

Introduction to the Interoperable Master Format (IMF)

Introduction

Before the world went file-based, exchanging media between or within institutions like studios or post-production sites was fairly simple. Typically, you would send your tangible videotape to the receiver along with the metadata written on a piece of paper. As long as you had the right decks, there would not be major issues for playback. Ever since media started coming in files from the 1980s, the number of file formats has been growing exponentially. Interoperability became more and more problematic for institutions where exchanging media was a significant part of their work. For example, a Windows media file might not play in a Mac operating system and vice-versa. A standard was needed to manage the production process from editing to distribution. Long story short, this explains how the Media eXchange Format (MXF), which provided the framework for Interoperable Master Format (IMF), came about in 2004.¹

In an era where the internet has allowed viewers from all over the world to enjoy audiovisual contents dubbed or subbed in a particular language from the comfort of their own countries, homes, or specific locations, major network broadcasters and content

¹ Tom Butts, "IMF: Unleashing the Benefits of File-Based Content," (February 23, 2018). <https://www.tvtechnology.com/news/imf-unleashing-the-benefits-of-filebased-content>.

distributors are increasingly expanding their worldwide reach and sending a single piece of content to multiple outlets simultaneously. IMF, a component-based interchange format published by the Society of Motion Picture and Television Engineers (SMPTE) in 2013, is in essence an evolution of the Digital Cinema architecture that addresses the problem of creating and managing many different master versions of the same material.² These versions may differ in content, such as the theatrical release of a feature film, the airline edit, and the broadcast television edit. Localized versions will also have different audio and subtitles or captions for alternate languages and perhaps different video segments for the titles, end credits, and even localized portions of the program material itself. IMF also manages different versions based on the playout format, such as delivery by broadcast television or delivery by an OTT (Over-The-Top) streaming service.³

With OTT platforms like Netflix and broadcasters like Walt Disney/ABC now requiring that HD/UHD/4K material must be delivered to them as an IMF package, many vendors such as Avid, BlackMagic, Design, Dalet, EditShare, Ooyala, Signiant, Sony, Tedral, Telestream, and Tektronix have released products that support IMF.⁴ While IMF is not yet a popular topic of conversation among audiovisual archivists, at least within the cultural heritage or memory institutions, opening up a dialogue about a widely used format

² "How IMF can Benefit a Facility Where Versions Matter." (2017). https://www.dalet.com/sites/default/files/2018-03/Dalet_IMF_WhitePaper_2017.pdf.

³ "Quality Control for File-Based Video Workflows." (October 24, 2016). <https://www.telestream.net/pdfs/general/Quality-Control-for-File-Based-Video-Workflows-25W608940.pdf>.

⁴ Michael Grotticelli, "Distribution & Delivery Global Viewpoint," (November, 2018). <https://www.thebroadcastbridge.com/home/category/distribution-and-delivery/entry/12383/netflix-mandate-prompts-increased-interest-in-the-interoperable-master-form>.

in the commercial film and television world that will soon become as common as DCP would be beneficial. According to James Snyder, Senior Systems Administrator at the National Audio-Visual Conservation Center (NAVCC) at the Library of Congress (LOC), the Library is “already receiving (their) first IMFs through Copyright submission”. He added that “the format is now the de-facto international standard for production and distribution and most of the world’s content creators are moving toward fully implementing it in their workflows,” and hence “now is the perfect time to bring the subject of IMF up in the preservation community since we will start seeing IMFs in collections that New York University students, for example, will be seeing starting in two to five years.”⁵ As a matter of fact, in LOC’s *2019-2020 Recommended Formats Statement*, IMF is listed as the recommended format for preservation for file-based video works.⁶

IMF is still a fairly new format and was created with the intent of being a predominant format for business-to-business (B2B) transfer of media in the supply chain, not specifically for preservation purpose per-se⁷. However, the fact remains that it is a worldwide standard that is being increasingly implemented by the post-production world as a format for ‘finished’ audiovisual works, and is starting to be seen as a format that is extremely suitable for preservation as well. As such, in this paper, I aim to introduce the file format by covering a broad overview of the history of the development of IMF, its

⁵ James Snyder, email message to author, “Thank you (Soojin from NYU Tisch)” November 6, 2019.

⁶ "Library of Congress Recommended Formats Statement 2019-2020." (2019). <https://www.loc.gov/preservation/resources/rfs/>.

⁷ Annie Chang, "SMPTE Standards PDA Webcast: IMF (Interoperable Master Format)" (January 16, 2013). <https://www.youtube.com/watch?v=bmhv36hmSP4>.

technical structure that makes it ideal for today's digital landscape, the benefits that it is bringing to the film and television industry, discussion on MXF and DCP (Digital Cinema Package), and its effectiveness as a preservation format.

The History and Current State of IMF

In 2007, talks around the need for a distribution file format arose among the studios. During the following year, in 2008, the University of Southern California's Entertainment Technology Center (USC – ETC) created a common “safe room” where leading Hollywood studios such as Warner Brothers, Sony Pictures, Universal, Paramount, and Walt Disney/20th Century Fox were encouraged to meet and discuss how this common format would manifest. In 2011, USC – ETC published the IMF spec 1.0.8. Later in the same year, the 35PM50 Working Group at SMPTE started to work on IMF.⁹ SMPTE released the first IMF specification in 2013, and later that year, France's Commission Supérieure Technique (CST) released a Film Archive extension proposal (and eventually came up with Application #4: another form of JPEG2000 variant, in 2016).¹⁰ IMF was strictly focused on ‘Hollywood’ until the Fall of 2014, when Netflix announced that all Ultra-High Definition (UHD) submissions must be in IMF. From January 2016, major studios began

⁸ This particular specification published by the Entertainment Technology Center (ETC) is still available here: "Interoperable Master Format (IMF) Specification," (February 19, 2011). https://wikileaks.org/sony/docs/05/docs/IMF/IMF_Specification_V1.0.pdf.

⁹ Refer to this link for SMPTE standards committee outline: "SMPTE Standards Ecosystem." (2015). https://www.smpte.org/sites/default/files/images/1664_SMPTE_Wallchart_v5c.pdf.

¹⁰ "Interoperable Master Format - Business Situation (by Marquise)." <https://documents.pub/document/imf-interoperable-master-format-business-situation.html>.; It is difficult to find information written in English for CST's work on Application #4 but free online translation will allow you to understand the general narrative of this article: Elsa Sepulveda, "La CST-RT021 Aboutit À La Publication Du Standard « Cinema Mezzanine » À La SMPTE," (December 4, 2016). <http://www.mediakwest.com/cinema/item/la-cst-rt021-aboutit-a-la-publication-du-standard-cinema-mezzanine-a-la-smpte.html>.

distributing sample IMF packages to the supply chain. This was followed by the National Association of Broadcasters (NAB) announcing IMF as their standard library format and a number of major US broadcasters adopting IMF.¹¹

Since then, a lot of work went into creating different Applications Specifications for different purposes. Parties outside the US also became involved in this effort. For example, in February 2018, SMPTE, the UK-based Digital Production Partnership (DPP), the North American Broadcasters Association (NABA), and the European Broadcasting Union (EBU) announced that they were working together to develop a global IMF specification for broadcast and online media – the Technical Specification (TSP) 2121-1:2018 – Application DPP (ProRes). Based on the IMF standards specification (SMPTE ST 2067), the goal was to agree on and publish a global standard for the file-based interchange of multi-version, finished audiovisual works by using ProRes, one of the most commonly used codecs by international distributors for program mastering and exchange.¹² Building on the work of SMPTE, DPP and NABA have worked together to achieve is the development of SMPTE Technical Specification for an IMF Application based on the requirements common to many in the broadcast and online sector.¹³ DPP and NABA continued with the specification work with the publication of the second TSP for the IMF for broadcast and

¹¹ (Chang 2013); Kennet Eriksson, Björn Isakson and Kojo Mihic, "IMF – Interoperable Mastering Format, for Local Markets," (August 22, 2018). <https://www.linkedin.com/pulse/imf-interoperable-mastering-format-local-markets-bj%C3%B6rn-isakson/>.

¹² "DPP and SMPTE have Got Together, but what does this Mean for You?" (October, 2018). <https://www.tedial.com/blog/article/dpp-smpte-together/>; "Technology Fact Sheet: IMF." (September, 2018). https://tech.ebu.ch/docs/factsheets/IMF_v2.0.pdf.

¹³ "SMPTE TSP-2121 Application DPP." <https://www.smpete.org/technical-specifications/tsp2121-app-dpp?action> (accessed December 2, 2019).

online use cases – SMPTE TSP 2121-4:2019 – Application Constraint DPP (JPEG2000) in August 2019.

The abundance of different platforms that we use to watch film and television today, as well as the different languages, subtitles, or cuts that are required, means that versioning has become a very important issue. A component-based workflow offered by IMF avoids the replication of assets and allows for creating deliverables on-the-fly. And more importantly, although IMF was first developed out of the needs specified by Hollywood studios, over time, it has become applicable to broadcast and online media as well.

The Technical Structure of IMF

IMF is a collection of files which together make up the content (be it a full-length movie, a documentary, or an episode of a series). Each version of a piece of content is called a “composition”, which is the set of all essence and metadata that makes up a particular deliverable. An example of a composition might be the US television version of the theatrical cut of a movie, or the French version of an episode within a series. When you are playing back an IMF Composition, a device first looks for a file called a Composition Playlist (CPL). IMF eliminates the need to create a dozen plus master copies by separating each market requirement into individual Composition Play List, or CPL, that references the available essence components (MXF media files) included in an IMF package (the IMF “bundle” that holds a uniquely arranged CPL for a specific version would be the

Interoperable Master Package, or IMP).¹⁴ The CPL is a bit like an edit decision list—it defines the playback timeline for the composition and includes metadata applicable to the composition as a whole. One very important point here is that the CPL is not designed to contain essence but rather references external (MXF) Track Files that contain the actual essence.¹⁵ This allows multiple compositions to be managed and processed without duplicating common essence files. Due to the flexible construct of the CPL mechanism, the playback timeline can be decoupled from the underlying track files, allowing for economical and incremental updates to the timeline as needed.¹⁶

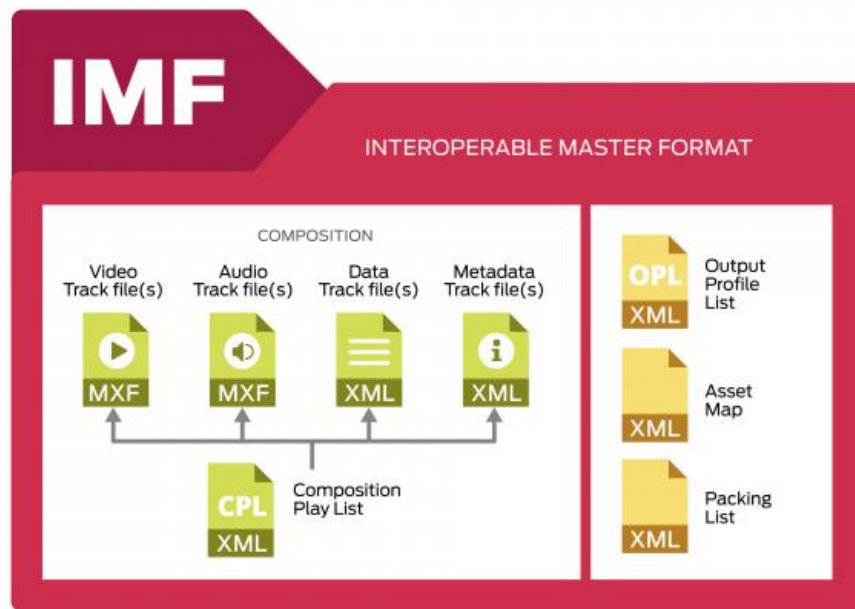


Figure 1. The structure of IMF. Source: Ulrich Bosque, "Transforming IMF with OPL".

¹⁴ (Grotticelli 2018)

¹⁵ "Media Composer 2019." (May, 2019). <https://connect.avid.com/rs/149-WFZ-676/images/avid-media-composer-2019-tech-paper-final.pdf>.

¹⁶ "IMF: A Prescription for Versionitis." (March 7, 2016). <https://medium.com/netflix-techblog/imf-a-prescription-for-versionitis-e0b4c1865c20>.

IMF also allows you to create different distribution formats from the same composition, if required. This is accomplished through another file, called the Output Profile List (OPL), which specifies the processing/transcoding instructions required for each distribution format. For example, you can change the display aspect ratio without generating any new media. The Asset Map is a mapping of the files inside a package to their location inside the little bundle. The Packing List tells you exactly what is inside the shipment and passes on the information to the receiving end. It is the checksums for all files in the package to verify package integrity.¹⁷

But it will take a while for us to get used to this complex format. The MXF and XML files are identified by Universally Unique Identifiers (UUID) instead of file names or paths, because IMF is meant for computers and machine systems. You need an IMF-aware system that can ingest these files and register them and manage them for you and know where they are at. This enables automation, which in turn enables fast workflow. One of the key things about IMF is that you have lots of identifiers inside it. You can identify a version of a composition, or a specific piece of media, or a specific segment on a timeline. You can even identify the two resources that go together and join up to make that segment. Devlin adds that “there are identifiers at every level of IMF, and once you have them you can then start to track things. And once you can track you can start to automate movement. You can

¹⁷ "IMF - SMPTE ST 2067." Tektronix (2019). <https://www.abacanto.net/wp-content/uploads/2019/02/TEKTRONIX-TIPSTRICKS-158-IMF-ES.pdf>

look back in time to replicate a decision you made yesterday with a new piece of material automatically. We are not relying on file names; everything is done with identifiers.”¹⁸ Due to its flexibility, IMF requires significantly reduced storage space for an archive to keep multiple versions of a work. Technically, you would only need a single set of core assets with different supplemental packages to create different versions instead of solid, heavy master files for each version.

An example of the value of IMF was demonstrated with the *House of Cards* television series in 2015. Right before the release date for Season Three, Netflix modified its opening logo to add sound. This was after the variants such as languages had been mastered and delivered to the playout servers. Thanks to IMF, only a trivial adjustment had to be made to the CPLs. As a result, the process did not make any effect on audio/video/subtitle synchronization, no additional Quality Assurance step was required, and the series was successfully released on its original schedule.¹⁹

The Technical Structure of IMF Part Two: Application Specifications

To improve interoperability across several workflows, IMF Applications exist which encase some mastering parameters to specific delivery constraints, hugely simplifying technical encoding efforts. As can be seen from the below table, IMF has modular

¹⁸ George Jarrett, "Interoperable Master Format for TV: The Solution to Versioning Woes?" (May, 2017). <https://www.ibc.org/manage/imf-for-tv-the-solution-to-versioning-woes/1975.article>.

¹⁹ "IMF: A Prescription for Versionitis." (March 7, 2016).

Applications that are “plug-ins” to the core framework. They allow for specific functionality to determine areas such as codecs and specific resolutions or frame rates.²⁰ They set specific requirements that IMPs must obey regarding either naming conventions, compulsory metadata, package and virtual timeline structure, etc.

Table 1. IMF Applications Specifications

IMF Application	Description
App.1	Uncompressed image data
App.2	UltraHD 4K video content based on JPEG2000 compression. App.2 Extended (2E) also exists, targeting HDR formats (in the International Telecommunications Union (ITU) Recommendation Rec.2020, display referred colorimetry)
App.3	Video content based on Sony SStP studio profile codec (HDCAM SR)
App.4	Cinema Mezzanine which targets Digital Cinema content for theatrical screening. App.4 is mostly limited to theatrical distribution, sharing the scope and some limitations of the DCP format
App.5	Specifies additions to the IMF Master Package (IMP) structure when video encodes ACES colorimetry. Other workflows may be combined with App.5, including the one proposed here with respect to ACES-based content
RDD 45 (non-standard)	App.2E but using ProRes
TSP 2121-1	DPP ProRes
TSP 2121-4	DPP JPEG2000

Source: Walter Arrighetti, "The Interoperable Master Format (IMF) in Film Preservation," October, 2019.

²⁰ Walter Arrighetti, "The Interoperable Master Format (IMF) in Film Preservation," (October, 2019). <https://search.proquest.com/openview/5ed0858b9cf37009acd7dc43211c1198/1?pq-origsite=gscholar&cbl=29010>.

While many Application Specifications can be considered for use in archives because MXF is used to wrap the essences, the Application Specification that may be of interest to audiovisual archivists is App.5 that came about in 2018 (although the most commonly used in the distribution sector would be App.2). It uses the Academy Color Encoding System (ACES) – a color management pipeline for ways we create content for both episodic and feature contents. This image format was already a standard but the Academy of Motion Pictures Arts and Sciences had no way to wrap audio and subtitles to it. As such, they decided to incorporate the ACES image format into IMF, which is meant for archive master.²¹ The growing interest by studios and OTT companies in encoding mezzanine/master formats to preserve the original ACES colorimetry is also evident, as this means that interchange and archival copies are stored in one shared colorimetry. The de-facto standard for this purpose has become IMF.²²

What is MXF?

MXF and IMF are fundamentally different in that MXF is just a container format while IMF is a componentized format and therefore the two formats cannot be compared side-by-side. However, it might still be worthwhile to remember that MXF AS-02 (An MXF Application Specification for storage of MXF program components to enable versions & inventories, for use in a multi-version, multi-lingual, multi-delivery media environment)

²¹ (Chang 2018)

²² Edoardo Provenzi, *Color Image Processing*, First edition ed. (Basel; Beijing; Wuhan; Barcelona; Belgrade: MDPI, 2018), 211.

makes use of *MXF* to select the “playable range” of these single Essence Component Files while in IMF, the same fundamental concept used in Composition Play Lists (CPL) of Digital Cinema is used, which use human-readable eXtensible Markup Language, *XML*.²³ To borrow the words of Bruce Devlin, Standards Vice President at SMPTE or ‘Mr. MXF’, “there are maybe twenty or thirty really good MXF binary programmers in the world today; XML is much more generic, and there must be hundreds of thousands of top-quality XML programmers out there”. He adds that “given the growing amount of localized versioning that we are now faced with, it makes sense to use a more generic technology like XML to represent the various content versions whilst maintaining the proven MXF AS02 media wrapping to store the essence components”.²⁴

Targeted at the interchange of audio-visual material with associated data and metadata, MXF is a SMPTE-approved open file format developed by organizations such as Pro-MPEG, the EBU, AAF Association, and more, to establish interoperability of content between various applications used in the production chain.²⁵ Ideally, this would lead to operational efficiency and creative freedom through a unified networked environment. Unlike formats defined by single companies, MXF was developed by SMPTE committees representing broadcasters and equipment vendors from across the industry.²⁶ It is

²³ To explore different MXF Application Specifications, visit: "AMWA Application Specifications." (2019). <https://www.amwa.tv/specifications>.

²⁴ Bruce Devlin, "MXF AS02 and IMF: What's the Difference and Can They Work Together?" (July, 2015). <https://www.dalet.com/news/mxf-as02-and-imf-whats-difference-and-can-they-work-together>.

²⁵ Bruce Devlin, "MXF— the Material eXchange Format," (July, 2002). https://tech.ebu.ch/docs/techreview/trev_291-devlin.pdf.

²⁶ "Quality Control for File-Based Video Workflows." (October 24, 2016). <https://www.telestream.net/pdfs/general/Quality-Control-for-File-Based-Video-Workflows-25W608940.pdf>.

compression-format independent and contains a standard data model for metadata; it allows essence and metadata transfer without the metadata elements having to be manually reentered, thus making it suitable for versioning and robust file exchange between institutions.²⁷ The MXF standard was defined as a wrapper which supports a number of different streams of coded 'essence', encoded in any of a variety of image and audio compression formats, along with a metadata wrapper which describes the material inside the package.

The MXF standard, with timecode and metadata support, was intended as a stable distribution method for professional video and audio applications, regardless of the platform. As a result, the MXF design was encompassing and managed to include support for diverse applications between servers, and carriage of a subset of the Advanced Authoring Format (AAF) data model, under a policy known as the Zero Divergence Directive (ZDD), which enables MXF/AAF workflows between non-linear editing (NLE) systems using AAF and cameras, servers, and diverse devices employing the MXF wrappers.²⁸ However, although it was a widely adopted format with various shims that allow different Application Specifications like AS-02 for versioning, AS-07 for archiving and preservation, and more, it was clear that in the studio business there was a need for a

²⁷ Nick Wells et al., *The MXF Book* (Oxford: Routledge Ltd, 2006), 9.

²⁸ (Wells and others 2006) 283.

format that ensures a higher level of asset compatibility from one institution to its suppliers, clients and outlets.²⁹

The standard was effective at media interchange but by 2005, there were interoperability issues because the specifications were too broad a design. MXF compliant files were not necessarily interoperable with other MXF compliant systems that had adopted a different application of the details of the specifications, and different vendors adopted different sub-format versions of the specification in order to promote their products that were technically compliant but not necessarily interoperable with similar systems from a different vendor.³⁰ Hollywood learned from the MXF experience and understood the need to define a digital media specification for reliable cinema distribution, which resulted in the Digital Cinema standards.

Why IMF When We Already Have Digital Cinema Package (DCP)?

While the DCP is about theatrical content distribution, IMF is about providing businesses with a master format for creating multiple tailored versions of the same piece of content for different audiences. In today's digital landscape for film and television culture, in which the

²⁹ Shim is "an application-specific constraint set that constrains an Application Specification in order to tailor the general specification to a specific purpose," from: "MXF Archive and Preservation Format Registered Disclosure Document." (December, 2018). http://www.digitizationguidelines.gov/guidelines/rdd48-2018_published.pdf.

³⁰ "A notorious example of these vendor to vendor interoperability problems was the Sony XDCAM and the Panasonic DVCPRO P2, both of which were MXF compliant, yet their files were mutually unintelligible to the other system," from: Jay Batista, "Software Infrastructure Global Viewpoint - IMF Supports Interoperability and Increases Performance," <https://www.thebroadcastbridge.com/home/category/software-infrastructure/entry/11410/using-imf-supports-interoperability-while-increasing-performance>

distinction between film and television has noticeably blurred, a myriad of different screens and platforms are thrown into the equation. In this respect, it seems only logical that IMF had to be developed despite the existing robust componentized structure preceded by DCP.

In reality, DCP is not an ideal choice for preservation purposes because it uses intra-frame, JPEG2000-based, visually lossless (yet lossy) compression. DCP is also constrained to projection technology standards, limited as regards resolution (HD, 2K, 4K), aspect ratio (Scope, Flat, or "Scope-across-flat" Container), frame rates (24, 25, 30fps plus their HFR variants), soundfields (stereo, 5.1, 7.1, Dolby Atmos and other immersive audio). Also, encrypted DCPs, which is frequently used as archived masters, can be played back on pre-determined devices only and pending certificates' expiration, with the risk of preventing generation of any new decryption keys, unless a resilient preservation chain for the whole Public Key Infrastructure (PKI) is established and maintained. Once KDMs expire, or authorized playback devices become obsolete, the content will be forever locked inside the encrypted DCP.³¹ IMF is free from this worry as it is a B2B tool assuming that agreed-upon content-security measures are already in place among the exchanged parties.³²

³¹ (Provenzi 2018) 220.

³² (Provenzi 2018) 219.

IMF for Preservation

In addition to the advantages of IMF listed above, the most impressive trait of IMF is that it uses consistent references across its asset files via both hashes and UUIDs, thus making it possible to archive IMPs in a physical media that are spread across vaults, or sublimate them in several Cloud “data lakes”. It will still be possible to address the individual content as if played back, at logical level, from one file system.³³ There are also several open-source tools available for processing IMPs, as can be found in the official IMF User Group website.³⁴

However, since IMF was not developed specifically *for* preservation purpose, there needs to be more discussions around how it can be molded so that the advantages of IMF can be used efficiently and fully as a preservation format. An example of how this is manifesting was shared by David Deelo, Executive Director of Engineering & Technology at Sony Pictures Global Mastering & Servicing, at the “Workshop on Preserving Movies with IMF” event (organized by the IMF User Group and held in Amsterdam on September 13, 2019) – where he said that Sony has been “a big proponent of using IMF for all the distribution mastering, and has also been looking at the Archive eXchange Format (AXF) as a solution for archive mastering”.³⁵ AXF is a standardized interoperable format for data and metadata

³³ (Arrighetti 2019)

³⁴ "Open Source." <https://www.imfug.com/open-source/> (accessed December 2, 2019).

³⁵ "Workshop on Preserving Movies with IMF." (November 15, 2019). <https://www.youtube.com/watch?v=7oyJFhgIrwz>.

preservation that was designed with long-term preservation as a key characteristic. It is storage agnostic where objects can span across medium, can store and relate all kinds of data, of any type, and preserves full context of data within a standardized archive. It can also hold metadata unlimited in languages, formats used, and standards applied. As such, there is a growing interest in combining the traits of IMF and AXF together to create a synergized effect.³⁶ The audiovisual archiving community must figure out where the crossover is between AXF and IMF so that their advantages can be best utilized for preservation purpose.

Conclusion

While it was difficult to capture the complexity of such a highly intricate file format within a short term paper, it should be a sufficient source of information as an introduction. The one critical missing piece of information is the (possible) usage of the format outside of the immediate communities it was created to serve. Since IMF was developed as a B2B solution, it can be assumed that it will not be a popular choice amongst non-profit or small archives, in which the lack of employees with strong technical background could also play a part. However, the shift in our digital landscape is extremely rapid, and as far as digital preservation goes, archival trends and practices could possibly take unexpected turns. More importantly, it is crucial that communities share knowledge and information as we do not

³⁶ "Archive eXchange Format Community Home. <http://www.axf.io/history.html> (accessed December 5, 2019).

know when or where there may be a crossover. From what it looks like now, it looks like IMF will stick around for quite a while. With DCP's intrinsic disadvantages eliminated, IMF is being widely adopted by the film and television industry for its ability to simplify distribution workflows and lower costs and time-to-market; and there are a lot of discussions around how it can be shaped into ways that can serve different, specific purposes. This paper was written with the mission of introducing, to fellow audiovisual archivists, a new format that will be the new DCP. It would be interesting to see how much change will take place in just a few years' time.

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