National, Provincial and Territorial Archives Conference Audiovisual Working Group

Recommendations on Preservation Files for Use in the Digitization of Analog Audio and Video Recordings

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NPTAC Audiovisual Working Group

Contents

1. Scope

These Recommendations were developed by the National, Provincial and Territorial Archives Conference (NPTAC) Audiovisual Working Group to provide advice on the preservation files that could be adopted when digitizing analog audio or video recordings.

These Recommendations do not contain information on:

- The benefits and risks of digitization;
- Selecting or prioritizing recordings for digitization;
- Required hardware and software;
- Workflow;
- All available codecs and file formats that could be used in the digitization of audio and video recordings;
- Quality assurance of digital files;
- Metadata;
- The quality control of files produced during the digitization process;
- File naming;
- Files for access purposes;
- Digital asset management including storage, backup and future migration; or,
- Born digital audio or video content.

2. Application

These Recommendations were developed to provide organizations embarking on digitization projects with a reference from which to develop their own digitization standards.

3. Expected Results

These Recommendations restrict the number and types of preservation files to those that the NPTAC Audiovisual Working Group members have reasonable confidence are sustainable and therefore suitable for long-term preservation. The wide-spread adoption of these Recommendations will aid the preservation of audio and video content nationally.

4. Basic Concepts

Sustainability

Sustainability is ensuring that content is preserved and accessible over time balanced against an organization's resource capacity.

Digitization

Digitization is the process of capturing and converting analog signals into digital form.

Preservation File

A preservation file meets two conditions:

1. It is a high quality digital representation of an analog recording that captures as many attributes of the original content as possible.

2. It demonstrates an adequate level of interoperability, community adoption and documentation to allow the digital information or "essence" of the file to be accessible over the long-term and be retrievable in the future without proprietary intervention or adverse consequences to its quality.

Essence

The digital information within a video or audio file format is called the essence. The essence can be coded in a variety of different ordered formats and with varying levels of compression.

Codec

A codec is hardware or software capable of encoding and/or decoding the essence of a digital audio or video file. The coded format of the essences in a file is often identified by the type of codec that is required to decode the essence for playback. A codec describes the specific set of instructions required to accurately interpret and present the digital essence. For example, JPEG2000, H.264 and ProRes422 are just a few examples of the many different codecs that are used to encode video in a digital file format.

File Format/Container/Wrapper

A file format for digital audio or video, also referred to as a container or wrapper, serves to package the coded essence and associated metadata (structured data about data) together in a specified file format. .MOV (QuickTime), .MXF (Material Exchange Format) and .MP4 (MPEG4) file formats are all examples of different standardized containers or wrappers that could encapsulate coded digital video essence.

A codec and a file format are two different components to a digital audio or video file and the terms are often improperly applied. For example, simply referring to a video .MOV file as a QuickTime file does not adequately describe how it can be properly interpreted as it is a container file that could encapsulate digital video and audio essence that could be coded using one of dozens of different codecs.

Data Compression

Data compression is a process by which a codec is used to decrease the size of a file so it requires less storage space and lower bit rates. Bit rate is the amount of data being processed per unit of time during playback and transmission.

For audio, preservation file sizes are already so small that file size is not an issue therefore files are uncompressed.

The majority of video compression codecs are lossy, meaning some level of information from the original source signal has been lost or interpolated mathematically. There is always a trade-off between visual quality, file size and processing power or system requirements needed to encode and decode a given video compression codec. There are a tier of codecs that are identified as visually lossless, meaning that a subjective comparison made by the naked eye of an average viewer will not detect any visible differences between the original signal and compressed version. However, mathematically there is a difference and it is one that could become more apparent over time as the compressed file goes through future conversions and repeated compression. There are codecs that support lossless compression (Uncompressed V210 or JPEG 2000) which mathematically preserve all the information of

the source signal, but they will require the highest bitrates, largest file sizes and potentially the most computing power to process.

Sample Rate

A sample is the measured value of a signal at a single point in time. Sample rate is the frequency that a signal is sampled at along the axis of time.

When digitizing audio, sample rate is the number of samples per second taken from a continuous, analog signal to make a discrete, digital signal. Analog audio that has been digitized at a sample rate of 96 kilohertz (kHz) has been sampled 96,000 times per second. A greater sampling rate enables the digitization of higher audio frequencies, resulting in a preservation file that captures more of the qualities of the original recording.

During video digitization, the luminance or "luma" (gray-scale brightness) and colour information or "chroma" of the analog video signal are sampled. In a National Television Standard Committee[1] analog video signal, twice as much signal bandwidth is allocated to the luma (Y) information as to the two chroma components (Cb and Cr) because the human eye is less sensitive to colour detail as it is to luminance. In digital video, this sampling rate is referred to as a ratio: 4:2:2 (4 Y, 2 Cb, 2 Cr). Standard definition digital video with 4:2:2 colour sampling is the same ratio of information between signal components as analog and is considered adequate sampling to capture the full signal bandwidth from an analog video source. Digital video sampled at higher ratios of colour sampling (i.e. 4:1:1 or 4:2:0) will create smaller file sizes, but at the cost of colour precision.

Bit Depth

Bit depth is the number of bits of information in each sample. Increased bit depth equals increased precision of the sample and therefore increased quality of the preservation files.

When digitizing audio, a greater bit depth will enable a greater ratio between the quietest and loudest possible values of a signal. This ratio is called dynamic range. It is imperative that digital conservation copies have a greater dynamic range than the original to ensure that all the information is transferred. Digitizing at 24 bits bit depth ensures a dynamic range greater than any audio equipment and format.

In a digital video, the bit depth refers to how many bits of information are used to describe each colour channel (red, green and blue) for each pixel in the frame. The more information allocated per channel, the greater number of colours can be represented in the frame.

5. Evaluation Criteria

The criteria used by the NPTAC Audiovisual Working Group for evaluating codecs and file formats to be used for preservation purposes is entirely derived from the approach advocated by Library and Archives Canada (LAC) in their document *Guidelines on File Formats for Transferring Information Resources of Enduring Value*.[2]

[1] The analog television system employed in Canada.

[2] The criteria is used with the permission of Library and Archives Canada. Please see: http://www.bac-lac.gc.ca/eng/services/government-information-resources/guidelines/Pages/guidelines-file-formats-transferring-information-resources-enduring-value.aspx#aa.

LAC's criteria focuses on ensuring that preservation files meet the definition in *Section 4 Basic Concepts.* In order to gauge the sustainability of a given codec or file format LAC considered the following:

Openness/transparency

- The relative ease with which knowledge of the file format and its technical information can be accumulated.

Adoption as a preservation standard

- The extent to which the format has been formally adopted by national libraries, archives and other memory institutions internationally.

Stability/compatibility

- The degree to which the format is backward and forward compatible.
- The degree to which the format is protected against file corruption.
- The relative frequency of updated or replacement versions of the format over time.

Dependencies/interoperability

- The degree to which the format relies on proprietary/non-proprietary hardware or software.

6. Other Considerations

The Working Group recommends adopting the file formats and codecs that an organization can confidently sustain. Resources are limited; recordings are often in poor condition; playback equipment is scarce. Most organizations will only have a single opportunity to digitize their analog holdings and should try to future-proof their work by making informed file format and codec choices now.

Simply put, a losslessly compressed or uncompressed preservation file will capture the maximum number of attributes of the original recording. However, a blanket statement declaring that lossless uncompressed preservation files are the only option to be considered completely ignores the realities facing most organizations tasked with preserving audiovisual collections. The size of your collection or resources (financial or technical) may render such a choice unsustainable, requiring compromises to be made to ensure a balance between quality and sustainability. Compromise should not be viewed as failure if it enables an analog AV collection to be migrated off obsolete carriers and into a modern digital form.

The NPTAC Audiovisual Working Group acknowledges that every organization will face technical and practical considerations when adopting codecs and file formats. In addition to the four criterion applied by the Audiovisual Working Group in developing these Recommendations, the preservation file choices of organizations will be influenced by other factors including:

Mandate

- The choice of preservation files should always be informed by the mandate of an organization. If the mandate of an organization is long-term preservation then creating uncompressed or losslessly compressed preservation files is recommended in order to capture the maximum fidelity of the original recording. If however, your organization maintains audio and video recordings to achieve only short-term goals than a lower quality preservation file might be justifiable.

Attributes of the material to be digitized

- The extent, quality, uniqueness and value of your analog audio and video recordings may be factors that influence preservation file format decisions. If a collection is made up of copies of recordings where originals or better quality copies exist and are accessible then it may be valid to select a less complex or less storage intensive codec. If a recording is the only copy known to exist, or if an organization has the potential to monetize their collection in the future, then it is reasonable to allocate the resources to create uncompressed or losslessly compressed preservation files.

Current and future use of the content

- When selecting a preservation file, the needs of an organization's user community must be considered. If the complexity of a file negatively impacts the ability of an organization or its stakeholders to repurpose content, then it might not be a wise choice. No one can predict all of the future needs of clients or the technological environment in which files will be used, but the negative attributes of preservation files may be magnified in the future.

Expertise

- The adoption of preservation files requires informed technical expertise. Those making these choices should understand the nature of the original analog recordings as well as file formats/codecs in order to appreciate the immediate and long-term implications that any choices have. If the expertise does not exist internally, there are digitization services that can be engaged. But, all organizations need a basic understanding of their collection, goals and resources in order to ensure that sustainable preservation files are being generated.

  The use of open source file formats/codecs may come with benefits in regards to cost and customization, but organizations who choose this route must be prepared to maintain a minimum level of internal expertise over the long-term to actively participate in the programming communities that support the open source technologies they have adopted.

Storage infrastructure

- The choice of preservation files will dictate the amount of storage space required. Your organization will require infrastructure to securely and confidently sustain preservation files long-term. The infrastructure must also be scalable if collection growth is anticipated.

7. Approach

The file formats and codecs are identified as either[3]:

- Recommended; or,
- Acceptable.

Recommended file formats and codecs are those that ensure that preservation files meet the definition in *Section 4* as well as possessing a high degree of long-term sustainability because they best meet the evaluation criteria in *Section 5*.

Acceptable file formats and codecs are those that meet some of the evaluation criterion in *Section 5* balanced by the considerations in *Section 6*.

[3] File formats are simply listed in *Section 8* and *Section 9*. The order of the list does not suggest that one format is preferable to another. However, a recommended format is always preferable to an acceptable format.

8. Audio Recommendations

Recommended Formats	Recommended Codecs	Recommended Sampling Rate and Bit Depth	File Size per Hour of Content	Minimum Sampling Rate and Bit Depth	File Size per Hour of Content	Pros	Cons	Format Specifications
Broadcast Wave (BWF)	Linear Pulse Code Modulated Audio (LPCM)	96 kHz / 24 bits	2 GB	48 kHz / 24 bits	1 GB	**Openness:** Fully documented and specifications are freely available. **Adoption as a preservation standard:** BWF has become the de facto standard in the audio industry and is specifically recommended by the International Association of Sound and Visual Archivists (IASA), The Audio Engineering Society (AES) and the National Academy of Recording Arts and Sciences (NARAS). **Stability/Compatibility:** BWF audio is compatible with any hardware or software that supports the WAVE format. There have been three iterations of the BWF format under the general specification number EBU Tech 3285 (Version 0 (1987), Version 1 (2001) and Version 2 (2011). **Dependencies/Interoperability:** Universally adopted throughout the audio, computer and broadcast industries as a digital audio format. Embedded metadata (BEXT chunk), facilitates the exchange of sound data between computer platforms and applications and permits synchronization with other recordings.	**Stability/Compatibility:** While hardware and software that does not support the BWF format will recognize the file as a WAVE file, the embedded metadata will not be supported. **Other:** Limited to 4 gigabyte file size.	*European Broadcast Union (EBU). Technical Specification of the Broadcast Wave Format (BWF) – Version 1*: http://web.archive.org/web/20091229093941/http://tech.ebu.ch/docs/tech/tech3285.pdf *Specification of the Broadcast Wave Format (BWF) - Version 2.0:* https://tech.ebu.ch/docs/tech/tech3285.pdf
Acceptable Formats	**Acceptable Codecs**	**Recommended Sampling Rate and Bit Depth**	**File Size per Hour of Content**	**Minimum Sampling Rate and Bit Depth**	**File Size per Hour of Content**	**Pros**	**Cons**	**Format Specifications**
WAVeform Audio (WAV)	Linear Pulse Code Modulated Audio (LPCM)	96 kHz / 24 bits	2 GB	48 kHz / 24 bits	1 GB	**Openness:** fully documented and specifications are available. **Adoption as a preservation format:** massive adoption in the international archival community. **Stability/Compatibility:** It is an extension of the WAV format – any software that can interpret/render BWF content can also interpret/render WAV content; protected against file corruption; has been updated: WAV: Version 1.0: 1991; Version 3.0: 1994; Multichannel: 2001 / BWF: Original: 1997; Updates: 2001, 2003 **Dependencies/Interoperability:** universally adopted throughout the audio, computer and broadcast industries so all digital audio software and devices can play this file format.	**Other:** Limited to 4 gigabyte file size. **Other:** Technical metadata cannot be embedded in the file.	*Multimedia Programming Interface and Data Specifications 1.0*: http://www-mmsp.ece.mcgill.ca/Documents/AudioFormats/WAVE/Docs/riffmci.pdf
Multichannel Broadcast Wave (MBWF / RF 64)	Linear Pulse Code Modulated Audio (LPCM)	96 kHz / 24 bits	2 GB	48 kHz / 24 bits	1 GB	**Openness:** Fully documented and specifications are freely available. **Adoption as a preservation format:** Adopted by the EBU as a multichannel audio file standard and archival standard for files exceeding 4 GB in size. **Stability/Compatibility:** MBWF is a BWF-compatible file format which has been specified by the European Broadcasting Union. The file format is designed to meet the requirements for multichannel sound in broadcasting and audio archiving. It is based on the Microsoft RIFF/WAVE format and Wave Format Extensible for multichannel parameters. The technical specification for MBWF/RF64 is EBU - Tech 3306. RF64 is also a BWF compatible multichannel file format.	**Stability/Compatibility:** While most digital audio workstations support the RF64 file format, some older audio software does not support RF64.	*European Broadcast Union (EBU) MBWF /RF64 : An Extended File Format for Audio:* *https://tech.ebu.ch/docs/tech/tech3306-2009.pdf*

9. Video Recommendations

Recommended Formats	Recommended Codecs	Recommended Sampling Rate and Bit Depth (Standard Definition)	File Size per Hour of Content	Minimum Sampling Rate and Bit Depth (Standard Definition)	File Size per Hour of Content	Pros	Cons	Format Specifications
Material Exchange Format (MXF) OP1a	Image: JPEG 2000 lossless compression Audio: PCM / Broadcast Wav (Audio, Video and timecode information are wrapped together in the MXF container as defined by SMPTE ST 377-1:2011)	10-bit, variable bitrate Lossless minimum average 50mbps 24-bit, 48khz	40 GB	8-bit, Variable bitrate Lossless minimum average 50mbps 16-bit, 48Khz	40 GB	**Openness:** Codec and wrapper are either an ISO or SMPTE standard. JPEG 2000 is a fully documented ISO standard. **Adoption as a preservation format:** Adoption by larger organizations in the international archival community, including the Library of Congress and the UK Digital Archives. **Dependencies/Interoperability:** Software encoding and playback of MXF wrapped JPEG2000 is now possible without custom hardware on high end multi-core CPU systems. **Other:** Lossless compression allows for file sizes to be up to 2.5 times smaller compared to uncompressed.	**Stability/Compatibility:** lack of consistency between different vendors in the implementation of the MXF standard can cause playback compatibility difficulties. The issues experienced have centered on variances in how the JPEG2000 essence is being described in the .MXF wrapper. The Library of Congress is currently leading a project to have a set of constraints formalized for the construction of .MXF files and having these templates recognized as standard operational patterns within the format. **Dependencies/Interoperability:** JPEG 2000 requires higher system specifications for encoding and playback in real time. Support for the format in consumer level devices is rare and open-source support is in its infancy due to licensing fees.	SMPTE ST 377-1:2011, *Material Exchange Format (MXF) File Format Specification*: http://standards.smpte.org/ ISO/IEC 15444-1:2004, *Information technology – JPEG 2000 image coding system: Core coding system*: http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=37674
QuickTime (MOV)	Image: Uncompressed 4:2:2 Audio: PCM (Audio, Video and timecode information are wrapped together in the MOV container as defined by QuickTime file format specifications)	10-bit uncompressed v210 codec - approx. 36 MB/sec 24-bit, 48khz	130 GB	8-bit Approx. 29 MB/sec 16-bit, 48Khz	105 GB	**Openness:** QuickTime file format is well documented and near full format disclosure is available from freely from Apple Inc. The QuickTime format was used as the basis for the standardization of the MPEG-4 file format (ISO/IEC 14496-14:2003). **Adoption as a preservation format:** File format enjoys wide community adoption in large institutions, video post-production and including many consumer level devices. Support for editing and transcoding in virtually all professional editing software. **Dependencies/Interoperability:** 8-bit QuickTime uncompressed 4:2:2 is supported by virtually any system that can support the base QuickTime codec package and system/storage requirements to handle large media files.	**Dependencies/Interoperability:** The 10-bit uncompressed v210 codec variant that allows for 10-bit colour depth in a QuickTime wrapper is not included in the base QuickTime codec package and although freely available, is potentially tied to proprietary vendor support. (i.e. AJA v210 codec) **Other:** File sizes are very large.	*QuickTime File Format Specification*: https://developer.apple.com/library/mac/#documentation/QuickTime/QTFF/QTFFPreface/qtffPreface.html

Acceptable Formats	Acceptable Codecs	Recommended Sampling Rate and Bit Depth (Standard Definition)	File Size per Hour of Content	Minimum Sampling Rate and Bit Depth (Standard Definition)	File Size per Hour of Content	Pros	Cons	Format Specifications
Audio Video Interleaved Format (AVI)	Image: JPEG 2000	10-bit variable bit rates - dependent on level of compression Lossless compression is a minimum average of 50mbps	File sizes are variable with lossy compression. 40 GB in lossless mode.	8-bit variable bit rates - dependent on level of compression	File sizes are variable with lossy compression. 40 GB in lossless mode.	**Openness:** The AVI file format was first introduced by Microsoft in 1992 and is a derivative of the RIFF (Resource Interchange File Format). JPEG 2000 is a fully documented ISO standard. **Adoption as a preservation format:** Lossless JPEG 2000 has been adopted by larger organizations in the international archival community, including the Library of Congress and the UK Digital Archives. **Dependencies/Interoperability:** The AVI file container format is well documented and has been supported natively in every version of the Windows operating system since its introduction. **Other:** JPEG 2000 when used in lossy compression mode will create decidedly smaller target files than lossless or uncompressed codec options.	**Adoption as a preservation format:** The AVI file container has not been widely endorsed as a preservation file format as it has several limitations, including: • The AVI format does not specify a standardized way to include embedded aspect ratio information • There are more than one competing approaches to wrap timecode information in an AVI file • The AVI format was never designed to accommodate any compression method that required access to future frame data beyond the current frame being decoded. As a result, implementations that support inter-frame compression codecs in an AVI wrapper are proprietary in nature and may depend on specific hardware/software support. **Dependencies/Interoperability:** JPEG 2000 requires higher system specifications for encoding and playback in real time. Support for the format in consumer level devices is rare and open-source support is in its infancy due to licensing fees. **Other:** Any codec that introduces lossy compression will result in some amount of detail and information from the original analog recording to be lost during the digitization process. This loss may be minimal or "visually lossless", but future transcoding or conversion of the format through multiple digital generations may begin to introduce visible artifacts. The smaller the target file size gets, the greater loss of original detail will occur due to greater compression.	*AVI RIFF File reference*: http://msdn.microsoft.com/en-us/library/ms779636.aspx ISO/IEC 15444-1:2004, *Information technology – JPEG 2000 image coding system: Core coding system*: http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=37674
	Audio: PCM	JPEG 2000 24-bit, 48khz		JPEG 2000 16-bit, 48Khz				
Audio Video Interleaved Format (AVI)	Image: DV-NTSC (DV AVI)	8-bit Bitrate: 29mbps DV-NTSC parameters are not configurable as they are a hard restriction of the format to maintain compatibility	13 GB	Same (parameters restricted)	13 GB	**Openness:** The AVI file format was first introduced by Microsoft in 1992 and is a derivative of the RIFF (Resource Interchange File Format). DV-NTSC was first standardized through the IEC (International Electrotechnical Commission) family of standards in 1995. This standard outlined more than just the video encoding parameters, but also how DV video was to be recorded on videotape. Subsequent revisions developed by Sony and Panasonic lead to additional standardization by the SMPTE. **Adoption as a preservation format:** Although not necessarily recommended as a preservation format, DV-NTSC is potentially a good alternative option for recordings that are on digital tape formats (i.e. MiniDV, Digital 8, DVCAM) as the DV-NTSC codec would maintain the identical information that is on the tape. DV-NTSC has wide adoption at the consumer level and is easily edited. **Dependencies/Interoperability:** The AVI file container format is well documented and has been supported natively in every version of the Windows operating system since its introduction. The DV-NTSC codec has wide support in many software and hardware devices from the professional to the consumer level **Other:** DV-NTSC will create decidedly smaller target files than lossless or uncompressed codec options.	**Adoption as a preservation format:** The AVI file container has not been widely endorsed as a preservation file format as it has several limitations, including: • The AVI format does not specify a standardized way to include embedded aspect ratio information • There are more than one competing approaches to wrap timecode information in an AVI file • The AVI format was never designed to accommodate any compression method that required access to future frame data beyond the current frame being decoded. As a result, implementations that support inter-frame compression codecs in an AVI wrapper are proprietary in nature and may depend on specific hardware/software support. **Other:** Any codec that introduces lossy compression will result in some amount of detail and information from the original analog recording to be lost during the digitization process. This loss may be minimal or "visually lossless", but future transcoding or conversion of the format through multiple digital generations may begin to introduce visible artifacts. The smaller the target file size gets, the greater loss of original detail will occur due to greater compression.	*AVI RIFF File reference*: http://msdn.microsoft.com/en-us/library/ms779636.aspx *Microsoft NTSC DV-AVI File reference*: http://msdn.microsoft.com/en-us/library/windows/desktop/dd407250%28v=vs.85%29.aspx *IEC 61834-1:1998 (NTSC-DV)*: https://webstore.iec.ch/publication/5979
	Audio: PCM	DV-NTSC 16-bit, 48khz						

Acceptable Formats	Acceptable Codecs	Recommended Sampling Rate and Bit Depth (Standard Definition)	File Size per Hour of Content	Minimum Sampling Rate and Bit Depth (Standard Definition)	File Size per Hour of Content	Pros	Cons	Format Specifications
QuickTime File Format (MOV)	Image: JPEG 2000	10-bit, variable bit rates - dependent on level of compression. Lossless compression is a minimum average of 50mbps	File sizes are variable with lossy compression. 40 GB in lossless mode.	8-bit variable bit rates - dependent on level of compression	File sizes are variable with lossy compression. 40 GB in lossless mode.	**Openness:** Quicktime file format is well documented and near full format disclosure is available from freely from Apple Inc. The Quicktime format was used as the basis for the standardization of the MPEG-4 file format (ISO/IEC 14496-14:2003). JPEG 2000 is a fully documented ISO standard. **Adoption as a preservation format:** Lossless JPEG 2000 has been adopted by larger organizations in the international archival community, including the Library of Congress and the UK Digital Archives. **Other:** JPEG 2000 when used in lossy compression mode will create decidedly smaller target files than lossless or uncompressed codec options.	**Dependencies/Interoperability:** JPEG 2000 requires higher system specifications for encoding and playback in real time. Support for the format in consumer level devices is rare and open-source support is in its infancy due to licensing fees. **Other:** Any codec that introduces lossy compression will result in some amount of detail and information from the original analog recording to be lost during the digitization process. This loss may be minimal or "visually lossless", but future transcoding or conversion of the format through multiple digital generations may begin to introduce visible artifacts. The smaller the target file size gets, the greater loss of original detail will occur due to greater compression.	*QuickTime File Format Specification*: https://developer.apple.com/library/mac/#documentation/QuickTime/QTFF/QTFFPreface/qtffPreface.html ISO/IEC 15444-1:2004, *JPEG 2000 image coding system*: http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=37674
	Audio: PCM	JPEG 2000 24-bit, 48khz		JPEG 2000 16-bit, 48Khz				
QuickTime File Format (MOV)	Image: DV-NTSC (DV 25)	8-bit Bitrate: 29mbps DV-NTSC parameters are not configurable as they are a hard restriction of the format to maintain compatibility	13 GB	Same (parameters restricted)	13 GB	**Openness:** Quicktime file format is well documented and near full format disclosure is available from freely from Apple Inc. The Quicktime format was used as the basis for the standardization of the MPEG-4 file format (ISO/IEC 14496-14:2003). DV-NTSC was first standardized through the IEC (International Electrotechnical Commission) family of standards in 1995. This standard outlined more than just the video encoding parameters, but also how DV video was to be recorded on videotape. Subsequent revisions developed by Sony and Panasonic lead to additional standardization by the SMPTE. **Adoption as a preservation format:** Although not necessarily recommended as a preservation format, DV-NTSC is potentially a good alternative option for recordings that are on digital tape formats (i.e. MiniDV, Digital 8, DVCAM) as the DV-NTSC codec would maintain the identical information that is on the tape. DV-NTSC has wide adoption at the consumer level and is easily edited. **Dependencies/Interoperability:** The DV-NTSC codec has wide support in many software and hardware devices from the professional to the consumer level. **Other:** DV-NTSC will create decidedly smaller target files than lossless or uncompressed codec options.	**Other:** Any codec that introduces lossy compression will result in some amount of detail and information from the original analog recording to be lost during the digitization process. This loss may be minimal or "visually lossless", but future transcoding or conversion of the format through multiple digital generations may begin to introduce visible artifacts. The smaller the target file size gets, the greater loss of original detail will occur due to greater compression.	*QuickTime File Format Specification*: https://developer.apple.com/library/mac/#documentation/QuickTime/QTFF/QTFFPreface/qtffPreface.html
	Audio: PCM	DV-NTSC 16-bit, 48khz		DV-NTSC: same (parameters restricted)				

Acceptable Formats	Acceptable Codecs	Recommended Sampling Rate and Bit Depth (Standard Definition)	File Size per Hour of Content	Minimum Sampling Rate and Bit Depth (Standard Definition)	File Size per Hour of Content	Pros	Cons	Format Specifications
QuickTime File Format (MOV)	Image: Apple ProRes 422	10-bit HQ mode Bitrate: variable approx. 63mpbs	27 GB	8-bit standard mode Bitrate: variable approx. 42mpbs	18 GB	**Openness:** Quicktime file format is well documented and near full format disclosure is available from freely from Apple Inc. The Quicktime format was used as the basis for the standardization of the MPEG-4 file format (ISO/IEC 14496-14:2003). **Dependencies/Interoperability:** Apple ProRes enjoys wide support in broadcast post-production and professional editing software. Playback of the codec is included in the base Quicktime codec package and open-source playback compatibility exists.	**Openness:** ProRes is a lossy video compression codec developed by Apple Inc. primarily for use as an intermediate codec in video post-production. The codec is well described publicly by Apple Inc., but it has not been standardized by any international body. **Adoption as a preservation format:** Apple ProRes has not been widely adopted as a preservation format as it is an inherently lossy format. As an intermediate codec, it was designed to balance quality and processing efficiency in a broadcast/post-production environment. **Dependencies/Interoperability:** Encoding Apple ProRes is free when working on Apple hardware (MAC OS), but requires hardware and software products that operate on other platforms to be strictly licensed by Apple Inc. **Other:** Any codec that introduces lossy compression will result in some amount of detail and information from the original analog recording to be lost during the digitization process. This loss may be minimal or "visually lossless", but future transcoding or conversion of the format through multiple digital generations may begin to introduce visible artifacts. The smaller the target file size gets, the greater loss of original detail will occur due to greater compression.	*QuickTime File Format Specification*: https://developer.apple.com/library/mac/#documentation/QuickTime/QTFF/QTFFPreface/qtffPreface.html *Apple ProRes White Paper October 2012*: http://images.apple.com/finalcutpro/docs/Apple_ProRes_White_Paper_October_2012.pdf
	Audio: PCM	Apple ProRes HQ: 24-bit, 48khz		Apple ProRes: 16-bit, 48khz				
Matroska File Format (MKV)	Image: FFv1 (lossless compression)	10-bit lossless	~40GB	8-bit lossless	~40GB	**Openness:** The Matroska file format is open-source and the specification is freely available. The FFv1 codec is open-source and the specification is freely available (although incomplete). **Other:** Software implementation costs are free as open-source software does not carry any license fees. Version 3 of the FFv1 supports frame level CRC fixity information and more self-descriptive properties at the codec level such as field dominance, aspect ratio and colour space information. This can be viewed as an advantage as other codecs often require the wrapper to carry this information which contributes to interoperability problems.	**Dependencies/Interoperability:** Commercial vendor support for the use of FFv1 and the Matroska file format is weak. A pre-requisite to an institution adopting open-source technologies is the understanding that a long-term commitment to retaining development expertise will be required to actively participate in the programming communities that support these file formats and the tools that can create them.	*Matroska file format:* http://www.matroska.org/index.html *FFv1 Video Codec Specification:* http://www.ffmpeg.org/~michael/ffv1.html
	Audio: PCM	24-bit, 48Khz		16-bit, 48Khz				

Appendix A: Recommended Reading

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