White Paper

Ensuring Clean IMF Deliveries

The Power of Automating IMF QC Workflows

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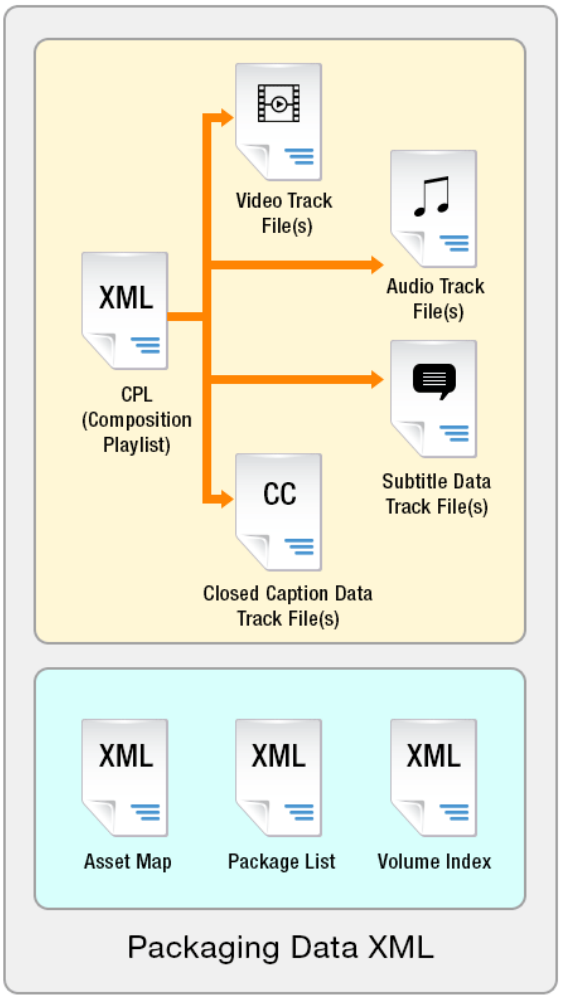
1. WHAT IS IMF?

Interoperable Master Format (IMF) is a SMPTE standard based on the digital cinema standards developed to provide a single, interchangeable master file format and structure for the distribution of content between businesses around the world. IMF provides a framework for creating a true file-based final master. IMF was created to address the needs of major Hollywood studios to more efficiently manage various localized versions of their master content. The scope is limited to a pure business-to-business (B2B) file-exchange environment. Over-the-top (OTT) providers that serve different markets with localized versions of their own content also have a strong interest in simplifying the exchange and creation of distribution copies. The SMPTE Technology Committee 35PM is working to standardize IMF and has produced the ST-2067 series of specifications.



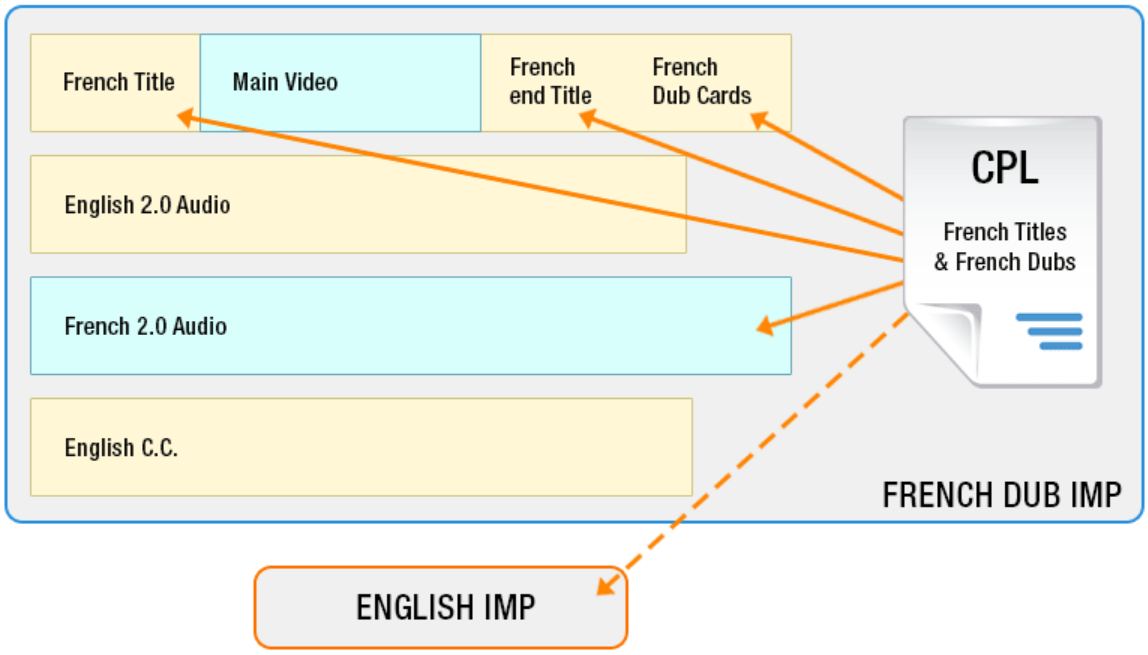
IMF is an interoperable file-based framework designed to facilitate the management and processing of multiple content versions (i.e., airline edits, special editions, different languages, etc.) of the same high-quality finished work (features, episodes, trailers, advertisements, etc.) for distribution channels worldwide. Each content version is embodied in a composition, which combines metadata and essence.

An IMF package contains:

- Audio and video essences in individual MXF track files
- Data essence (subtitles and closed captions) in MXF track files
- Composition Playlist (CPL) – which combines and synchronizes track files as an XML file
- Output Profile List (OPL) – which transcodes profiles as an XML file
- Package list and asset map as XML files

IMF streamlines the distribution of unique versions from content owners to service providers or distributors — and to multiple final destinations. For example, a widely distributed major

motion picture might require dozens of different versions in order to support multiple market segments, such as airlines or VOD providers. It also needs to be made into multiple versions to address promo spots or edits for cable television, OTT services (e.g., Netflix), DVD authoring, and more. IMF eliminates the need to create more than a dozen master copies by separating each market requirement into individual "component formulas" (CPLs) that reference the available essence components (namely MXF media files) included in an IMF package. Individual CPLs are used to create versions based on the master essence components for each of the differing market audiences.



Netflix is one of the early adopters of IMF and accepts 2K/4K content delivery only as an IMF package. The other companies and vendors working on IMF include:

- Major studios and broadcasters (Fox, Disney, Warner Bros., Sony, NBC Universal)
- Manufacturers (R&S, Avid, Imagine Communications)
- Vendors (Technicolor, Deluxe, Fotokem)
- Over 200 members from 122 different companies, plus consultants

2. IMF – FUTURE OF CONTENT DISTRIBUTION

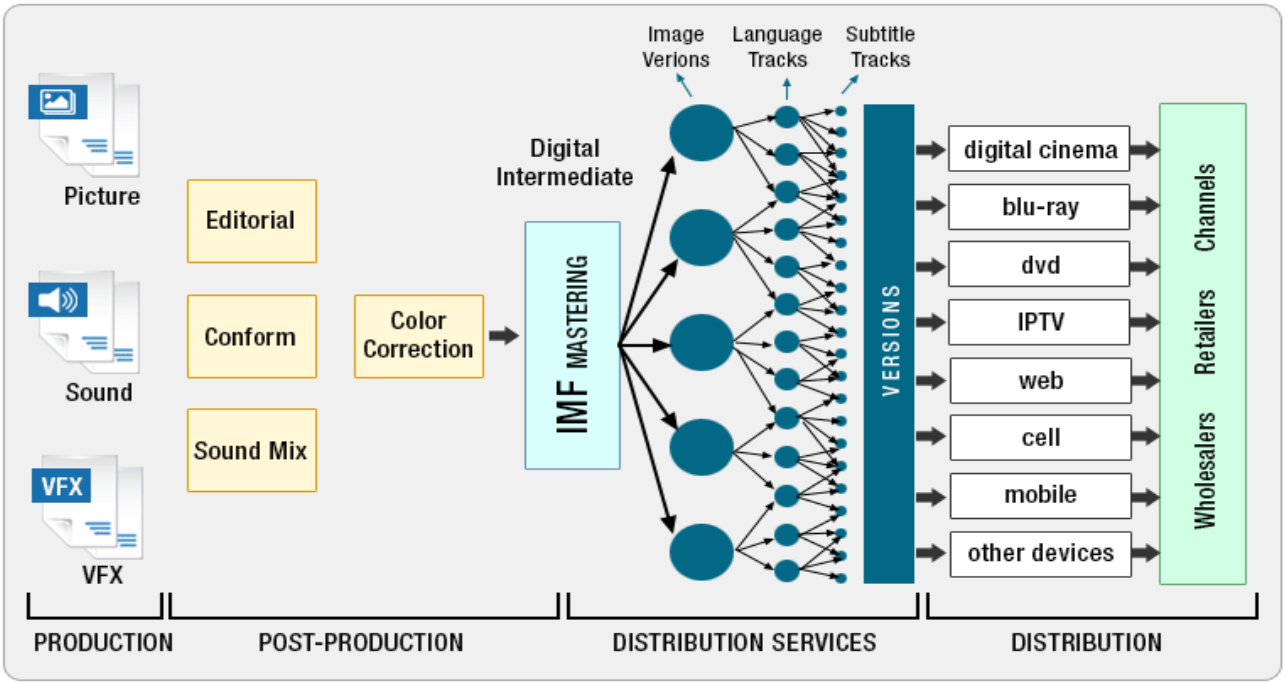
IMF has been embraced by some of the largest players in the industry for several key reasons:

1. **IMF simplifies distribution by reducing the need for:**

    a. *Multiple versions* of each piece of content for international film and TV distribution
    b. *Multiple audio mixes*, including numerous different versions for subtitling and CC
    c. *Multiple edits*, including censure edits, localization edits, a director's cut, and more
    d. *Multiple delivery formats* for cinema, broadcast, internet, mobile devices, airlines, and OTT
2. **IMF creates one final master file**: IMF provides an industry-standard, high-quality final master file. It offers one place to store all of the assets (image, audio, subtitling, and captioning) and metadata (technical and playlists) related to a specific film, episode, or piece of content.
3. **IMF increases the efficiency of content exchange**: IMF maximizes the efficiency of content exchange between content owners, distributors, service providers, and multiple file destinations (theaters, broadcast platforms, and OTT service providers like Netflix).
4. **Mezzanine-level compression**: IMF minimizes storage requirements by using mezzanine-level compression and storing only the differences between the original version and subsequent edits and variants.
5. **Low-cost, fast distribution**: IMF lowers the cost of making and storing multiple masters and assets for the same piece of content, improving time to market and streamlining global distribution.

Based on these advantages, IMF is gaining adoption in the industry. Among the major studios, platforms, and broadcasters behind the initiative are Fox, Warner Bros., Sony, NBC Universal, Disney, and Netflix.

IMF provides an end-to-end content workflow, from production to delivery. The IMF mastering diagram below demonstrates how it streamlines the end-to-end content production and distribution process, along with the various benefits of having a universal master format.

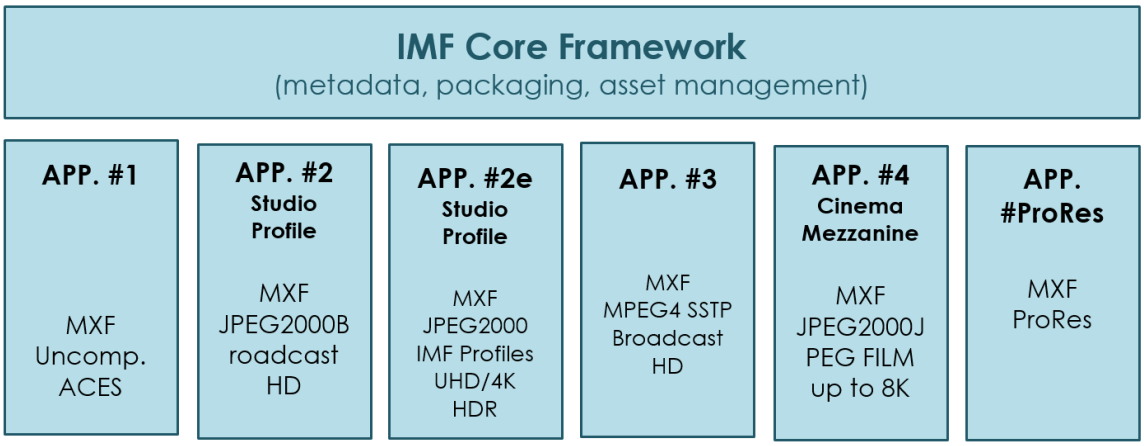


3. CHALLENGES IN IMF WORKFLOWS

IMF solves various media exchange challenges, with versioning being at the top of the list. But every new technology comes with its own share of issues, some of which are discussed below.

Flexible Core Framework

IMF is based on the SMPTE ST-2067 series of specifications that is defined with a very modular approach. The specification defines the core framework and the various implementations — called applications — derived from this core framework. This is depicted in the schematic below.



The core framework for IMF defines the package as a playlist with underlying essences wrapped in MXF. Also, it defines the basic image, audio, and data parameters, along with the mechanism through which these will be related. It is the underlying applications that extend the core framework and define the exact formats, resolutions, and compression standards that will be used. For example, IMF App 2 defines the structure of HD content meant for transforming a show or movie title into multiple versions. Similarly, other application types, like App 2e, extend support for HDR content, while App 3 has support for MPEG-4 Visual Simple Studio Profile codec, and App 4 is intended for exchange of cinematographic work after digital post production.

The core framework defines the basic components of IMF, but it is left to the individual manufacturers to define and deliver the final mix. Each IMF mastering tool can define its own folder structure, file naming conventions, relative path in which the final version will be stored with respect to the original version, and more. This gives the manufacturers flexibility but could become an interoperability nightmare for the content aggregators and broadcasters. The independent and modular architecture of IMF has an advantage of introducing new applications without affecting the core framework, but it also increases the risk of violating standard constraints. Therefore, it becomes important for an automation tool to ensure compliance with codec specifications defined in the respective applications while simultaneously ensuring integrity with the core framework.

It is difficult to keep track of the evolving standards and best practices, particularly with a flexible core framework specification like IMF. It is realistically impossible to perform integrity

checks on the IMF structure XMLs, ensure that the core framework isn't violated, and perform deep analysis of the underlying video and essences. Broadcasters and aggregators must perform in-depth analysis of an IMF package using an automated content verification system — one that is continuously abridged with the latest developments and adopts the trends of an evolving IMF specification.

Complex Composition structure

One of the major driving factors of implementing IMF workflows is to solve versioning issues and to eventually save on storage and network bandwidth. Each unique version is defined as a playlist and represented in the IMF package as a CPL. The CPL is not designed to contain essence but rather to reference external track files that contain the actual essence. This allows multiple compositions to be managed and processed without duplicating the essence in common.

The original version or main package is self-contained, and the CPL refers to external essences that all reside within the package. However, the CPL present in a version file or supplemental package can refer to essences that might reside is a different folder or an altogether different storage location, traceable only through UUIDs. The problem becomes worse when a version file must be delivered that has essences referring to multiple other packages and spread across various storage locations. Further compounding the problem is the complexity of varied folder structures and file naming conventions for content coming from multiple production houses.

Thus, an IMF package can be complete, containing all the referenced constituents, or it might depend on previous packages for one or more video and audio main essences. An IMF package might point to a single timeline, or it might have multiple compositions for various language versions in the same package. An automated QC tool will understand the various flavors of IMF and optimize its analysis to perform thorough checking at a maximum speed.

Evolving Standard

Around 2012, the SMPTE 2067 specification for IMF was conceptualized based on the specification for digital cinema deliveries. Based on the adoption of the current specification and future requirements, the new SMPTE App DPP TSP 2121 was introduced in 2018. Building on the pioneering work of SMPTE, which created a mastering format (IMF) for feature films, the Digital Production Partnership (DPP) and the North American Broadcasters Association (NABA) have collaborated to develop a SMPTE technical specification for an IMF application based on the requirements common to many in the broadcast and online sector. This SMPTE technical specification is based on the image formats referred to in ITU-R BT.2100 and references the SMPTE ST 2067 Interoperable Master Format suite of standards and SMPTE RDD 45:2017 Interoperable Master Format – Application ProRes.

For content aggregators or broadcasters, it is difficult to keep track of an evolving standard and to continuously upgrade their setups or workflows to suit the dynamic environment. These users definitely require substantial automation to keep ahead of the curve.

Metadata Consistency

The CPL defines the playback timeline for the composition and includes metadata applicable to the composition as a whole. For convenience, metadata contained in the track files is also exposed in the CPL and available as individual essence descriptors. For a given video file, the metadata is available in the CPL, in the MXF headers, and in the underlying video essence. The problem becomes worse when, for a given video timeline, the metadata is formed using multiple segments, and each segment carries metadata at the MXF and video level. It is practically impossible to ascertain the consistency of metadata at various levels without the use of an automation tool.

There is an overwhelming amount of IMF metadata contained in the various XML files, the MXF container of each video, audio, and data essence, and the actual essence itself. The first challenge is to read and assimilate the metadata available at various levels of the distributed content structure, and the second is to ensure that it is consistent at all levels. For example, video resolution will be present in the CPL file, in the MXF header metadata, and in

the underlying MJPEG2K/ProRes video essence. It is important that these three values are consistent such that any third-party application that depends on the metadata at any level can operate properly. An AQC tool will fulfill the critical responsibility of ensuring metadata consistency at all levels of content structure.

Playback

Unlike a regular media file that can be played back using freely available tools like VLC Media Player, QuickTime Player, or others, IMF packages have a componentized structure and comprise at least eight to 10 individual files (and possibly many more) that are linked through underlying XMLs. The usual media players can play back individual video, audio, data essences but not the intended IMF timeline that is contained in the CPL. For a content aggregator that has acquired multiple versions of a movie or episodic content as IMF packages, it might be a nightmarish experience to figure out the difference in two versions in the absence of a commercial playback solution. Further, it might be an uphill task to perform in-depth QC or even a quick analysis of the media content.

But despite the various aforementioned complexities of an IMF package, the ability to play back the IMF timeline is currently not available with any free player. Also, it is difficult to play back an error segment identified during content analysis and sync it with an external video, audio, data essence. Therefore, the right automated QC tool will include IMF playback capability to make it a complete solution. An automated QC tool must be accompanied by a playback option to easily visualize the various errors identified during content analysis.

Processing Modes

The applications for IMF relate to production and distribution of finished content. These will always be high-res files with high bitrate and maximum resolution. For an IMF package, the overall size of the media files will be very large and will depend upon compression format, frame rate, bitrate and other parameters of the underlying video and audio essence. For example, the size of a one-hour 4K media file can vary from a few hundred gigabytes to a few terabytes. For IMF packages of such a large size, processing these media files can be

very time-consuming, thus the processing speed of the automated tool becomes very important.

High-speed analysis of the content can be a challenge for a QC tool. To some extent, it can be achieved by using high-quality and modern decoders, but this approach has its limitations. To overcome this challenge, the right AQC tool will use different analysis strategies, such as in-depth analysis or shallow analysis of the content. In the case of shallow analysis, only the header metadata will be parsed and validated, skipping the essence decoding. On the other hand, an in-depth analysis will do the complete decoding and metadata validation. This approach gives users an opportunity to choose a QC strategy that fits their schedules and delivery commitments.

4. INTERRA SYSTEMS' SOLUTION

Interra Systems offers leading machine learning (ML)- and artificial intelligence (AI)-driven, file-based QC solutions that offer comprehensive quality checks and verification efficiency in a flexible environment.

Interra Systems' solution meets all of the extensive requirements for analyzing various flavors of IMF, with an option to auto-discover the media files in a supplemental package that came with the original version. This solution also supports the various flavors of MXF container and all underlying video and audio formats, such as MJPEG, ProRes, and others. System checks are available to validate the metadata across the CPL, MXF container, and underlying media essences. Interra Systems' solution has the most extensive audio and video quality checks to ensure delivery of pristine content for all downstream applications. Finally, our BATON Player application can play back all flavors of IMF content to enable hybrid QC and validation of errors reported by the BATON application.

5. CONCLUSION

When it comes to facilitating uniform deliveries for content exchange, IMF is critical. The nexus of XML files gives the necessary functionality to hold the content timeline, update content location as needed, store content hash values to ascertain content integrity, and store only the changes in order to optimize storage and network bandwidth. Even so, the IMF

system introduces complexity that calls for an accomplished, continually evolving automation quality control tool that is always up to date. The solution should perform in-depth analysis of IMF structure and in-depth video, audio, and data analysis with minimal human intervention.