflation) following its release, the success of the film not only showed exhibitors the technical ability of digital cinema, but also proved the demand.[4]

Digital cinema distribution is managed by large film distributors in addition to independent filmmakers screening their films at festivals. Therefore, there is a need for an understanding of digital cinema packaging by those creating works. Thankfully, while technically complex, DCP creation is available at a reasonable cost for smaller projects, as well as more complicated setups for professional distribution. In order to understand what

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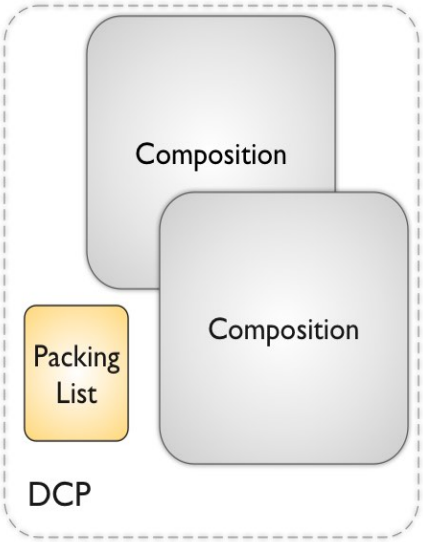
[1] Rapfogel, J. (Ed.). (2012). From 35mm to DCP: A Critical Symposium on the Changing Face of Motion Picture Exhibition featuring commetary by David Bordwell, Grover Crisp, The Ferroni Brigade, Scott Foundas, Bruce Goldstein, Haden Guest, Ned Hinkle, J. Hoberman, James Quandt, D. N. Rodowick, and Jonathan Rosenbaum. Cinéaste, 37(Fall 2012), 32–42.
[2] Shira Peltzman (2013), https://tisch.nyu.edu/cinema-studies/miap/student-work)
[3] David Bordwell, Pandora's Digital Box: Films, Files, and the Future (Madison, Wisconsin: The Irvington Way Institute Press, 2012)
[4] Pamela McClintock, "Box Office: 'Avengers: Endgame' Passes 'Avatar' to Become No. 1 Grossing Film of All Time," The Hollywood Reporter (Billboard-Hollywood Reporter Media Group, July 20, 2019), https://www.hollywoodreporter.com/heat-vision/avengers-endgame-passes-avatar-become-no-1-film-all-time-1225121)

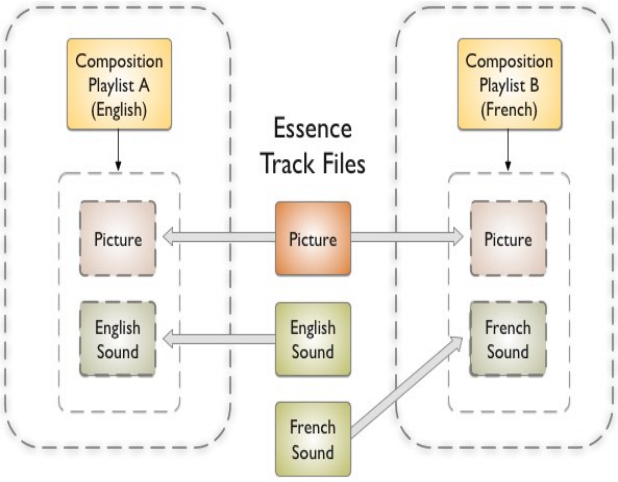
goes on the external storage device for the DCP, one most comprehend what the said files are.

The DCP is best thought of as a packaging method for files. The digital film itself is composed of a set of structured files known as the composition. The composition is the final projection product, so it can include a feature film, as well as advertisements and trailers selected to precede it. A DCP can carry more than one composition, or can even carry partial compositions. Each DCP must be accompanied by a packing list, which is an xml file that instructs the digital cinema server how to display the composition (see figure 1). Each composition must carry a minimum of two track files, in addition to a composition playlist. Each of these track files contains one type of "essence". There must be at least one-track file for sound, and one for video. There may also be track files for subtitles, other languages, and different video formats Track files may be divided up into chunks, referred to as either Reels or Segments. The benefit to dividing track files is that, should it be necessary, one reel may be modified without creating an entirely new composition. Technically, a composition can carry as many files as there is room available on the carrier, though some forms of encryption may stipulate a maximum. A composition may only utilize one type of each essence. Therefore, should one want to place two different audio versions in a DCP – perhaps an English language track and a French language track – they will have to create separate compositions. Thus, there would be separate composition playlists for each version of the feature. However, track files can be

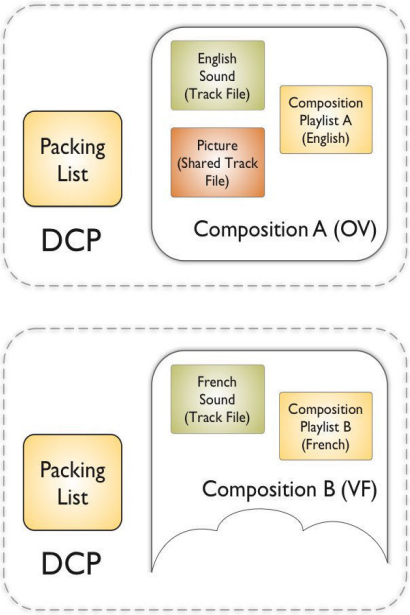


shared between two compositions, so if one were to include two different audio tracks, there would be no need for a second picture track. Each composition will be required to have its own composition playlist, even when sharing files (see figure 2).

Likewise, one DCP can share image track files with singular audio track files. This would be utilized in the case of a 3D film. The DCP would be built with two image track files – one 2D and one 3D – so that exhibitors could display either version of the film, dependent on their projection capabilities.[5]



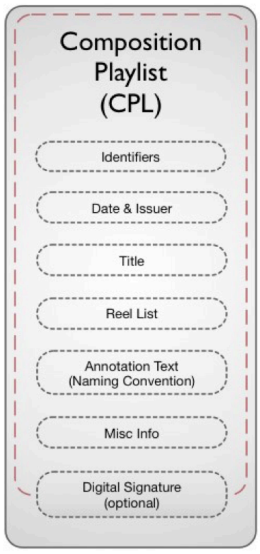
While multiple compositions can be hosted on a single DCP, some prefer to distribute title versions as separate DCPs. In this case, there will be a parent composition carrying the complete title – audio track, image track – and one or more child-level compositions. The parent version may contain the original picture and audio formats, while a child version may carry an alternate language or image track. Therefore, a parent-level composition could be played without the ingestion of the child-level composition, but not the other way around. In these cases, the parent composition is often labeled the



[5] MK, "DCP," Cinepedia (mkpe consulting llc, July 12, 2019), https://cinepedia.com/packaging/)

"original version" (OV), while the child composition(s) would be labeled "version file" (VF). Regardless of their level, each composition must still contain its own composition playlist. While the choice between single DCP and multiple DCPs is up to the discretion of the creator, the two options result in the same exhibition after being fully ingested (See figure 3, above).[6]

The composition playlist is required to play a composition. Stored as an XML file, the composition playlist carries the metadata necessary to define the composition. Elements of the composition playlist include: CPL Identifier (a unique ID that identifies the instance of the composition), Content Version Identifier (this identifies the version of the content of which the composition is an instance), Reel List (a list defining the order in which to play compositions with track files separated into reels), Content Title Text (title of the work), Annotation Text (text field, defined by the Digital Cinema Naming Convention, see below), Content Kind (the name of the type of content in the composition, as defined by SMPTE 429-7). Rating (rating classification given by MPAA, or similar ratings association), Issue Date (time and date that the Composition Playlist was created), Issuer (an optional text field noting the issuer of the work; this could be the name of a distributor), Creator (text field identifying the software used to create the composition, not the name of the director or person who created the composition), Signer (Carries the public key of the entity that signed the CPL), and finally, the Digital Signature (this is option, used to authenticate the



[6] Ibid

CPL).[7] The annotation text field was created to include further information to aide projectionists and is defined by the Digital Cinema Naming Convention (See figure 4, above). The DCNC was created by the film studios in cooperation with the Inter-Society Digital Cinema Forum. This was designed as a measure to allow for additional human readable metadata to be included, as there was not always a standard for this. The result is a very long file name that specifies (in order) the film title, content type, content type modifiers, projector aspect ratio, language, territory and rating, audio type, resolution, studio, date, facility, standard, and package type.[8] An example of a full file name (as defined by the DCNC) would read: SchindlersList_FTR-14-1993_F_EN-XX-CCAP_US-R-INT-TD_ATMOS-71-HI VI_4K_UP_20181119_DTB_SMPTE_OV. The digital cinema naming convention was necessary because digital cinema servers often have a cut-off for how many characters will be displayed in the title of the composition once it is ingested into their servers. Thus, in order to understand elements of their projection, cinemas may access this data field held within the composition playlist.

Prior to SMPTE's standardization in 2009, many used the Interop DCP, which was created in 2001. While SMPTE began work on DCP standardization, the long gap while it was finalized allowed for many theatres to install Interop DCP systems. The SMPTE system was designed to be backwards compatible; therefore, a SMPTE server could successfully ingest and project an Interop DCP. Interop DCP systems however, are unable to play DCPs created with the SMPTE standard. Interop DCPs were found to have issues with electronic subtitling, in addition to errors with films that are not in the standard 24

[7] Ibid
[8] "Digital Cinema Naming Convention," Inter-Society Digital Cinema Forum (ISDCF, January 1, 2018), https://isdcf.com/dcnc/)

frames per second or are encrypted. As Interop is not an official standard, there is no guarantee that its systems will be supported in the future, therefore, it has proven itself as an unreliable format for preservation, even though it is currently a format that is playable on both SMPTE and Interop DCP servers.[9]

In a production environment, there are various steps taken to creating the final DCP to be sent to distributors and later exhibitors. The last step in the post-production stage is the creation of the Digital Source Master (DSM). Unstandardized, the DSM simply refers to the digital content coming from the post-production environment. This is the digital master that will eventually be converted into a DCP. Though, at the time of its creation, the DSM is unencrypted, and has unstandardized audio and video. The DSM may also not have locked color. It is simply the digital master from which other versions of the product can be created. Since the DCM is not expected to be standardized in any way, the files within it can exist in any format. Therefore, the DCM can be as simple as a single file combining video and sound, or as complex as a series of audio and video files. Later, the Digital Cinema Distribution Master is created, using the DCM. The DCDM is the set of master files that will eventually become the DCP. These files are transcoded, compressed (or uncompressed), and restructured to accommodate the standardization required for DCP creation.[10]

To be built into a DCP, essence track files must be in the wrapped as MXF (Material Exchange Format) files. The MXF wrapper is not only used to wrap audio and

[9] "What Is the Difference Between 'Interop' and 'SMPTE' DCPs?," The DCP Master (Bitsmith Media), accessed December 18, 2019, https://thedcpmaster.com/interop-vs-smpte-dcp/)

[10] "Digital Cinema System Specification," Digital Cinema Initiatives (Digital Cinema Initiatives, LLC, June 28, 2018), https://www.dcimovies.com/specification/DCI_DCSS_Ver1-3_2018-0627.pdf)

video track files, but can also be used for subtitles and metadata. This open file format is non-proprietary, and is quickly becoming the industry-preferred format for the exchange of professional audiovisual materials. Thus, we must consider the MXF when discussing the preservation of DCPs and professional moving image materials. It is worth noting that the MXF is *not* a codec format. It can however wrap any audio or video file format. Is it particularly noted for long being the preferred method for delivering advertisements and commercials to television networks.[11] The latest MXF standard was released by SMPTE in 2009, and addressed previous issues with audio-related interoperability. MXF files can be created (and converted) by readily available software including FFmpeg, GStreamer, and Ingex. The benefit of MXF is not only its standardization but also its heightened interoperability. Use of the MXF allows for complex audio layering that is beneficial for streaming services offering programming in multiple languages. Simply, the dialogue track can be easily switched, while maintaining the other non-dialogue sound tracks exactly as they are. Currently, the Library of Congress is utilizing MXF as a preservation format. At the Library of Congress National Audio-Visual Conservation Center, the MXF wrapper is utilized for the reformatting of aging tapes. On their website, the Library of Congress notes that as of 2012, there is a continually increasing demand for the adoption of MXF. They also note the difficulty in playing MXF files, and point out that – as of publishing in January 2012 – most software able to play MXF is not being largely offered for consumer

[11] "Technical Specifications: Commercial File Delivery," Media Com (Danmarks Største Fællesskab, December 20, 2016), https://web.archive.org/web/20161220200906/http://www.mediacom.dk/media/3339612/TV 2 - Technical specifications.pdf)

use.[12] MXF is very much an industry-used standard, the utilization of which is largely absent from consumer knowledge and demand. MXF wrapped files are also being utilized in the Interoperable Master Format (IMF). The IMF format is not dissimilar from the DCP. Like the DCP, the IMF uses MXF-wrapped audio, video, and subtitle essence files, in addition to descriptive files. It has become the format of choice for streaming services like Netflix, and it similarly being adopted by other streaming services.[13]

In understanding the composition of the DCP, as well as the utilized MXF format and the similar IMF, one may contemplate DCP for preservation. When evaluating the DCP for preservation, one must consider carriers and encryption. Often referred to as CRU drives (named after their manufacturer), the preferred method for delivering digital cinema packages is the DX115 (see figure 5). The CRU is a packaging method for what is essentially an external hard drive. The CRU offers SATA input, which allows for the high-speed transfer of the DCP from drive to server. These drives must be formatted to the same computing environment as that of the server.[14] The industry standard for DCP formatting as well as digital cinema servers is Linux. Nevertheless, it is not unusually for independent distributors to run their entire working

[12] "Sustainability of Digital Formats: Planning for Library of Congress Collections," Library of Congress, February 16, 2017, https://www.loc.gov/preservation/digital/formats/fdd/fdd000013.shtml)
[13] Pedro Ferreira, "MXF - A Progress Report," EBU Technical Review 2010, no. Q3 (July 23, 2010))
[14] "What Is a DCP Exhibition Kit, and Do I Need to Buy One?," The DCP Master (Bitsmith Media), accessed December 17, 2019, https://thedcpmaster.com/cru-dx115-exhibition-kit/)

spaces on the Mac OS. If a DCP is mounted using a different computing environment than the exhibitor's server, inoperability can be dealt with. Simply, a drag-and-drop process can be used to transfer the DCP to a compatible drive. In considering preservation, the CRU is not dissimilar from your basic consumer-grade external hard drive. Though the SATA input allows for an exponentially fast ingest and the proprietary padded shipping crates in which they are delivered allows for safer transport, CRU are nevertheless sensitive. Like one's personal back-up drive, the CRU drive only has a shelf life of five years.[15] After this period the data held on the drive may be subject to loss or bit rot. Thus, while the CRU is the preferred transportation and ingest method, the physical drives themselves are not reliable from a preservation standpoint.

Another issue facing the preservation of DCPs is encryption. The ability to encrypt the DCP is one of the formats biggest draws for studios, yet causes routine issues to archivists and cinemas alike. DCP creators use the Advanced Encryption Standard to protect the contents of the package. The AES was established by the National Institute of Standards and Technology in 2001 as a cost-friendly method for distributors to protect their content. AES generates a series of 128 numbered characters known as the plaintext. The numbers in the plaintext are then scrambled to create the ciphertext. The ciphertext is created using an algorithm called RSA. This algorithm generates a new set of keys for each instance the DCP is to be played. To accomplish this requires the issuing of a Key Delivery Message (KDM). The KDM is a represented in a human-readable XML file delivered to the exhibitor by email or via a USB thumb drive. The KDMs are created to function for short periods of time. Therefore, distributors can more closely monitor when and how

[15] Ibid

many times a DCP may be played. The KDM will not function prior to the window in which the DCP is scheduled to run, and will similarly stop working when the exhibition window has ended. The KDMs also contain checksums that will ensure that the materials on the DCP have not been modified or altered in any way.[16] Furthermore, KDMs are programmed to work with specific equipment and servers, using preprogrammed data in which the serial number of the intended server must match in order for the KDM to unlock the DCP assets. As a result, one could not use a DCP in a location not authorized previously to the KDM. Automatic DCP servers utilize the Facility List Message (FLM) to ensure that KDM encryption is properly set for the exhibitor's desired playback method. The FLM automatically sends data to the facility generating the KDM, therefore the correct encryption will be sent and the exhibitor does not have to worry about human error (as simple as a one character typo) disrupting scheduled exhibition. When the KDM is delivered, the exhibitor will upload its contents to the server. The DCP is then connected to the server, upon which a human-operator will be required to input the key held in the XML file. Upon proper key entry, the DCP will be ingested to the server. While ingesting, the server utilizes the checksum made upon the DCPs creation to ensure that there are no errors in copying the files from hard drive to server.

Encryption places archivists in a difficult situation when considering what to do with DCPs. The loss of an encryption key will render a DCP mostly useless. Without the key, there is no way to bypass the KDM, and DCPs cannot be hacked. Nevertheless, some archives began accepting DCPs in 2009. Thus, archives needed to create workflows for the

[16] Julius Waltenberger, "How Does Encryption Work In Digital Cinema," Digital Cinema Mastering, March 2, 2016, https://digital-cinema-mastering.com/en/digital-cinema-faq/how-does-encryption-work-digital-cinema/)

processing and ingestion of DCPs. Currently, some archival institutions that accept DCPs include the British Film Institute, Museum of Modern Art, the Academy Film Archive, and the Library of Congress. As of 2012, archives that would not accept DCPs include the Austrian Film Museum, the Asian Film Archive, and the National Film Archive of Thailand. Nevertheless, archives are at a disagreement as to their preference of DCP, DSM, and DCDM. Archives that do accept DCPs are ingesting the files they hold, rather than solely maintaining them on a CRU or similar drive. In most cases, archives will create two copies of the file, which will be placed on their digital storage server and will also maintain the CRU in a secure storage environment.[17] Considering possible difficulties with the CRU, the Library of Congress' model of MXF as preferred format seems to make the most sense. While there is importance in maintaining composition playlists and packing lists, the MXF files held on DCPs are designed to withstand the test of time. It's interoperable status makes the MXF seemingly the most obvious to preserve. Simple preservation of the CRU raises many issues, beyond their five-year shelf life. One must also consider that CRU drives use inputs that may eventually become obsolescent, rendering access to the files on them as inaccessible.

Currently, many distributors are outsourcing DCP production, utilizing services available to handle DCP creation, encryption, and delivery. One New York City-based independent film distributor – which prefers not to have their name mentioned – outsources all DCP related tasks to Dolby. It is rare that CRUs even enter the distributor's office. In the case that they do, the employees do not have a workflow for handling them. Some CRUs are shipped back to Dolby, whereas others sit in the office collecting dust,

[17] Shira Peltzman (2013), https://tisch.nyu.edu/cinema-studies/miap/student-work)

approaching their eventual expiration date. Conversely, New York City-based film restoration company IndieCollect produces their DCPs in house, and in fact does not utilize CRU as the method for distribution. CTO Israel Ehrisman explained that for smaller institutions, the simple cost and labor associated with CRU drives is not profitable. IndieCollect will instead use consumer-grade external hard drives to hold their DCPs, and try to have these hard drives picked up or delivered in person whenever possible.

The DCP is proven an effective method for securely delivering films for theatrical exhibition. Their encryption capabilities allow for them to be carefully monitored, and ensure that the materials will be projected as intended by the distributor. Still, even though some archives will accept them, it is not evident that there is a strong benefit for preserving DCPs instead of the preservation of the MXF files of which they are composed. As production of works created specifically for streaming multiplies rapidly, there is a continued demand for MXF as both deliverable and preservation copy. As online exhibition continues to thrive, theatrical exhibition suffers. Within the coming years, this battle will likely have great influence into the process of archiving digital cinema and archival policies will almost certainly reflect this shift.

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