International Association of Sound and Audiovisual Archives
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Technical Committee
Standards, Recommended Practices, and Strategies

# Guidelines for the Preservation of Video Recordings

IASA-TC 06

## *Part D. Planning, Setup, and Workflows for Video Digitisation*

From IASA-TC 06, Edition 1
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# D.1 PLANNING, SETUP, AND WORKFLOWS FOR VIDEO DIGITISATION

## D.1.1 Introduction

### D.1.1.1 Applicability to in-house and outsourced operations

This section has two audiences. First, it is intended to be helpful to someone setting up and operating a digitising facility. It is not, however, a facility-builder's how-to document. Production facilities are purpose-built, cater to a given organization's needs, and vary from instance to instance. Nevertheless, some useful things can be said about setup, operations, and quality control that apply to a range of production arrangements.

The design and build of a large-scale video facility must take into account all of the components described as parts of the video infrastructure (D.1.3.1.3). Proper execution of such a design-build activity requires solid technical expertise and experience, and many large archives have engaged specialist system integrators (often from the broadcast realm) to support planning and development.

Second, this section is intended to be helpful to those who outsource digitisation, understood to include what the contractor Memnon calls *insourcing*, work executed on an archive's premises with archive staff participation. The concepts and practices described in this section apply to work performed by a contractor, and some level of description of operations and quality control ought to be part of the contract's terms and conditions.

### D.1.1.2 Artisanal and high volume "factory" operations

The range of models for digitisation operations is broad. At the 2016 IASA annual meeting, Technical Committee member Jörg Houpert of Cube-Tec sketched this helpful distinction, in effect marking two ends of a spectrum of operational models:

Traditional audiovisual digitisation method

- Carried out by professional, using an artisanal or "arts and crafts" approach
- One person digitises content from beginning to end, through all of the production steps
- The method requires skilled personnel
- The method does not scale up well for large quantities of material

Large-scale "factory" method

- The work is broken out into independent process steps
- Process is more complex than the traditional method
- Setup and management requires skilled personnel, many action steps can be carried out by "technician-level" staff
- Quality control and assurance is not possible on a "personal" level
- Automated measures manage the process, with tools for quality control and assurance

### D.1.1.3 Digitising in terms of three *zones*

This discussion is framed in terms of three conceptual *zones*, each of which includes a number of elements. The zones and elements are most clearly defined for Houpert's factory setup, but to a degree they come into play for all operational setups. Since the zones and elements can only be defined in reliable detail for a given facility when the details of its setup and procedures are known, this section treats them in a general way.

D.1.2 Planning and preparing collection materials for digitisation
D.1.3 Setting up and testing a digitising facility and system
D.1.4 Operating a digitising facility and system

## Sidebar: What is entailed when digitising video?

There is no one answer: the multiple components of the source recording vary, as do the methods applied and, for that matter, there is variation in an archive's preferences regarding the extent to which they wish to reproduce every feature of the original. However, in order to illustrate several possible aspects and actions that may comprise digitisation, here is an example based on a 1-inch type C recording.

### PICTURE

- Play the tape: the picture output is an analogue composite baseband signal that is, in turn, the picture input to the conversion system.
  - Device: playback VTR, with "intimate" (and in some cases, built-in) supporting devices, e.g., a time base corrector and a processing amplifier (see D.1.3.1.4).
- Transform the baseband composite signal into an analogue component signal.[1]
  - Device: may be the VTR, may be a downstream device; some digitising systems execute some or all of the remaining actions under the covers.
- Sample/quantize the analogue component luma and chroma to produce a component digital data stream that conforms to the SMPTE SDI (Serial Digital Interface) standard, 10-bit 4:2:2.
  - Device: may be the VTR, may be a downstream device; some digitising systems execute some or all of the remaining actions under the covers.
- Structure the SDI digital stream digitally into a standardized bitstream format that can be wrapped as a computer file; in this illustrative example, we assume V210.[2]
  - Device: some digitising systems execute some or all of the remaining actions under the covers.
- Wrap the V210 structured data (and the rest of the video payload) into a file wrapper.
  - Device: some digitising systems execute this and preceding actions under the covers.

1 Analogue *composite* video contains two major commingled parts: (1) *luma* or brightness information that produces a black-and-white picture and (2) *chroma* or colour information. Prior to the start of digital broadcasting in the early 2000s, television signals reached the home in composite form and every analogue receiver contained a filter to separate the luma and chroma into a *component* signal for display. Filters are still needed today when reformatting composite video recordings. The least expensive (and inferior) type is a *notch and bandpass filter*. Professional types fall into the class called *comb filters*, and these come at varying levels of quality. Lower quality types lose resolution in horizontal, vertical, or both dimensions. Some produce visual artefacts such as crawling dots where patches of different colours meet or rainbow swirls where thin stripes should be. As is often the case with signal-processing technology, "everything is a tradeoff". The perfect filter does not exist, although many experts favour what are called *3D comb filters*. A thorough discussion of this topic is presented on *TV Comb Filters* (Jayne: 2015).

2 "V210 Video Picture Encoding" (page on the Library of Congress Format Sustainability website, http://www.digitalpreservation.gov/formats/fdd/fdd000353.shtml, accessed 16 December 2017.

**SOUND**

- Play the tape: output is analogue audio
  - Device: playback VTR.
- Sample/quantize the analogue to produce LPCM digital audio; one stream for each original track. In order to provide metadata for which sound on which track, a manual process may be required.
  - Hand off the LPCM stream(s) to the digitising system employed for picture, so that the audio data is embedded into the SDI stream, and then carried forward in parallel with the picture information.

**ANCILLARY DATA AND MORE**

- Encoding device provides new "master" (synthetic) time code to the stream to be preserved.[3]
  - This is the main time code in the SDI stream described above
- Varying according to target format selection, system provides documentation of legacy time codes (what type, start number, drop/non-drop frame, indications of discontinuities). The MXF target format wrapper can carry and tag these, as can some other formats, otherwise, this documentation goes to a sidecar file.
- If captions/subtitles [binary] are in the original, conversion system converts to XML Timed Text and, varying according to target format selection, sends them to include in final file wrapper, or into a caption/subtitle sidecar file.
- More ancillary data types may be in play, not elaborated upon here.

### D.1.1.4 Quality assurance, control, and critical control points

#### D.1.1.4.1 Quality assurance and quality control

In ordinary English, *quality assurance* and *quality control* are often used interchangeably to refer to the methods or approaches used to ensure the quality of a service or product. For many businesses, especially in the field of manufacturing, these words become *terms*, and the practices associated with *quality assurance* have been enshrined in the well-respected international standard ISO 9000.[4]

*Quality assurance* pertains to the prevention of mistakes or defects in manufactured products and avoiding problems when delivering services, with a strong dependency on what ISO 9000 defines as "part of quality management focused on providing confidence that quality requirements will be fulfilled"[5]. Thus quality assurance can be seen as an overall process guarantee that depends on a variety of factors ranging from good administrative management to the specific actions categorized as *quality control*.

3 Consideration of new master time code and existing legacy time code(s) makes for a complex and nuanced topic, explored below in section D.1.4.2.1, as well as in B.1.3.2.1.1, B.1.3.2.2, B.3.3.2.1, B.3.3.2.2, and B.3.3.2.3. The capabilities of encoding devices vary, including such features as the ability to "stripe" new time code, avoiding discontinuous time code, and determining where time code(s) reside in the destination file(s) and/or in sidecar files such as the Dalet TCD file.

4 The phrase that ends this sentence is shorthand for what ISO refers to the "ISO 9000 family of standards," with publication and revisions dating from 1987 to 2015. Some description and several links to other documents are provided from https://www.iso.org/iso-9001-quality-management.html.

5 ISO 9000:2005, Clause 3.2.11.

The concepts and terminology used in IASA-TC 06 to describe quality assurance and control are outlined in sections D.1.1.4.2 and D.1.1.4.5, below, with additional information provided in section D.1.4.3. Readers should note that a valuable, experience-based description specific to audiovisual materials, using alternate concepts and terminology, is provided in Mike Casey's "Quality Control for Media Digitization Projects" (Casey 2019).

### D.1.1.4.2 Critical control points and quality control

Each of the three digitising zones defined in section D.1.1.3 offers at least one *Critical Control Point*. This concept is borrowed from the structure employed by the U.S. Food and Drug Administration for the inspection of food production: Hazard Analysis and Critical Control Point (HACCP) management.[6] The HACCP approach identifies, evaluates, and controls food safety hazards in terms of the process steps at which control can be applied. The application of HACCP is essential to prevent or eliminate a food safety hazard or to reduce it to an acceptable level. "The proper identification of Critical Control Points," the FDA writes, "ought to emerge as a result of a careful analysis of an actual production system".

Critical control points are the focus for quality control actions. Since IASA-TC 06 discusses production systems at a general and somewhat abstract level, the discussion of quality control is also relatively generic.

D.1 Table 1. Operational "zones" and quality control

| Name of zone | Comment on quality control for this zone |
| --- | --- |
| D.1.2 Planning and preparing collection materials for digitisation | Generally, a matter of "good housekeeping," good administration; technology metrics are not significant. |
| D.1.3 Setting up and testing a digitising facility and system | Generally, a matter of (a) good design when assembling and interfacing devices, together with (b) performance testing of devices and systems, which includes technology metrics for some devices. |
| D.1.4 Operating a digitising facility and system | Quality control in this zone is complex and multifaceted; commercial and open source tools exist, each of which offers similar-but-not-identical coverage; technology metrics are significant. Attentive observation by technical staff is also always necessary; no archive should rely solely on reports from automated tools. |

### D.1.1.5 Quality control: how much science, how much art?

Parts B and C of IASA-TC 06 underscore the variability of the digitisation of video for the sake of long-term preservation. Types of originals vary, preferences for target formats vary, the complexity of the video payload leads to variation in the aspects that a given archive chooses to emphasize. It is not surprising, therefore, that similar variation exists regarding quality control, for many of the same reasons.

6 The main home page for HACCP is https://www.fda.gov/Food/GuidanceRegulation/HACCP/default.htm.

As noted in the preceding table, the quality control actions for D.1.2 and D.1.3 have an *indirect* bearing on the preservation files that are produced. Quality control for D.1.2 is a matter of good administration, and D.1.3 entails testing the devices and systems that will be used to produce the preservation files.

In contrast, the quality control actions for D.1.4 have to do with assessing the quality of video playback, signal transfer, file-making, and the finished files in a *direct* way, either (a) as the digitising transfer is under way and the file is being made or (b) checking the file after production has been completed. As will be reported in the Critical Control Point sections for operations (D.1.4.3), most archives (or their contractors) use tools to support quality control in these zones. And it is here that considerable variability is encountered. Some quality control tools are commercial products while others are open-source. Although there are significant differences in coverage, each adds a level of discipline to the control of quality and provides some level of support in identifying flaws and helping correct them. More information is provided in section D.1.4.3.3 and in D.1 Appendix A.

### D.1.1.6 Broadcast community quality control initiatives for file-based video

#### D.1.1.6.1 The EBU quality control activity: insight into QC dimensions

The somewhat loose nature of file-based-video quality control has inspired at least one standards body to begin to develop a more systematic (and scientific) approach. First unveiled at the 2013 IBC (International Broadcasting Convention), the European Broadcasting Union (EBU) announced its work on the standard TECH 3363 *Quality Control Test Definitions*. One EBU promotional blurb states that "Manual Quality Control alone is not adequate anymore and does not scale … broadcasters are finding it difficult to keep up with manual checks [and] look into automated file-based quality control systems to cope with the large amount of content and the abstract nature of digital files."[7] This work continues and, although it caters to the production and multifaceted distribution of broadcasts in the twenty-first century, memory institution archives have much to gain by studying its direction and progress.

One insight from the EBU effort is a view of the "layers" that are relevant in video file quality control:[8]

- File wrapper. This is about the container and its structure and integrity. Digital library specialists familiar with JHOVE will recognize the emphasis on format validity and well-formedness.[9]
- Essence bitstream. This is looking at the structure and integrity of essence elements, mainly picture and sound but also forms of ancillary data, as they are represented in the stream of bits in the wrapper.
- Baseband (decoded essence). Similar to the bitstream focus although here concerned with "playing" the stream of bits to evaluate their adherence to broadcast requirements using a different yardstick.
- Cross-check. Method to verify that data from multiple layers agree.

7 Quality Control, https://tech.ebu.ch/qc#quality-control. An excellent starting point for the overall EBU quality control effort is https://ebu.io/help/qc/. Formerly defined in a spreadsheet, EBU QC test items are shared via an online platform that allows for exporting the information. Sometimes referred to as a tool, the EBU QC database is under continuing development, with a helpful introduction: https://ebu.io/help/qc/guide. (All URLs accessed 23 December 2018.)

8 The IASA-TC 06 authors are grateful to IASA Technical Committee member Jörg Houpert for this analysis.

9 *JHOVE2*, http://www.dcc.ac.uk/resources/external/jhove2, accessed 16 December 2017.

Incidentally, EBU has also revisited aspects of the digital metrics used to ensure that program content conforms to broadcast requirements. For example, EBU's 2016 recommendation *Video Signal Tolerance in Digital Television Systems* associates luma ("brightness") levels that have been traditionally represented in terms of voltage and displayed on a waveform monitor by recommending measurement based on ranges of digital sample values (like what you see on a Photoshop histogram).[10]

### D.1.1.6.2 The DPP and digital-format program interchange

The Digital Production Partnership (DPP) is a UK broadcast-community group, launched in 2009 and incorporated in 2015, with active involvement from the BBC and the ITV Network, and with outreach and connections to broadcasters in Europe. In order to facilitate the exchange of file-based program content, including examples that may be presented in different language settings, the DPP has drafted a number of detailed broadcast-program technical profiles, called Application Specifications, generally with the identifier AS-11.[11]

The DPP AS-11 specifications are for MXF-wrapped recordings that feature high quality lossy compression of the picture essence. Thus they do not meet the preservation-oriented recommendations of this guideline. Nevertheless, the DPP activity includes an instructive example of a well-developed approach to interoperability and quality control. From the start, DPP planned to support AS-11 conformance and certification, "to speed the implementation of the file-based delivery process by ensuring products can correctly create, read, and/or process files which meet the AS-11 DPP HD standard"[12].

10 *EBU R 103 Video Signal Tolerance in Digital Television Systems, ver. 2.0,* https://tech.ebu.ch/docs/r/r103.pdf, accessed 16 December 2017.

11 The DPP AS-11 Application Specifications have been approved and published under the auspices of the Advanced Media Workflow Association (AMWA). The main website for DPP file delivery is https://www.thedpp.com/filedelivery/as-11, accessed 20 June 2020.

12 The DPP Compliance Programme is discursively described in a 2017 blog (from which this quote was taken), now accessible via the Internet Archive, https://web.archive.org/web/20170506111800/https://www.digitalproductionpartnership.co.uk/what-we-do/compliance-programme/. More recent information, less discursive but offering a thorough and instructive technical structure, is provided from the *DPP Quality Control Requirements V2.0.1* (updated 1 March 2020), linked from this page https://www.thedpp.com/downloads#qc-requirements, accessed 20 June 2020.

## D.1.2 Planning, preparing collection materials for digitisation, and related logistics

### D.1.2.1 Description and background for planning, collection preparation, and related logistics

#### D.1.2.1.1 Project planning and the selection of materials for digitisation

The full range of issues to consider when planning a digitising project and selecting materials to digitise includes, for example, such matters as the archival appraisal of content for research value. Although this technical guideline is not positioned to examine content appraisal, the authors seek to provide planners and other administrators with helpful information on *technical and logistical aspects* of planning and selection.

For organizations planning their first in-house digitisation operation, the authors suggest digitising the least technically troublesome formats first, which will achieve higher throughputs and may help attract further funding for ongoing work. Starting with smaller quantities will help archives new to the process build their capacity on all fronts, not least the capability to receive, store, and manage the extremely large sets of digital data produced by digitising projects.

Expert advice, in-house or from a consultant, can support planning in useful ways. Every project will present some cost-benefit tradeoffs, as the archive assesses needed equipment and the expertise needed to operate that equipment. For example, it will not be cost effective to create the infrastructure to migrate a few dozen 2-inch quadruplex tapes, as compared to sending them to an outside specialty contractor. In contrast, it may well be sensible to migrate a thousand digital Betacam tapes in the archive's own facility. The preceding was a relatively easy comparison; some cost-benefit calculations are more challenging and will benefit from careful analysis.

Readers should note that the following subsections do not offer specific descriptions or comments that pertain to important planning elements, including:

- Metadata requirements. This section alludes to aspects of technical metadata, i.e., the types of information, often referred to as *parametric*, that concerns the technical features or characteristics of a digital file, often useful in performing quality review or repository-ingestion processes on batches of files. In contrast, little is said here about the types of collection and workflow management databases (containing metadata) that support the preparation and movement of materials through a facility, or of the types of descriptive and administrative metadata that many archives employ to provide an intellectual frame for their content and/or track such facts as provenance or rights status.
- Staff resource requirements. No attempt is made to assess the need for technicians, operators, engineers, and administrative staff.
- Data infrastructure requirements. Planners may wish to think of these in two broad categories: (1) the infrastructure needed to operate the digitising facility itself, including "local" or interim digital storage of work in progress and completed digital files, staged for ingestion into a repository; and (2) the repository system used for the long-term management of digital data (where *digital preservation* really happens). Subsection D.1.3.1.1. below includes some discussion of (1). Meanwhile, (2) is generally omitted since repository systems are out of scope for IASA-TC 06. (As noted in the introduction to this guideline, long-term, managed digital storage is a complex subject of its own, shared with all types of digital data.)

### D.1.2.1.2 Assessing condition and preparing source materials for digitisation

This topic is covered earlier in this guideline, in section C.1, *Introduction to Carriers: Assessment, Preparation, and Cleaning*.

### D.1.2.1.3 Barcodes and management systems

The preparation and movement of collections for processing should be carefully planned. Item-level and container-level ("box-level") barcodes and an associated inventory control database will be useful to record audiovisual items that have been packed into registered crates or boxes for registration and repacking for return. Barcode identification will enable controlled movement and processing of audiovisual items. Even if smaller collections that do not require multi-stream transfer (see subsection D.1.3.1.8) are digitised, they still require unique identifiers that relate to the original carrier and the resulting filename must be determined for digitisation processing.

If collection items have existing barcodes that are supported by the control system, they could be utilised; otherwise new barcodes would need to be created. Barcode placement should be on the cassette itself, with the option to have a duplicate barcode on the container. To the degree possible, barcodes should not be placed on any part of the cassette or reel that could inhibit normal mechanical functionality, over any existing information, or on the tape pack window. (This can sometimes be a challenge for very small tapes such as MiniDV.) If items are going through a robotic digitisation process, barcodes will need to be placed where the robotic scanning system requires.

Barcode readers at various points in the movement of materials will send information to the facility's system to track and control the full process, including movements, registration, cleaning, conservation treatment, items that require further treatment outside standard processing, encoding, manual and automated quality control, data verification, and delivery medium inventories. These systems of control could be simply spreadsheets, through to Media Asset Management or Collection Management Systems.

**Sidebar: Additional notes on logistics**

If an archive is outsourcing digitisation to a vendor, there are further considerations regarding transport logistics:

- For large-scale digitisation projects, it is customary to make consignments to a vendor or in-house facility in batches of an agreed-upon extent to assist in overall project control.
- Packing heavy items like 2-inch reels (stacking considerations, safety considerations)
- Double boxing, packing material
- Labelling
- Courier considerations: quoting for collection relocation depending on size and weight of collections
- Ship mid-week: sending or receiving material just before a weekend or holiday reduces the risk that collection items will be stored in less than ideal conditions

### D.1.2.1.4 Shipping logistics when digitising is outsourced

Outgoing or incoming collection items should be stored in a temporary location that has ensured security, temperature and humidity control, clean and well-maintained storage of material off the floor, and the items should be stored either in their delivered boxes or on appropriate shelving. Original material should be easily accessible during the project, this will assist in any urgent prioritisation (such as content required for on air for a television news broadcast archive). Collection items may require acclimatisation before any treatment or playback is undertaken if material is retrieved from cold storage or transport locations to minimise damage to the carrier.

If the work arrangement entails shipping materials back to a facility, most archivists argue that it is a good practice to ship the original media and the digitised copies in different consignments to minimize the impact in case one shipment is lost or damaged. By the same token, most outsourcing requires that the contractor retain copies of the digital masters for an agreed-upon period and/or until the archive notifies them that the delivered copies have been safely stored in the archive's systems.

It is worth noting that many projects fall short because the project owners are not aware of the extensive and sometimes expensive logistics required, i.e., moving objects into and out of the collection, and keeping track of where things are in the process. Trucking and shipping, e.g., via FedEx or some other carrier, can keep people very busy during a project. These issues can be minimized by good planning with allocation of staff and resources.

### D.1.2.1.5 Manifests to support collection movement

A consignment manifest, i.e., an item-level listing of what is included in the shipment, should be prepared when moving items to a contract service provider, or even to an in-house digitisation location. The manifest should be sent to the recipient prior to the arrival of the material, which can then be confirmed on delivery. This manifest can also be used as a checklist, to confirm steps have been undertaken, such as inspection, any conservation and digitisation.

This manifest can also serve as a tool to collect information regarding item-level conservation actions, digitisation problem notes, and other technical metadata. Ideally the format for the manifest will be such that the metadata it carries—enriched after digitising has been completed—can then be transferred into the archive's collection management system for further digital preservation management and control.

Receipt, evaluation, and approval of the delivered digital files and returned collection items should be undertaken in a timely manner, often governed by contract terms or in-house standard operating procedures.

## D.1.2.2 Critical control point for planning, collection preparation, and related logistics

As the preceding subsections indicate, the critical control factors for activity planning, collection preparation, and related logistics depend upon well-chosen and well-managed administrative tools. Unlike the critical control factors for some of the other critical control points described below, there are no specific numerical pass-fail metrics in this zone.

## D.1.3 Setting up and testing a digitising facility and system

### D.1.3.1 Description and background: digitising system setup and testing

**D.1.3.1.1 Applicability to in-house and outsourced operations**

The elements described in this important and extensive subsection must be considered by archives planning to build their own facilities. However, as noted in subsection D.1.1.1 above, archives will also wish to be reassured that contract vendors also conform to these facility elements. Archives may wish to include a requirement that bidders outline their setup when they respond to a Request for Proposal (or Tender). The elements of the video-digitising facility infrastructure listed here are required for safe and optimal transfer of video collections.

**D.1.3.1.2 Initial setup testing and periodic retesting**

This section is written as if the testing associated with setting up a facility were a one-time action. In fact, although the monitoring of ongoing operations (section D.1.4) is the day-to-day means for managers to track the condition and performance of systems, many or most of the setup-testing actions outlined in this section ought to be periodically repeated in order to ensure continued success. This is a normal part of a quality assurance program (section D.1.1.4.1).

**D.1.3.1.3 Video digitising infrastructure**

Although similar in their needs, the video digitising infrastructure for a factory operation is more extensive, that for an artisanal operation less so. In fact, the needs for any specific operation will depend on many details of implementation and can be arrayed along a spectrum or range of options. The authors provide the notes in this table pertaining to two hypothetical points on the spectrum in hopes that they will be suggestive to planners.

Table 2 below, as well as sections D.1.3.1.5, D.1.3.1.6, and D.1.3.1.7, are written in terms of traditional, conventional video cabling (often coaxial) and interfaces (often SDI), as if they were a permanent part of video facilities. In fact, at the time of writing, broadcasters and others in the entertainment field are leading a revolution in the "networking" of video production, production-oriented archiving, and dissemination playout via terrestrial broadcasting and Internet "over-the-top" delivery. This revolution is a continuation of the move from tape-based to file-based video recording, resulting in the development of video facilities where the cabling and interfaces are like those used for information technology, "packet-based media networks" in the jargon of the trade. These developments are marching in step with new standards from SMPTE, and they will have an effect on archival preservation practices over time.[13] Broadcaster and entertainment industry efforts in this area also begin to shape the formatting of data, as in the case of the UK Digital Production Partnership (DPP)[14] and Hollywood's IMF effort.[15]

13 Examples of SMPTE standards pertaining to moving digital video over an IP network include SMPTE ST 2022-1:2007 *Forward Error Correction for Real-Time Video/Audio Transport Over IP Networks*, which defines row/column FEC (Forward Error Correction) for IP video streams; SMPTE ST 2022-2:2007 *Unidirectional Transport of Constant Bit Rate MPEG-2 Transport Streams on IP Networks*, which specifies how constant bit rate compressed video signals that are encoded within MPEG-2 transport streams are encapsulated into IP packets; SMPTE ST 2022-3:2010 *Unidirectional Transport of Variable Bit Rate MPEG-2 Transport Streams on IP Networks*, which defines IP packets for variable bit-rate MPEG-2 TS streams that are constrained to have a constant bit rate between PCR messages (called piecewise-constant); SMPTE ST 2022-4:2011 *Unidirectional Transport of Non-Piecewise Constant Variable Bit Rate MPEG-2 Streams on IP Networks*, which is similar to part 3, except that it removes the constraint on bit rates; SMPTE ST 2022-5:2012 *Forward Error Correction for High Bit Rate Media Transport Over IP Networks*, which expands on Section 1 to allow larger row/column FEC combinations to support signals with bit rates up to 3 Gbps and beyond; SMPTE ST 2022-6:2012 *Transport of High Bit Rate Media Signals over IP Networks (HBRMT)*, which specifies a way to transport high bit-rate signals (including uncompressed 3 Gbps 1080p video) that are not encapsulated in MPEG-2 transport streams; and SMPTE ST 2022-7:2013 *Seamless Protection Switching of SMPTE ST 2022 IP Datagrams*, which describes a way to send two matching streams of packets from a source to a destination over different paths, and have the receiver switch automatically between them. Other related specifications include Technical Recommendation TR-01 *Transport of JPEG 2000 Broadcast Profile Video in MPEG-2 TS over IP*, published by the Video Services Forum (http://www.videoservicesforum.org, accessed 16 December 2017); and the IEEE 1722 *Audio Video Transport Protocol*, which specifies different methods for encapsulating SDI video, one of which eliminates the RTP headers found in 2022 and maps video into Ethernet frames (packets). The complexity of implementing IP-based production in professional venues that conforms to these standards has motivated multiple (and often related) efforts to support the process. For example, the JT-NM (Joint Task Force on Networked Media, http://jt-nm.org/, accessed 26 December 2018), a cooperative effort between SMPTE, the VSF, and the European Broadcasting Union, is mapping out a strategy for using packet-based networks in the professional media industry to encapsulate uncompressed SDI and HD-SDI signals for transported over IP networks within a studio, in place of baseband signals over coaxial cables. JT-NM has also published JT-NM TR1001-1, System Environment and Device Behaviors for ST 2110 Media Nodes in Engineered Networks to support the easy integration of equipment from multiple vendors into a coherent video production system (http://jt-nm.org/documents/JT-NM_TR-1001-1:2018_v1.0.pdf, accessed 1 February 2019). Meanwhile, as another example, the Advanced Media Workflow Association (AMWA) is developing publicly shared and/or open-source specifications and tools under the rubric of Networked Media Open Specifications (NMOS, https://www.nmos.tv/).

14 Digital Production Partnership (DPP), https://www.thedpp.com, accessed 20 June 2020.

15 Information about IMF is provided in Annie Chang's *SMPTE Standards PDA Webcast: IMF (Interoperable Master Format)*, available via YouTube, https://www.youtube.com/watch?v=bmhv36hmSP4, accessed 12 October 2020.

D.1 Table 2. The video infrastructure

| Row | Infrastructure component | Required or very desirable for factory operation | Required or very desirable for artisanal operation |
|---|---|---|---|
| 1 | VTRs and intimate supporting elements | VTRs for the playback of the source materials to be digitised, together with supporting elements such as high-quality time base correctors (TBCs), processing amplifiers, frame synchronisers, audio balancers, etc. See D.1.3.1.4 for elaboration.<br>Composite-format (aka CVBS[16]) recordings must be transformed via a comb filter to colour-difference component, initially analogue, then digitised. Some older VTRs are capable of performing the transform from analogue composite to analogue component, and offer an analogue-component output, with digital serialization yet to come. However, many digitising setups assume that the VTR output will be composite and carry out an analogue-composite to digital-component transform "downstream" of the VTR (see next cell below).<br>As noted in row 11 below, some VTRs offer an alternate output: Y/C.[17] If an archive's collection includes VHS tapes (or other formats for which a Y/C output may be offered), the supporting systems ought to also be able to work with that source-encoding input. | Same |

16 Composite video is often designated as *CVBS*, for colour, video, blanking, and sync.

17 Y/C stands for luma/chroma and is shorthand for S-Video, also known as separate video. This signal format separates the black-and-white (luma or Y) and colour (C or chroma) information and thereby achieves better image quality than composite video, although it has lower colour resolution than colour-difference component video, which carries separate luma and two chroma elements.

| Row | Infrastructure component | Required or very desirable for factory operation | Required or very desirable for artisanal operation |
|---|---|---|---|
| 2 | Other components that support VTRs | Sync pulse generators and distribution amplifiers that provide external reference to genlocked VTRs. Some encoders benefit from signal stability utilising reference input. If house reference is not available, set VTRs and encoders to *internal reference* (Cape and Smith: 2005, and Weise and Weynand: 2007).<br>The VTR output may require a composite-component transform (see notes in cell above). In modern digitising setups, the chip-based devices generally employed for this purpose carry out a dual transform: (a) composite to colour-difference component and (b) analogue to digital. These devices are employed in close association with the VTR.<br>Some VTR models require specialized supportive equipment. For example, 2-inch quad needs an air compressor and an air dryer; 1-inch type B requires a sync pulse generator. | Set VTRs and encoders to *internal reference*.<br>The VTR output may require a composite-component transform (see notes in cell above). In modern digitising setups, the chip-based devices generally employed for this purpose carry out a dual transform: (a) composite to colour-difference component and (b) analogue to digital. These devices are employed in close association with the VTR.<br>Some VTR models require supportive equipment. For example, 2-inch quad needs an air compressor and an air dryer, 1-inch type B requires a sync pulse generator. |
| 3 | Playback and signal monitoring tools | Calibrated analogue technical analysis devices are preferred when aligning analogue VTRs if available, such as waveform monitors, vectorscopes, and CRT monitors, and audio level meters, audio phase scopes.<br>Headphones for critical audio monitoring.<br>Support for multi-display confidence viewing of multi-stream transfers; see D.1.3.1.4 and D.1.3.1.7. | Calibrated analogue technical analysis devices are preferred when aligning analogue VTRs if available, such as waveform monitors, vectorscopes, and CRT monitors, and audio level meters, audio phase scopes.<br>Headphones for critical audio monitoring |
| 4 | Cabling, connectors, patch panels | High quality cables and connectors approved by a video engineer should be used to ensure highest signal quality (ePanorama.net: n.d.). See D.1.3.1.5 for elaboration.<br>See also the paragraph preceding this table that sketch the ongoing development of IT packet-based video signal movement within production facilities. | Same |
| 5 | Patch Panels | Passive patch panels for convenience, or direct connect VTRs to encoders. | Same |
| 6 | Support for multi-stream and robotic transfer options (see section D.1.3.1.7) | Requires multiple instances of VTRs and supporting elements, requires extensive overall infrastructure. | Not required |

| Row | Infrastructure component | Required or very desirable for factory operation | Required or very desirable for artisanal operation |
|---|---|---|---|
| 7 | Electrical power | Clean power is a requirement for a video digitisation facility. This can be achieved through existing building infrastructure, or dedicated equipment such as an Uninterruptible Power Supply (UPS). It is critical to have stable clean power for the safety and proper function of items being cleaned or played back, the VTRs, and IT infrastructure and storage.[18] | Same |
| 8 | Environmental factors (air quality, temperature, humidity) | Building environment requires a level of security and environment control while digitisation is in progress. Air conditioning is a requirement for the control of temperature and humidity. All processing infrastructure must be kept in a clean state. | Same |
| 9 | Environmental safeguards (smoke detectors, other detectors) | Environment sensors could be used to monitor temperature and humidity fluctuations, fire or smoke detection, water detection or airflow. | Same, although the extent and distribution of devices will be reduced. |
| 10 | Availability of compressed air | Compressed air is a useful cleaning tool and depending on scale could be simply cans of HFC-free invertible compressed air or included in building infrastructure along with an air dryer, which is a requirement for 2-inch quad replay. | Compressed air is a specialist requirement for 2-inch playback.<br>Compressed air is a useful cleaning tool, and depending on scale could be simply cans of HFC-free invertible compressed air |

18 The audiovisual engineer Eric Wenocur of Lab Tech Systems in Maryland (US) recommended additional electrical power references to the TC 06 authors, noting that this is a topic area with a wide range of opinions and beliefs and one that is undergoing change as new networking and digital technologies are implemented. Wenocur particularly recommended Bill Whitlock's AES presentation An Overview of Audio System Grounding and Interfacing (Whitlock: 2012); he also cited Chris Loeffler and Ed Spears's UPS Basics: Everything You Ever Wanted to Know About Uninterruptible Power Systems But Were Afraid to Ask (Loeffler and Spears: 2011) and Jim Brown's Power and Grounding for Audio and Audio/Video Systems: A White Paper for the Real World (Brown: 2007). Meanwhile, the video expert Jim Lindner highlights the value of certain types of UPS equipment, writing that it "has less to do with blackouts and everything to do with actually getting clean power and particularly clean grounds … Basically you want the UPS to use the batteries to hold the energy and then have an inverter to 'manufacture' clean power [that] includes a clean ground. You DONT want one that is 'standby' power that uses house power and then switches if there is a under-voltage condition. You want clean power all the time." (AMIA listserv, 5-7 September 2018, https://lsv.uky.edu/scripts/wa.exe?A1=ind1809&L=amia-l#60).

| Row | Infrastructure component | Required or very desirable for factory operation | Required or very desirable for artisanal operation |
|---|---|---|---|
| 11 | Digitisation systems<br>Described in section D.1.3.1.9, understood to mean "downstream of playback" (rows 1, 2, and 3 in this table). The digitisation system output is the preservation master file (and often some extras), ready-to-write-to (or written to) the interim storage system (row 14). | Analogue inputs: When the signal source ("input") is analogue, preference for systems that can accept the best quality, i.e., Y/C preferred over CVBS (composite); colour-difference component ($YP_bP_r$, colloquially *YUV*) preferred over Y/C.<br>Digital input: For the types of recordings discussed in this *initial* edition of IASA-TC 06, digital signal input will generally be SDI. Future editions will cover born-digital sources and, anticipating this, a fully realized digitising system will also receive other digital data inputs.<br>Systems should include automated quality control tools (see sections D.1.4.3.3 and D.1.4.3.4) in order to ensure the safe and accurate transfer of video collections, and to inspect the completed master files.<br>Systems should support the target formats recommended by IASA-TC 06, especially lossless JPEG 2000 and FFV1 encodings, with 4:2:2 capabilities, and wrappers such as MXF and Matroska; see section B.3.<br>Best systems will include support for enterprise database workflow and tracking (or API) for the management of physical items, through to workflow engines and digitisation status, with support for management of (or handoff of) final digital preservation files. | Analogue inputs: When the signal source ("input") is analogue, preference for systems that can accept the best quality, i.e., Y/C preferred over CVBS (composite); colour-difference component ($YP_bP_r$, colloquially *YUV*) preferred over Y/C.<br>Digital input: For the types of recordings discussed in this *initial* edition of IASA-TC 06, digital signal input will generally be SDI. Future editions will cover born-digital sources and, anticipating this, a fully realized digitising system will also receive other digital data inputs.<br>Systems may include automated quality control tools (see sections D.1.4.3.3 and D.1.4.3.4) in order to ensure the safe and accurate transfer of video collections, and to inspect the completed master files.<br>Systems should support the target formats recommended by IASA-TC 06, especially lossless JPEG 2000 and FFV1 encodings, with 4:2:2 capabilities, and wrappers such as MXF and Matroska; see section B.3. |
| 12 | IT infrastructure | Appropriate bandwidth performance of network and storage is needed to ensure accurate encoding and playback of files without dropping frames while other processes are taking place, and to allow files to be written to storage in a timely manner. These requirements will vary depending on the number of encoders, the proposed or restrictions around network or connectivity (e.g. 1GB, 10GB, or 40GB Ethernet, or direct connection between storage units), the amount of processing applied to the files post digitisation, and the type and speed of storage they are being written to. | Appropriate bandwidth performance of network and storage is needed to ensure accurate encoding and playback of files without dropping frames while other processes are taking place, and to allow files to be written to storage in a timely manner. |

| Row | Infrastructure component | Required or very desirable for factory operation | Required or very desirable for artisanal operation |
|---|---|---|---|
| 13 | Digitisation and IT system safeguards | Digitisation infrastructure and IT environments should be regularly scanned for viruses, drive health, software updates, and not used for non-digitisation and general internet usage (competition for CPU cycles/ disk bandwidth may lead to errors in audiovisual data transfer or writing to disk). | Same |
| 14 | Interim storage system "in the conversion lab"<br>In OAIS terms, the interim storage system contains *submission information packages* (SIPs) ready for ingestion.[19] | Gathering place for work in progress, and staging area for handoff to long-term data management system (see section D.1.3.10.2). Will benefit from the use of RAID storage and/or duplication of data (for safety) whilst awaiting ingestion into long-term storage. | Gathering place for work in progress, and staging area for handoff to long-term data management system (although oriented to factory operations, see section D.1.3.10.2). Will benefit from the use of RAID storage and/or duplication of data (for safety) whilst awaiting ingestion into long-term storage. |
| 15 | Long-term storage and data management | Archive in the OAIS sense, aka *Trusted Digital Repository*: people, administration, and systems that have accepted the responsibility to preserve content in digital form for the long term.[20]<br>Long-term digital data storage and management systems are out of scope for IASA-TC 06 (see section D.1.3.10.1). | Same<br>Artisanal operations may receive long-term support from a cooperating organisation and/or a service bureau. |
| 16 | Technical library (may be physical and digital) | The more the better. | Same |
| 17 | Service personnel, staff and contracted on-call | Core group of permanent expert staff members; expert consultants as needed. | Expert consultants as needed. |

19 The critically important Open Archival Information System (OAIS) Reference Model, has been standardized as ISO 14721:2012. An OAIS-conformant archive consists of an organization of people and systems that has accepted the responsibility to preserve information and make it available for a designated community. The Wikipedia article *Open Archival Information System* provides a good overview, https://en.wikipedia.org/wiki/Open_Archival_Information_System, accessed 16 December 2017.

20 ISO 16363:2012 (CCSDS 652.0-R-1), *Space data and information transfer systems -- Audit and certification of trustworthy digital repositories.*

### D.1.3.1.4 Setup and testing playback VTRs and intimate supporting elements

*D.1.3.1.4.1* ***Critical importance of VTR alignment and calibration***

For older videotape collections, playback VTRs are the most critical link in the digitising production chain, and they must be aligned and calibrated as optimally as possible. The best VTR performance evaluations will be accomplished when "intimate" devices such as a time base corrector (TBC) and a processing amplifier support playback. Various aspects of VTR setup and testing are discussed in the subsections that follow.

*D.1.3.1.4.2* ***Intimate supporting devices: TBC, processing amplifier, and less desirable alternatives***[21]

An ideal video transfer will (a) maximize compliance with the RS-170 standard[22] (see section B.1.2.6, *Timing: video signal elements must be synchronised*) and (b) ensure that the luma and chroma levels and phases are in the best possible conformance to broadcast requirements (see section B.1.2.7, *Range of picture brightnesses and blanking "brightness"*). Special devices that manage VTR playback accomplish these outcomes.

This is not the same thing as the recording quality of the video content itself, which is a function of the ability of any given videotape to record the frequencies in a video signal. The higher the detail in a video signal, the higher the frequencies contained in that signal.[23]

Failure to comply with RS-170 (or its PAL and SECAM equivalents) leads to a lack of stability that can cause picture breakup or even abort the transfer, and the *time base corrector* (TBC) addresses this problem. Time base errors happen when video, an electrical signal, is recorded onto physical media (tape) by a mechanical device (the videotape recorder or VTR). Electrical signals include features that must be "timed" with accuracy to the millionths of a second, i.e., with a precision that surpasses that of most mechanical devices. Thus, we expect to encounter *timing* or *time-based* errors when videotapes are played back on VTRs. If these time-based errors are not corrected, the video recording will not play correctly and, by extension, the digitisation system will not digitise it correctly.

VTRs are mechanical systems: the videotape moves across a set of heads slowly and, for most of the VTRs discussed in IASA-TC 06, the heads rotate in a helical scan at a high rate of speed, recording (or playing) video tracks that are recorded at an angle to the tape. These video tracks are very tiny (thousandths of a metre across) and any mechanical error that prevents a videotape player from accurately reading the tiny tracks inserts an error. In most systems, e.g., VHS, the record and playback motors are locked together by the control track: a track of linear pulses recording along one edge

21 This section owes a great debt to contributions from video experts James Snyder (Senior Systems Administrator, Library of Congress National Audio Visual Conservation Center) and Ted Langdell (Moving Image Tools and Technology, http://www.flashscan8.us/) in postings on the AMIA listserv 2 June 2017, part of a thread titled "VHS digitization with TBC, Why?," https://lsv.uky.edu/scripts/wa.exe?A1=ind1706&L=amia-l&A1=ind1706&L=amia-l#69, accessed 20 June 2020.

22 Strictly speaking, RS-170 pertains to the NTSC signal family. There are PAL and SECAM equivalents and the discussion in this section should be understood to be about the relevant timing specifications for all three signal formats.

23 In his AMIA posting (op. cit.), James Snyder added that "for every 80 lines of resolution in a video signal, 1 MHz (megahertz) of bandwidth is required to reproduce that resolution faithfully. So 480 line video pictures (the number of active lines in a 525 video signal - the rest is vertical interval where the timing pulses are located) requires 6 MHz of bandwidth to record accurately. Analogue NTSC only transmitted 4.2 MHz of video bandwidth, so the actual reproduced resolution of a broadcast NTSC signal was 336 lines out of a total possible 480 lines out of 525". Snyder added the following, using a VHS recording as an illustrative example: "VHS tape averages about 2 MHz of recordable bandwidth, so a VHS tape at its best reproduces about 160 lines of resolution. That's why VHS looks so soft: it can't record the higher frequencies that produce the finer details in a picture".

of the videotape. If those control pulses are corrupted or fail to play back correctly, the playback motor will not mimic the recorder's motor well enough to reproduce the video accurately.

The time base corrector adjusts the signal to correct time base errors. In the best possible setup, the TBC is connected to its companion VTR via a video connection and an Advanced Sync connection (connected to the Sync connection of the VTR). It corrects time base errors by sending control signals over the Advanced Sync connection to minutely adjust the playback tape speed (the speed with which the tapes are moved past the video heads) and (in playback devices suitably equipped) to adjust the head drum and/or heads minutely to better reproduce the signal in the video tracks themselves.

High quality professional TBCs also identify tape dropouts (i.e., where the actual video signal has been lost due to the magnetic coating flaking off in small or large bits) and, within a certain range (like a group of pixels in a video line or an entire line or two of video) replace the lost video with signals interpolated from adjacent pixels or lines. Lower quality TBCs offer this feature but may not perform as well.

Readers should be alert to the fact that some inexpensive devices described as time base correctors are *frame synchronisers*, devices that replace the degraded horizontal and vertical sync pulses with new pulses but leave any artefacts in the actual video uncorrected or only slightly corrected. Another device, the *frame stabiliser*, is even more limited. Frame stabilisers clean up the corrupted horizontal and vertical sync within a certain range. If a given device does not include an Advanced Sync connector, it is a frame synchroniser or frame stabiliser not a true time base corrector.

It is the case however, that not all TBC's handle video signals and formats in the same way. Low quality heterodyne signals ("colour-under") generated from VHS or U-matic might not be successfully stabilised with some TBC's and in fact the TBC can introduce artefacts into the signal. Older TBC's manufactured at the same time as these formats tend to be more successful in stabilising picture without introduction of artefacts. Often, the transfer of EIAJ ½-inch open-reel and VHS can only be carried out on a best effort basis.

Meanwhile, video levels may depart from desirable values and, relevant in many cases, fail to meet broadcast requirements. The *processing amplifier* ("proc amp") addresses this problem by adjusting video, black (including the so-called *set up/pedestal* or *setup*; see section B.1.2.7), chroma level, and chroma phase (hue) of the video signal, to ensure that peak white is not more than 100 IRE units; black is 7.5 IRE for US NTSC, or 0 for Japanese NTSC, PAL, and SECAM; and that colours are neither oversaturated or undersaturated (i.e., that the phase of the colour signal is properly adjusted to ensure that flesh tones look like flesh tones, for example). The TBC can also correct chroma errors, to prevent chroma phase changing on a line, field, or frame basis.

#### *D.1.3.1.4.3 VTR tape tension adjustment*

Correct playback depends upon having the correct tension on the videotape as it passes across the heads. The settings vary by carrier type and are best done by experienced specialists. The topic is discussed in brief in sections C.4.4.7 and C.6.6.

#### *D.1.3.1.4.4 VTR alignment and calibration using pre-recorded tapes*

##### *D.1.3.1.4.4.1. Introduction*

Special pre-recorded videotapes are often used to calibrate and align VTRs; these are sometimes loosely referred to as "test tapes". The goal of calibration and alignment is to meet or to come as close as possible to the VTR manufacturer's specifications. There are no formal designations for categories of pre-recorded tapes and the IASA-TC 06 authors have invented the terms used in the subsections that follow.

Pre-recorded tapes will suffer from wear as they are played and for that reason their reliability over time is limited. Many sources suggest not using a given alignment and calibration tape more than 20 or 25 times; a few sources allow for as many as 100 passes.[24] As noted in D.1.3.1.4.4.3, engineers prefer the *manufacturer VTR alignment and calibration tape*. However, new instances of such tapes are no longer available from VTR manufacturers and, for this reason, most facilities protect any manufacturer tapes they possess and make copies for routine use. (These copies must be carefully made, preferably by an experienced engineer using a well-calibrated and aligned VTR.) In the case of *house-made (or third party) VTR alignment and calibration tapes* (D.1.3.1.4.4.4), many facilities will also make a "master" and also produce copies for routine alignment and calibration purposes.

### *D.1.3.1.4.4.2. Vectorscopes and waveform monitors*

Engineers employ two (sometimes more) types of oscilloscopes to evaluate the video signal, and to guide them when making adjustments in the playback system, including the calibration and alignment of VTRs: (1) *analogue waveform monitors* and (2) *analogue vectorscopes*. The three types of pre-recorded videotapes described in sections D.1.3.1.4.4.3, D.1.3.1.4.4.4, and D.1.3.1.4.4.5 assume that these "scopes" will be employed as VTRs are evaluated and adjusted. In some cases, additional scopes will come into play.

Waveform monitors are used to measure luma in an analogue or digital video signal. Waveform monitors are especially useful to ensure the video signal is within legal limits, i.e., they permit an engineer to view different aspects of luma with a special eye on the aspects relevant to compliance with RS-170 (or its PAL and SECAM equivalents; see B.1.2.6), including such elements as horizontal sync pulse and the distribution of electronic values derived from an image of a set of colour bars. For technically minded non-engineers, an excellent introduction to the waveform monitor and its use is provided in Marcus Weise and Diana Weynand's *How Video Works* (Weise and Wynand: 2007, pp. 83–93); some useful information is also provided in the Wikipedia article "Waveform monitor"[25]. The 1999 Tektronix publication *NTSC Systems: Television Measurements* provides good "what, how, and why" information for the professional engineer.[26]

Analogue vectorscopes allow the calibration and monitoring of chroma characteristics, such as chroma saturation and chroma phase or hue. The pattern on the screen provides a graphical representation of the vectors in the signal that encode information about hue. For technically minded non-engineers, an excellent introduction to the vectorscope and its use is provided in *How Video Works* (Weise and Wynand: 2007, pp. 95–102); some useful information is also provided in the Wikipedia article "Vectorscope"[27]. For engineers, the Tektronix publication *NTSC Systems: Television Measurements* provides good information (Tektronix: 1999).

Overall, what does an engineer look for when calibrating and aligning a VTR? As in the preceding paragraphs, technically-minded non-engineers will find a helpful introduction in Weise and Weynand's *How Video Works*, although their discussion is focused on

24 The recommendation of 20–25 passes is found in a 1986 Ampex sales brochure, *Alignment Tapes: Precision Video and Audio Tapes for Optimum Equipment Performance* (Ampex: 1986, p. 4), while the higher figure is from *Free TV Australia Operational Practice OP-19: Alignment Procedures for 'C' Format VTR's (sic)* (Free TV Australia: 1986, p. 1).

25 Wikipedia, *Waveform monitor*, https://en.wikipedia.org/wiki/Waveform_monitor, accessed 17 December 2017.

26 The informational value of this publication, like many from Tektronix, overcomes the text's promotional aspect and, in this case, the emphasis on NTSC does not rob the underlying information of being applicable in useful ways in PAL and SECAM contexts: *NTSC Systems: Television Measurements* (25W-7049-4) (Tektronix: 1999).

27 Wikipedia, *Vectorscope*, https://en.wikipedia.org/wiki/Vectorscope, accessed 17 December 2017.

the NTSC signal with passing mention of PAL and SECAM. Chapter 20 ("Overview of Operations") includes an illustrated introduction to tape playback, including such elements as setting *black level* and what is called *setup* (see B.1.2.7), *video level*, *chroma (saturation)*, *chroma phase (hue)*, *horizontal and vertical blanking*, and other signal components (Weise and Wynand: 2007, pp. 245–253). Chapter 21 ("Test Signals, Displays, and Media Problems") presents an illustrated discussion of the ways in which the signal information on pre-recorded videotapes may be evaluated (Weise and Wynand: 2007, pp. 255–270).[28]

*D.1.3.1.4.4.3. Manufacturer VTR alignment and calibration tape*

This category of pre-recorded videotape supports the most complete, highest quality alignment and calibration of VTRs. Instruction books that accompany these tapes provide the manufacturer's specifications for features to be evaluated together with the procedures for measurement.

One useful introduction to manufacturer VTR alignment and calibration tapes is the 1986 document *Free TV Australia Operational Practice OP-19: Alignment Procedures for 'C' Format VTR's* (Free TV Australia: 1986). Although specific to the 1-inch type C format, many of OP-19's recommendations can be interpreted to provide more general guidance. For example, OP-19 recommends that, when being aligned and calibrated, the VTR should be connected to a (or use the built-in) time base corrector; many facilities will also connect a processing amplifier.

What can be checked and adjusted while using the alignment and calibration tapes? This is a matter of playing back the segments recorded on the tape, an action that generates a variety of types of signal data that can be used by an engineer to align and calibrate. Here are three illustrative examples:

OP-19 lists six typical VTR features that are aligned and calibrated by means of the signals produced by playing a manufacturer tape (Free TV Australia: 1986, pp. 2-3):

- control track phase and amplitude
- helical scan dropout
- video level alignment
- video performance
- audio level alignment
- audio performance

28 Weise and Weynand's discussion of test measurements extends to contexts other than VTR evaluation. For example, these metrics also come into play in, for example, a broadcaster's control room, where the source is likely to be a signal generator rather than a pre-recorded tape.

The documentation for a SONY alignment tape for 1-inch helical scan VTRs indicates that the tape includes recorded components to support the alignment and calibration of the same six features and identifies additional components to support the adjustment of three added features:[29]

- RF (radio frequency)[30]
- Tension
- K-factor[31]

An Ampex sales brochure for alignment tapes for 1-inch helical scan and 2-inch quadruplex tapes lists a similar-but-expanded set of components, including ones especially tailored to the unique needs of quadruplex tapes:[32]

- The basic 'Vertical Bar Tapes' may be used to set guide height and engagement, check control track level and phasing, set audio and cue channel playback levels, and check tach phasing.

- The 'Colour' tapes, recorded with signals recommended by SMPTE, EBU, CCIR, and ANSI, permit playback verification of the following parameters: 1) vacuum guide position, 2) video frequency response, 3) chrominance-to-luminance gain and group delay, 4) differential gain, phase, and K-factor, 5) moire and signal-to-noise (with PAL tape #1374503), 6) subcarrier phase and channel chroma levels, 7) control track level and phase, 8) video gain and carrier frequency, 9) audio and cue channel gains.

- The 'Quad/Audio' test tapes contain multi-frequency reference level tones recorded to the 2000/35 µs [microsecond] (80/4500 Hz) or ∞ [infinity] /35 µs [microsecond] (0/4500 Hz) curves to permit checking audio and cue channel playback response. Operating level tones, recorded at tape flux levels of 110 nWb/m for audio and 260 nWb/m for cue, are used to set playback gain controls.

29 This information is derived from the item-specific factory calibration sheet that accompanied the copy of the alignment tape in the author's collection. The BR5-2 alignment tape is used to align 1-inch helical-scan videotapes, and the calibration sheet carries this heading: *Sony BVH series Alignment Tape BR5-2 PS-A4, Sony Part Number: 8-944-005-63.*

30 When recorded on tape, the analogue video signal is frequency-modulated onto a carrier wave (see the Wikipedia article *Carrier wave*, https://en.wikipedia.org/wiki/Carrier_wave, accessed 17 December 2017). The frequencies in the modulated video signal are high enough to require the carrier to be set at *radio frequencies* (RF) so as not to lose content data. The term *RF* is an illustrative-comparative reference to the high frequencies employed by radio broadcast transmissions. In the NTSC signal, for example, the luma carrier frequency ranges from 3.4 MHz (black or sync tip) to 4.4 MHz (peak white). (Chroma information is modulated into what are called *subcarriers*.) The SONY alignment and calibration tape described in the main text above permits an engineer to (1) verify these "radio frequencies," i.e., the carrier(s), and (2) check their levels.

31 *K-factor* refers to a video signal's ability to represent high frequency picture values, a significant part of what is required to render fine detail. The mathematics that underlies K-factor involves measures of the video signal's bandwidth and rise time. See *Television Tape Fundamentals* (Ennes: 1962, pp. 15–16).

32 From *Alignment Tapes: Precision Video and Audio Tapes for Optimum Equipment Performance* (Ampex: 1986); the section quoted above leads off with this sentence: "Ampex produces a series of test tapes for use with quadruplex video recorders operating with 525/60 NTSC/PAL-M or 625/50 PAL/SECAM systems".

*D.1.3.1.4.4.4. House-made (or third party) VTR alignment and calibration tape*

Although its support for analysis is not as comprehensive as the manufacturer tapes described in the preceding section, house-made (or third party) VTR alignment and calibration tapes support reasonably good and relatively thorough alignment and calibration of VTRs. A qualified engineer should record the tape on unused blank stock using a calibrated VTR. As in the case of manufacturer VTR alignment and calibration tapes, these videotapes should be used with a connected (or built-in) time base corrector; many facilities will also connect a processing amplifier.

The IASA-TC 06 sections on 1-inch helical scan tapes, U-matic cassettes, ½-inch consumer and semi-professional cassette formats include specific advice on content that is suitable for house-made (or third party) VTR alignment and calibration tapes for those carriers. (The features are similar and can be applied to the production of house-made VTR alignment and calibration tapes for other carriers.) The sidebar that follows repeats the advice offered in those three sections. In years past, third parties produced suitable tapes for selected videotape formats.[33] Although it may still be possible to find copies, readers should be aware that worn, second hand tapes may be unreliable in their performance which could incur inaccurate calibration of the VTR.

A secondary purpose for house-made (or third party) VTR alignment and calibration tapes is to permit the archive to determine if certain types of defects seen on the final preservation digital master file resulted from a defect on the source videotape or from a defect in the VTR's playback performance. This determination is made at the end of the production process (or "in the middle," if the source videotape must be retransferred to correct the defect). The house-made VTR alignment and calibration tape is digitised into a file just as the source videotape had been. If the resulting file does not "repeat" the defect, then it was on the source tape. If the resulting file does repeat the defect, then the VTR is to blame.

33 For example, in 2014, the Australian supplier WES listed a series of test tapes for VHS VTRs. By 2020, the page had been removed from the WES website; a version harvested in 2017 is accessible at the Internet Archive, https://web.archive.org/web/20170222124335/https://www.wes.com.au/mediapub/ebook/wes-cat2014np/files/assets/basic-html/page1256.html, accessed 20 June 2020.

### Sidebar: Features recommended for a house-made (or third party) VTR alignment and calibration tape

Suggestions for the types of signal data to be recorded onto a house-made (or third party) VTR alignment and calibration tape are provided in several carrier-specific sections in Part C of IASA-TC 06. Such signal data is suitable for the alignment and calibration of VTRs when a manufacturer tape (see D.1.3.1.4.4.3) is not available. This signal data can also be used when tracking down the sources of certain defects that turn up in preservation master files, i.e., from the original tape or from the VTR?

### From section C.4.4.7: Calibration tapes and test media for 1-inch videotapes

[M]any tests can be undertaken with locally created tapes and alignment technology, providing the technician has a thorough understanding of the difference between a properly manufactured alignment tape, and the small-scale solutions developed to overcome their absence. In the absence of an engineered calibration tape, practitioners can record, on a recently aligned and certified machine, a few minutes of 75 percent EBU colour bars, and a series of tones at 100Hz, 1kHz, 10kHz, and 15kHz. In section D.1.3.1.4.4.4, this category of test tape is termed *house-made (or third party) VTR alignment and calibration tape*. Playing this house-made alignment and calibration tape in transfer situations can help technical staff troubleshoot the process when, for example, an operator is faced with a troublesome tape in replay. The self-manufactured test tape can help to determine whether the tape or the machine is at fault.

### From section C.5.8.1: Calibration tapes and test media for U-matic videocassettes

In 1993, SMPTE published a thorough *Specifications for Subjective Reference Tapes for Helical-Scan Videotape Reproducers for Checking Receiver/Monitor Setup*.[34] Unfortunately, such calibration tapes for U-Matic are rare at best. The next best thing is a tape that has a recorded signal (such as EBU 75 percent Colour Bars with +4 db 1 kHz test tone) that has been recorded on a broadcast quality machine in excellent condition and verified as a qualified test tape by a video engineer. In section D.1.3.1.4.4.4, this category of test tape is termed *house-made (or third party) VTR alignment and calibration tape*. Playing this house-made alignment and calibration tape will assist the video practitioner to identify the source of some issues, determining whether they have been caused by a problematic U-matic tape or from a fault with the VTR.

34 "SMPTE Recommended Practice: Specifications for Subjective Reference Tapes for Helical-Scan Video Tape Reproducers for Checking Receiver/Monitor Setup," *SMPTE Journal*, Oct. 1993, vol. 102, no. 10, pp. 979–981, reference at http://ieeexplore.ieee.org/document/7238740/, accessed 17 December 2017.

**From section C.6.6: Maintenance and testing of ½-inch consumer and semi-professional VTRs used for playback**

Although not ideal, test media can be locally produced, provided a machine can be assessed as still able to make reliable recordings. In section D.1.3.1.4.4.4, this category of test tape is termed *house-made (or third party) VTR alignment and calibration tape*. Playing this house-made alignment and calibration tape in transfer situations can assist technical staff in assessing the day-to-day performance of a machine and double-checking when a playback problem arises with a collection item. Locally produced test tapes can also provide an everyday alternative to the use of rare and expensive calibrated tapes that can be reserved for longer term maintenance purposes. Suggested content for test tapes includes:

- Video: 100 percent flat field for tracking checks and adjustments
- Video: 5- or 10-step staircase signal for linearity checks and adjustments
- Video: Multi-burst for checking and adjustments of the frequency response
- Audio: Tone series including 125 Hz, 1 kHz (reference level), 3 kHz (speed), and 10 kHz (azimuth)

Test signals should be electronically produced; the copying of an existing tape will introduce errors and distortion. SMPTE or EBU colour bars along with 0 VU audio tone are usual test signals. A grey field and silence is also useful for assessing noise levels. HiFi audio must also be recorded along with the linear audio track if supported by the format.

*D.1.3.1.4.4.5. House-made (or third party) signal-path assessment tape*

Although house-made (or third party) signal-path assessment tapes are not intended for VTR alignment and calibration, the category is listed and described here to avoid confusion. These tapes are used for signal-path assessment, described in section D.1.3.1.7. *Signal path* refers to the sum total of connections, patch panels, interfaces, etc., from the VTR to the digitising system.

Signal-path assessment tapes carry recorded content that includes test patterns, as well as specific reference charts. In some cases, suitable tapes are available from third parties; in other cases, elements like digital-file based test patterns are available, and a facility can use these to produce a tape for signal-path assessment.[35] The assessment may cover several features, such as:[36]

- Video levels (luma levels, black levels, chroma levels)
- Chroma phase
- Colour space
- Audio mapping
- Audio levels
- Timecode reproduction
- Aspect ratio
- Scaling
- Cropping
- Video quality (sharpness and geometry)
- Field order
- Motion continuity
- Captions/subtitles/teletext
- Video and audio synchronization

Engineers use signal-path assessment tapes to confirm that the signal path does not degrade the transmitted signal. Like VTR calibration and alignment, engineers evaluate the signal path prior to production operations.

Some facilities will include two sets of elements when prerecording a videotape to support testing: (1) features needed for VTR alignment and calibration and (2) features needed for signal-path assessment. This multipurpose tape will be used for both purposes, in turn.

*D.1.3.1.4.5 Additional VTR performance monitoring components*

Some VTRs are fitted with special capabilities that support performance monitoring, e.g., the SONY 9 pin RS422 and Interactive Status Reporting (ISR) protocol, the Status Monitoring and Diagnostics Protocol (SMDP), and the analysis of radio frequency signals (RF). Although these special features can support correct setup and testing of VTRs, they have a vital role in monitoring actual production and, for this reason, they are discussed in subsection D.1.4.1.3 below. Several widely used quality control tools, such as those described in subsections D.1.1.5 and D.1.4.3.3 (and following) depend upon these VTR features.

We recommend that operators keep an eye on the machines when they are running as well as keeping a close eye on the displays of information on vectorscopes, video level meters, audio level displays, chroma phase and level displays, and indicators of time code quality.

35 Test patterns in digital-file form are available from various vendors. For example, see the offerings from VideoQ Incorporated: http://www.videoq.com/vql.html.

36 Checklist from the VideoQ website, ibid.

In general, VTRs should be calibrated and aligned to their factory specifications. However, there are sometimes exceptional circumstances when departure from factory specification provides an improvement in signal output. For example, for U-matic VTRs, the best signal sometimes results from setting the internal amplification of the RF output to a different level from that recommended in the service manual. This adjustment should be performed by an experienced engineer as adjusting RF levels and offset on internal boards could cause other playback issues.

Scheduled checks and preventative maintenance of VTRs and audio playback devices ensures extracting the optimum signal off of the original carrier, for example, logging head replay hours.

*D.1.3.1.4.6* ***Cleaning VTRs***

While digitising videotapes, operators should watch for issues such as low RF, poor signal quality, loss of signal, or highlight tearing.[37] If such image artefacts or flaws are observed, it may mean that the VTR requires cleaning. The alignment and calibration tapes described above (sections D.1.3.1.4.4.3 and D.1.3.1.4.4.4) will assist in determining that the VTR is functioning correctly.

*D.1.3.1.4.7* ***Other notes on VTR selection, setup, and operations***

For a given job or batch, the archive should confirm that there is a "match" between the source recordings to be digitised and the digitisation devices and systems. Within the "class" of a given videotape format, there may be variations, often engendered over time as the format evolved. In effect, "not every U-matic VTR will play every U-matic tape properly". (Same for most other carrier formats.) Optimal playback should be confirmed prior to digitisation. This includes specific checks on the playback signal to ensure accurate profile encoding, such as:

- Confirmation of videotape and VTR compatibility
- Video standard (PAL or NTSC)
- Aspect ratio
- Audio channels and configuration
- Time code source (LTC or VITC)

If there are issues, multiple VTR checking can assist to determine this. Some instances of a given tape format will play back with fewer problems in certain VTRs than others.

Video levels including luma, black level, chroma phase, chroma levels, audio levels, and audio phase should be adjusted on the source VTR if possible, otherwise adjusted on the encoding system to legal and optimum levels. If the VTR has tracking adjustment, this should be adjusted to provide the highest RF signal.

If a collection has known recorded characteristics, such as a broadcaster or archive that has previously formatted legacy collections onto interim formats such as Betacam SP or Digital Betacam, then a pre-alignment of the recorded signal is not necessarily needed before digitisation.

37 Highlight tearing consists of trailing lines adjacent to bright areas of the picture and its presence often indicates a worn video head. See information under the heading "Highlight tearing and bad video heads," https://www.repairfaq.org/sam/vcrfaq.htm#vcrhtabvh, part of the web page *Notes on the Troubleshooting and Repair of Video Cassette Recorders* (Goldwasser: 2010). This segment of Goldwasser's text includes the comment, "Sometimes, this only shows up severely for tapes recorded AND played back on the same machine".

### D.1.3.1.5 Monitoring video and audio at the replay VTR and along the signal path

Facilities must monitor key points in the video and audio signal path to ensure successful digitisation. The infrastructure should include devices and tools to support troubleshooting and the calibration of audiovisual signals and ancillary data. Examples include support for visual observation via a display monitor connected to the VTR, waveform monitors and vectorscopes that present graphical representations of the signal, checking signals from the encoding device, and the ability to decode preservation files back to baseband SDI to permit the selected recordings to be played back for inspection. All of these (and other elements noted below) will assist in identifying or troubleshooting introduced or 'burnt in' artefacts. Additional information about unwanted artefacts is provided in section D.1.4.1.1 below.

For parallel digitisation (see subsection D.1.3.1.8 below), multi-display monitoring allows for multiple views of digitised signals at the same time, with additional features that could be employed, such as signal threshold alarms and logs. Waveform monitors, vectorscopes, audio level meters, and audio phase meters should be available for further alignment and technical examination.

Although automated monitoring tools, like those discussed in subsection D.1.4.3.3 and following, are critically important, there is still high value in operator observation; experienced operators are often very sensitive to anomalies that deviate from expected patterns in visible ways. The facilitation of this kind of observation is enhanced by some digitising systems; for example, one commercial system displays the two fields for interlaced video in separate windows to make it easier to spot problems on a field-by-field basis".

Monitoring the signals from the source VTR (often labelled as "Monitor Out") will allow for optimum signal playback and legal signals. In order to assess luma levels, chroma levels, chroma phase, black levels, audio levels, RF tracking adjustment, and VBI interrogation the facility setup requires a waveform monitor, vectorscope, audio meters, speakers, and video monitors for calibration and monitoring.

Older cathode ray tube video monitors (CRT's) are good for spotting analogue original artefacts, although they are becoming harder to come by and almost impossible to maintain. A combination of CRT and LCD displays are a good way of checking for artefacts. Monitors should be able to adjust aspect ratio and have underscan capability.

A professional picture monitor with SDI inputs is recommended when viewing files during the manual quality control process, as viewing files on a computer display can sometimes disguise issues. For example, decoding and viewing interlaced files on a progressive computer display may appear to behave correctly, however viewed on a professional monitor will indicate an incorrect setting with the encoder's interlaced settings.

Headphones are critical to monitoring audio from the source machine, as well as being used to monitor other points on the signal path and the output from the final preservation master file.

### D.1.3.1.6 Direct patch compared to passive and active routing

Routing technology adds efficiencies and ease of use for operators, but also has considerations depending on the system chosen. Hardwired is always the preferred method of connection, as it will provide the highest quality signal path, and is more reliable since an active router is also a possible point of failure in the signal path. Passive routing through a high bandwidth patch bay could be used with quality connectors, and this might be especially helpful in a large-scale operation.

- *Hardwired Encoders*. With good quality cabling, direct connections will reduce the amount of introduced noise to a signal path, if the correct video format is used, such as component or Y/C, balanced or unbalanced audio. Direct connection may cause inefficiencies for large collections if they are multi format due to manual cable work. This is the recommended method for single stream encoding.

- *Passive Routing*. Passive routing can be unpowered patch bay style, which could increase noise level influence depending on the length and quality of caballing, and the amount of connections through the signal path. There is also potential complexity in patching format combinations such as component, composite, and Y/C video. The tradeoff is this does add convenience for operators when changing source VTRs.

- *Active Routing*. As SD VTR technology is becoming obsolete, so is the supportive technology. Active routers that enable operators to switch analogue and digital video, audio, and remote commands through a digital interface are hard to come by and potentially are not supported by the manufacturers if bought second hand. This technology adds ease of operation for multi format operations, however does add an electronic manipulation of the signal.

### D.1.3.1.7 Signal path for video and audio

The stability and correctness of the signal as output by the VTR, as managed by its time base corrector (TBC), and as received by the digitising system depends upon the proper setup of the whole signal path.

To reduce the risk of degrading the quality of analogue signals, facilities should avoid or minimize video and audio processing within the signal path, such as automated gain adjustment on video or audio, compression, or limiting of the signal. Separated signals such as Y/C or colour-difference component should never be converted to composite in the signal path as this will degrade the quality of the video signal and introduce unwanted artefacts. Cable lengths should be kept as short as possible.

Conversion from analogue video to component SDI and embedded audio output for analogue formats might be possible if the VTR and tape format supports it. Relying on internal VTR analogue to digital conversion to SDI output (as offered by some Betacam VTR's) is acceptable if the VTR is operating at or above specification and the monitoring of signal extraction is extensive and reportable.

In keeping with the ethos represented by IASA-TC 03, this guideline is not recommending fully realized *restoration* of the content; a *preservation* copy ought to avoid or minimize this action. Media archivists adhere to the principle that the content of a tape should be retained without change in a digital preservation file, i.e., as an uncorrected transfer. Corrective restoration improvements, according this principle, ought to be applied only to subsidiary copies. However, the playback of content in order to digitise is often the best (and sometimes the last) point in the process where certain types of corrections and improvements can be made, e.g., dropout compensation or the management of levels.

Although it is important for an operator to carry out visual monitoring during a transfer, the signal path can be assessed prior to operations by playing a commercial or house-produced videotape, as described in section D.1.3.1.4.4.5, "House-made (or third party) signal-path assessment tape".

D.1.3.1.8 **Single-stream, multi-stream, and robotic transfer options**

Different approaches to video collection digitisation can be achieved based on size of the collection, operational budgets, and availability of staff. The one thing that all video collections have in common is that technology obsolescence and degradation pose a real threat to audiovisual information, and digitisation is needed to continue the existence of the collection.

- **Single-stream transfer.** Single-stream transfer, a variant of the artisanal approach described in D.1.1.2, may be considered if the collection is small. Smaller collections could be digitised in a realistic timeframe considering staff availability and having access to audiovisual preservation infrastructure. It is worth noting that in some single-stream setups, the digital output is sent to more than one encoder. For example, the output would go to one encoder to produce the lossless compressed stream for the preservation master file, and to a second encoder to produce a lossy compressed viewing or service file.

For institutions with large collections in need of preservation digitisation, single-stream transfer is not a realistic option. Kevin Bradley, a member of IASA Technical Committee and the main author of IASA-TC 04, extrapolated from an audio survey with similar features to estimate that from 600 to 1,000 hours of content can be digitised each year using a single-stream method. As indicated elsewhere in this guideline, equipment obsolescence and deteriorating media drive the need for higher throughput and, for this reason, many archives embrace the multi-stream methods described below.

- **Manual multi-stream transfer.** Multiple stream encoding is a viable option for digitisation of large video collections. Appropriate equipment is important, and just as important is workflow process and software to support the operator and minimize the potential room for error.

  Specific systems and quality assurances need to be in place to allow for quality preservation outcomes, including:

  - Database management, item registration, and workflow software tools for tape handling and matching with the destination file if required.
  - Software monitoring the baseband video and audio signals, with the ability to highlight and record particular issues (such as luma levels, chroma levels, VTR specific information such as servo lock, audio levels).
  - Additional monitoring such as multi viewers can also have software functionality to alert operators to loss of signal, much like in a traditional multi-channel master control broadcast environment.
  - Ability to isolate video or audio signals for critical monitoring.

- **Robotic multi-stream transfer.** Robotic transfer refers to a set-up that employs a videocassette auto-loading device, similar to the "next cassette in turn" devices formerly used by broadcasters to play a pre-defined sequence of programs and advertising content during a normal broadcast operation. A sophisticated robotic system would use the automated cassette feeder to load, for example, three to six rack-mounted VTRs that run in parallel. A Betacam digitising "factory" operated by the Italian broadcaster RAI is an example of such a system (Borgotallo, Boch, and Messina: 2011), as is the now-discontinued SAMMA system.[38]

  Known recorded characteristics, such as video standard, aspect ra-

38 The SAMMA patent describes the overall system, including the robotic elements: http://patft.uspto.gov/netacgi/nph-Parser?patentnumber=7853766.

tio, audio channels and configuration, and recorded time code information are prerequisites for robotic digitisation, unless auto detection can be implemented. Cassettes need to be in good condition for robotic digitisation, and if not, processed to an accepted level of operation prior to digitization. As with parallel digitization, workflow and software templates need to be applied, such as barcode scanning, tape tracking and management, video and audio monitoring, and file format settings for quality assurance and consistency through the digital collection.

Robotic tape handlers and libraries need to be well maintained to ensure cassettes are handled correctly. Robotic technology can include existing broadcast tape libraries, newly built library technology, and custom-built offerings.

Outsourced work should always be governed by a contract that spells out process details and describes the actions to be taken in order to reduce risk. If preservation digitisation will be carried out in a multi-stream facility, it may be the case that one customer's work is digitised at the same time as a collection from another customer. In order to ensure that the right file goes back to the right client, the archive requesting the work should ask the service provider to explain how physical collections and digital data will be managed and delivered.

- **Other transfer dependencies.** Regarding any form of multi-stream transfer, it is worth noting that efficiencies result not simply from having more than one transfer stream (under the eye of a single operator). To fully realize the advantage in throughput, a facility must also muster support for post processing and writing the data to archival or delivery media. Automation and parallel processing should be applied to checksum creation, quality control, embedding metadata, and transcoding. Some of these actions, as well as data verification, format validation, derivative-file production, and other forms of content duplication may take advantage of the interim storage system described in section D.1.3.1.10.2, as well as using infrastructure downtime such as overnight and weekends.

### D.1.3.1.9 Digitisation systems

What is a digitising system? Different specialists define the scope and draw the boundaries in different ways and the requirements for artisanal and factory operations (see D.1.1.2) vary as well. In the case of the multi-stream robotic systems described in the preceding section, the term might be *digitising subsystem*.

In this guideline, we draw one boundary in terms of input. We define our *digitising system* as the next component (or set of components) *downstream* of playback, i.e., downstream of the VTR and intimate supporting devices (D.1.3.1.4). But this boundary is somewhat conceptual and inexact. Although the input to the digitising system is the output from the playback component, that output varies. Depending upon the source format and available VTRs, playback output covers a range from (a) analogue composite to (b) analogue Y/C to (c) analogue YUV (more precisely Y'PbPr) and to one or another digital format, notably (d) SDI.[39]

The other digitising system boundary is at the output end. We consider the output to consist of encoded data, i.e., the digitised essences, ancillary data, and other payload

39 The discussion in this initial version of IASA-TC 06 is focused on the transfer of *video as video*; as we move into digital video as the source object, we will begin to explore the transfer of *video as data*, which by definition does not require a digitising system. We acknowledge that section C.7 on the Betacam family of carriers includes IMX and HDCAM, which do represent video-as-data transfers.

data (D.1.3.1.4 and D.1.4.2), wrapped in a file and, if needed, accompanied by sidecar files (D.1.4.2). That is, we think of the digitising system output as the preservation master file(s), ready to write to media. The devices and systems in actual use, however, tend to assemble and write data to media, e.g., a local hard drive and/or an interim storage system (see section D.1.3.10.2).

Boundary inexactitude notwithstanding, what can we say about digitising systems? Factory operations seek high throughput, often with multi-stream transfer (D.1.3.1.8). Many of these, especially in broadcast settings, employ playback components that output SDI. For them, the next-downstream system will provide a combination of essence-bitstream encoding, capturing of ancillary data, and wrapping in a file wrapper. The commercial marketplace offers high end devices and/or systems that do all of this and, in most cases, also feature additional capabilities like subsystems to output lower-resolution viewing ("browse") copies in addition to the master file, support workflow and metadata management, and support quality control (D.1.4.4).[40] It is worth noting that this is not "instead of open source": several commercial products employ integrated open source elements, including FFmpeg, MediaInfo, and MXFLib,[41] into their products.

In instances where the playback components do not provide SDI outputs from analogue tapes, there is a need for an added device to transform analogue composite, Y/C, or YUV to digital colour-difference component. There seems to be no well-established term for this category of device; examples are marketed with names that include words like *converter*, *frame sync and converter*, or *AD converter*. Prices, quality, and efficiency vary.

Artisanal operations generally make more modest capital investments than those made to support factory setups. For members of this community, open source or freely licensed software is very helpful. Hardware is also required and, in the artisanal setting, this too tilts in the modest direction.

It is worth emphasising, however, that factory and artisanal operations are the two ends of a spectrum with many options in the middle. Many in-the-middle operations can take good advantage of open source or freely licensed software, and such applications often include additional features similar to those listed for the factory/commercial systems above.[42]

40 The IASA Technical Committee does not test systems and does not endorse manufacturers. We can report, however, that the marketplace for systems, devices, and/or software applications that support reformatting and related actions includes the following companies, and others. It is not the case, however, that all of the systems listed include support for the target formats recommended in section B.3 of this guideline. Cube-Tec (https://www.cube-tec.com/en-uk/products/video/quadriga-video/features), NOA (http://www.noa-archive.com/products/archive-transfer-technology/), Digital Rapids (http://www.imaginecommunications.com/digital-rapids), EVS (https://evs.com/en), TeleStream (http://www.telestream.net/lightspeed-live/lightspeed-live-capture.htm), BlackMagic Design (https://www.blackmagicdesign.com/products), AJA Video Systems (https://www.aja.com/), and Metus (http://www.metus.com/metus-ingest/). Some of these manufacturers focus on larger (often "factory") operations, while others also offer lower-cost devices or applications that serve artisanal and "in between" operations.

41 https://ffmpeg.org/; https://mediaarea.net/en/MediaInfo; http://www.freemxf.org/ (all URLs accessed 31 May 2019).

42 Dave Rice's article "Digitization Software Obsolescence, Too?" (Rice: 2015) includes a very helpful overview under the heading "Open Source Projects". Rice sketches projects that creatively integrated the BlackMagic SDK (freely licensed) with software from FFmpeg (open source), as well as describing the DVA Profession software assembly from the Österreichische Mediathek in Vienna. In 2011, the DVA Profession website compiled a useful overview of the hardware and supporting software arrays needed to take advantage of the application's audiovisual preservation capabilities (Österreichische Mediathek: 2011).

### D.1.3.1.10 Interim storage and capability to inspect preservation master files

#### *D.1.3.1.10.1 Long-term preservation repository out of scope for IASA-TC 06*

The long-term preservation of content in digital form requires a combination of digital storage and data management. This requirement is not limited to audiovisual content: long-term access to digital data of all types depends upon systems that manage data storage and are capable of, when needed, updating the data itself, including the execution of format migrations. This topic is carefully treated in the extensive work associated with the seminal Open Archival Information System Reference Model, now an international standard,[43] and subsequent related standards with titles that include the term *Trustworthy Digital Repository*.[44] The topic of trustworthy digital repositories is too broad and complex for inclusion in IASA-TC 06, and readers are encouraged to consult the standards cited above and the abundant supporting resources that this work has spawned.[45]

#### *D.1.3.1.10.2 Interim "production" data storage system*

Digitisation facilities require a local *interim* storage system to hold works in progress and freshly completed files. In some cases, second-pass actions are part of the production activity, such as the creation of sidecar files, assembly of supplementary metadata, and the generation of file-level fixity data. In virtually all cases, a facility will benefit from a holding area where complete files are managed prior to ingestion by a preservation repository for long-term storage. In some cases, tools associated the long-term repository will automatically check a "watch" folder on, for example, a daily basis, and ingest that day's files into the preservation system.

As noted above, file-level fixity data should be created at the time of file creation and/or the time of placement of completed files in an interim production storage system. Tools like AVP's *Fixity* support the monitoring of these stored files by scanning a folder (or set of folders), creating a list of files and their checksums, and providing data that permits periodic comparisons to flag any changes.[46] The concept of interim storage and managed control of files is not limited to archives. Many film and television production units employ these approaches in the field, often placed in the hands of a staff member called a *digital imaging technician*.[47]

The availability of sets of completed files in the interim system provides an excellent opportunity for quality review and, as outlined in subsections D.1.4.3.3, D.1.4.3.4, and appendix A, some automated tools support such review. If these tools identify anomalies, the files are readily at hand for additional inspection and testing.

## D.1.3.2 Critical control point: digitising system setup and testing

### D.1.3.2.1 Introductory notes

Although much of what is discussed in this section applies to all transfer options, the criti-

43 ISO 14721:2012, *Space data and information transfer systems -- Open archival information system (OAIS) -- Reference model*, https://www.iso.org/standard/57284.html, accessed 17 December 2017.

44 ISO 16363:2012, *Space data and information transfer systems -- Audit and certification of trustworthy digital repositories*, https://www.iso.org/standard/56510.html, and ISO 16919:2014, *Space data and information transfer systems -- Requirements for bodies providing audit and certification of candidate trustworthy digital repositories*, https://www.iso.org/standard/57950.html, accessed 17 December 2017.

45 The Wikipedia article *Digital Preservation* is remarkably thorough and complete, and includes a bibliography that cites more than one hundred works, https://en.wikipedia.org/wiki/Digital_preservation, accessed 17 December 2017.

46 *Fixity* is one of several applications offered via https://www.weareavp.com/products/, accessed 17 April 2018.

47 Wikipedia, *Digital imaging technician,* https://en.wikipedia.org/wiki/Digital_imaging_technician, accessed 17 December 2017.

cal control elements identified here are especially important for the devices and systems employed in a factory-like multi-stream transfer setup. It is worth noting that the setup and operation of such a facility is not work for lay people: the tasks require persons with engineering specialisation, i.e., persons with experience with the legacy and contemporary technologies that are required for large scale digitisation of audiovisual collections.

The authors emphasize that few of these assessments are one-time "check it and forget it" items. We recommend that a number of the factors and metrics listed below become part of a facility's preventive maintenance program, i.e., periodic retesting of the equipment and systems.

Before digitisation commences, or if there is a change in technology or systems within the signal path, this needs to be tested by a video engineer to meet a level of standard to ensure no artefacts or noise are introduced into the digitisation process.

The results of each testing event ought to be documented and compared with the last and next tests. Scheduled tests and tasks are a good way of maintaining optimum throughput and quality, and they will often highlight an issue before it gets out of hand.

**D.1.3.2.2 Testing VTRs and intimate supporting elements**

This topic has been covered to the degree appropriate for this guideline in section D.1.3.1.4 above.

**D.1.3.2.3 Assessment of digitising system signal path**

Aspects of this topic have been covered in sections D.1.3.1.4.4.5 (signal-path assessment tape) and D.1.3.1.5 through D.1.3.1.7 (monitoring video, direct patch compared to passive and active routing, about the signal path).

Not mentioned in those sections is what is called (in today's digital context) *physical layer testing*. This assesses the selection, installation, and performance of cables and other system components that support the serial digital interface (SDI). Generally speaking, video engineers make this assessment with the aid of a oscilloscope. The user guide for one manufacturer's waveform device offers thorough descriptions of the following tests: SDI Check Field, SDI CRC Error Testing, Jitter Testing, and Eye Pattern Testing (Tektronix: 2016).[48] The *eye pattern* is an oscilloscope view of the analogue signal transporting the data. Works like *A Guide to Standard and High-Definition Digital Video Measurements* provide additional information on the evaluation of the performance of the serial digital interface (Tektronix: 2009).

**D.1.3.2.4 Setup and testing of non-VTR components**

This section concerns selected components of the video digitising infrastructure outlined in the table in D.1.3.1.3 above. As a general comment, it is the case that most instruments are quite stable over time, however, it is good practice to verify equipment calibration at frequent intervals. Many instruments have internally generated calibration signals that facilitate this process. In the absence of a calibrator, or as an additional check, a test signal directly out of a high-quality generator makes a good substitute. Calibration procedures vary from instrument to instrument and most user manuals contain detailed instructions. Some calibration depends on a measuring device and it is worth noting that these, too, require periodic calibration, which sometimes entails sending them back to the manufacturer.[49]

48 See also "RF Cable Testing" (RFcables.org: n.d.) and "Chapter 18, Measuring Digital TV Signals in the Broadband Cable" in *Digital Video and Audio Broadcasting Technology: A Practical Engineering Guide* (Fischer: 2010, pp 325 ff).

49 A thorough discussion of this topic is provided by *NTSC Systems: Television Measurements*, (Tektronix: 1999), especially pp. 2–5 (PDF p. 11) and 5-1 through 6-3 (PDF pp. 20–32).

D.1 Table 3. Metrics for testing infrastructure components

| **Component** | **General comment on metrics** | **Additional IASA-TC 06 specification or recommendation** |
|---|---|---|
| Signal generators, sync generators | TC 06 authors not aware of testing metrics for this component; comments welcome | No pass-fail aim points recommended at this time |
| Signal monitoring equipment (waveform monitor, vectorscope, audio signal scope) | Calibrate monitoring equipment using engineering test patterns and analysis hardware, following guidance in the manufacturer's user manual. | No pass-fail aim points recommended at this time |
| Picture monitor | Calibrate picture-display monitors for accurate representation<br>Generally speaking, the video preservation described in IASA-TC 06 aims to produce master files that contain picture data and metadata that fits the colour profile and gamma setting of display monitors that conform to ITU-R Recommendation BT.709 (colloquially *Rec. 709*). If conformance extends to the 16:9 frame specified by Rec. 709, most older video content will be pillarboxed to maintain its historic 4:3 aspect ratio in the widescreen frame.[50] | Calibrate to conform to ITU-R BT.709-6 (2015)[51] |
| Loudspeaker and/or other sound monitoring device | Devices and listening space tested for accurate representation. | No specific recommendation.[52] |
| Filter device or application to convert composite picture to colour-difference component (in the analogue realm)<br>As noted in the video infrastructure table, this filter may be within the VTR, or be a component of the "downstream" digitising system. | Filter options include the inexpensive and inferior *notch and bandpass filter* and professional grade *comb filters*, which come at varying levels of quality (Jayne: 2015).<br>Image quality in general, including the outcome of conversion tools, is often monitored by devices with names like Picture Quality Analyzers (PQA) and Video Measurement Sets. | No pass-fail aim points recommended at this time; comments welcome |

50 Wikipedia provides excellent introductory descriptions of Rec. 709, as well as four other important monitor specifications. See the articles *Rec. 709*, https://en.wikipedia.org/wiki/Rec._709; *Rec. 601*, https://en.wikipedia.org/wiki/Rec._601; *Rec. 2020*, https://en.wikipedia.org/wiki/Rec._2020; *Rec. 2100*, https://en.wikipedia.org/wiki/Rec._2100; and *DCI-P3*, https://en.wikipedia.org/wiki/DCI-P3; all URLs accessed 17 December 2017. This topic is also discussed in the sidebar that follows section B.1.3.1.3, titled *Colour and tonal specifications for digital video, and related matters.*

51 Rec. 709 is titled *Recommendation ITU-R BT.709-6: Parameter values for the HDTV standards for production and international programme exchange* (06/2015), http://www.itu.int/dms_pubrec/itu-r/rec/bt/R-REC-BT.709-6-201506-I!!PDF-E.pdf, accessed 17 December 2017.

52 The literature for audio preservation is surprisingly thin on the topic of preservation-studio acoustics and pre-amp, amplifier, and loudspeaker selection (as well as discussion of headphones, often discouraged for high-stakes audio transfer). For example, this topic is out of scope for *Guidelines on the Production and Preservation of Digital Audio Objects*, IASA-TC 04 (IASA-TC; 2008). Some information about the as-of-2007 audio preservation studios in use at Indiana and Harvard Universities is provided in the excellent report *Sound Directions: Best Practices for Audio Preservation* (Casey and Gordon: 2007, pp. 17 ff).

| Component | General comment on metrics | Additional IASA-TC 06 specification or recommendation |
|---|---|---|
| Picture analogue-to-digital conversion | Quantization of now-separate luma and chroma data to produce the 4:2:2, 10 bits-per-sample bitstream. | No pass-fail aim points recommended at this time; comments welcome |
| Audio analogue-to-digital conversion | Quantization of audio into linear PCM sampled data, typically 48 kHz at 24 bits-per-sample. | Highest quality metrics would meet the "pass" requirements of the 2016 FADGI *Analog-to-Digital Converter Performance Specification and Testing Guideline, v. 1.1* (FADGI: 2016). For video digitising, the tolerances for that guideline's metrics may be relaxed. |
| IT systems | Although critically important to digitising facilities, IT systems (especially networks) is an extensive topic that warrants a publication of its own and is out of scope for IASA-TC 06. | |

## D.1.4 Operating a digitising facility and system

### D.1.4.1 Playback of source materials

#### D.1.4.1.1 Typical errors and problems encountered when digitising (summary)

At the 2016 IASA meeting, Technical Committee member Jörg Houpert listed typical errors and problems related to playback VTRs and other system components in a preservation digitising facility. The errors and problems must be *discovered* (determining that they have occurred), they and their causes *identified*, and, to the degree possible, *corrective actions* taken. And—corrective action or no—many archives wish to document the errors and problems to enhance provenance metadata, i.e., to document facts for reference by future researchers.

Houpert summarised typical errors from analogue VTRs that affect the signal (essence data and other payload elements) and, especially, the picture:

- Tape dropout
- Head clogging
- Blocking artefacts
- Scratched tape damage
- Timebase corrector off-locks
- Timebase corrector dumping
- Capstan server off-locks
- Tape mistracking
- Burst/chroma phase error
- High luma levels
- Tape tension error

Houpert also summarised some adverse effects on the sound essence from the videotapes being digitised. Some of these unwanted artefacts can be attributed to VTRs while others result from problems in the original (source) recording or non-VTR components of the overall digitising infrastructure:

- Analogue-born errors
- Clicks and crackles
- Buzz, hum
- Analogue dropout
- High noise floor, low SNR
- DC-offset (direct current transmission)
- Analogue over
- Azimuth error
- Wrong stereo correlation
- Low bandwidth
- Wrong channel balance
- Digital-born errors
- Digital dropouts
- Digital overs
- Digital clicks
- Digital zeros in analogue recordings

Two published works offer detailed information and illustrations that describe many of the errors and defects--often called artefacts--that may appear during playback and digitisation. See *AV Artifact Atlas* (BAVC: n.d) and the dual language work *Kompendium der Bildstörungen beim Analogen Video/Compendium of Image Errors in Analogue Video* (Gfeller, Jarczyk, et al: 2013).

The discovery, identification, correction, and documentation of errors and problems depends upon a mix of human observation and the use of automated tools that monitor the production process and/or analyze the digital preservation files that are the output of that process. That family of actions is the subject of this section of this guideline (D.1.4), buttressed by the information in the preceding section (D.1.3).

**D.1.4.1.2 Clean and prepare videotapes and VTRs**

For information on this topic, refer to earlier sections in this guideline:

C.2 Carriers: Preparation, Cleaning, and Assessment of Videotapes
D.1.3.1.4 Setup and testing of playback VTRs

**D.1.4.1.3 Take advantage of VTRs with special features**

Certain VTRs have added features that support quality control, and it is sensible to use these whenever possible.

***D.1.4.1.3.1 Sony 9 Pin RS422 Protocol***

VTRs that have a RS-422 protocol interface should be utilised. This is useful in controlling the VTR from the encoder, also locking control from the front panel of the VTR. RS-422 remote control is needed for robotic encoding and automated tape handling. RS-422 connectivity is also an excellent method of obtaining and logging VTR information, such as channel condition errors and interpolated time code.

Channel condition errors can be read and logged during the digitisation process. This information is very useful during digitisation and the quality control steps performed on the file-based output.[53]

***D.1.4.1.3.2 Sony SMDP and ISR Protocols***

Some encoding platforms support recording diagnostics information based on SMPTE 273M-2003: Status Monitoring and Diagnostics Protocol (SMDP). SMDP is derived from the Sony Interactive Status Reporting (ISR) via the VTR RS232C Digital Interface. This can also be useful when reporting on playback quality, and status of the VTR. Not all Betacam family members support this protocol.[54]

***D.1.4.1.3.3 Radio frequency used to track signal output***

Some VTRs support the output of radio frequency,[55] such as U-matic, Betacam, and 1-inch open-reel (helical scan). RF information can also be useful for determining drop-outs and tape head clogging. Some TBC's have an *RF* input option that can be utilised when true Drop Out Compensation is selected. The archive must determine if this fits the organization's preservation practices.

RF information can be read and logged during the digitisation process. This information is very useful during digitisation and the quality control steps performed on the file-based output. Here is an example from the authors' own experience: a U-matic tape had been digitised and the RF signal was also recorded. There was loss of picture during playback, and the visual evidence suggested a head clog on the playback VTR. However, when the recorded RF levels were reviewed, they were constant and high during playback. This meant that the signal from the tape during the digitisation process was correct; if there had been a head clog, it must have been from a previous transfer

53 Descriptions of VTR support for channel condition reporting through RS-422 can be found in *PWS-100TD1: Tape Digitizing Station* (Sony: 2014) and *VVCR 422 Serial Protocol* (Drastic Technologies Ltd: n.d.).
54 *VVCR 422 Serial Protocol*, ibid.
55 The term *radio frequency* in the context of analogue video is discussed in a footnote in section D.1.3.1.4.4.3.

and was now "baked into" the source U-matic. Without the RF information, it would have appeared that the head clog occurred during the digitisation process.

*D.1.4.1.3.4 Automated tools for quality control with VTR special features*

Software tools can take advantage of the special features listed above and, in at least one case, provide the option, as hardware, to install a device that contributes to quality control monitoring. The NOA company's product line includes diagnostic tools that log events from the Sony Interactive Status Reporting (ISR) protocol via an RS232 port on the VTR. For added tracking during transfer, NOA states that they can fit certain VTR models with a sensorplate (hardware) that enables the readout of RF traces, further supporting the ability to distinguish between 'errors on tape' and 'errors during transfer.'[56].

**D.1.4.1.4 VBI information that may support correct playback**

The Vertical Blanking Interval (VBI) always carries some information and/or control signals and may carry a variety of ancillary information of value; see section B.1.3.2 for an introduction to this topic. Some of this content counts as *data* that many archives will wish to retain in the preservation master file.

In contrast to the data-carrying aspect of VBI, the vertical interval may also carry data elements that can support the management of the transfer of the video payload during digitisation (Weise and Weynand: 2007, pp. 36-37):

- Vertical Interval Test Signals (VITS) one-line representation of different test signals
- Vertical Interval Reference Signals (VIRS) developed for colour fidelity.
- Wide Screen Signalling (WSS) was employed by some broadcasters around the time when 4:3 and 16:9 aspect ratios for SD transmission were both in use. Transmission equipment would automatically correct the broadcast aspect ratio depending on the WSS used.

## D.1.4.2 Beyond picture and sound: capture or create other data and metadata

This subsection is intended to march in step with section B.3.3.2 ("Capabilities regarding ancillary and associated data"), which lays out the arguments for retaining certain forms of non-picture, non-sound data (or information) that may be found in older video recordings, as well as providing arguments in favour of creating and adding certain other types of data or metadata as digitising proceeds. These types of data are varied and, in some cases, are not familiar to non-specialists. In order to draw attention to them, and to highlight their value, IASA-TC 06 sometimes refers to them as part of the total video *payload*.

Several of the data types described in this subsection are termed *ancillary* by video engineers, and many of these are carried in the VBI of the source video recordings. The VBI types of interest in this context represent data that an archive may wish to retain as part of their preservation master. Other types of VBI data may offer technical support to the digitising process itself, and these are discussed in the preceding subsection (D.1.4.1.4).

56 Video Transfer Control, http://www.noa-archive.com/products/archive-transfer-technology/video-transfer/video-transfer-control/ (accessed 6 May 2019). This description was taken from the page titled Processors for the Transcription of Archive Carriers (http://www.noa-archive.com/products/video-transfer/video-migration-qc/), active as late as December 2017 but not accessible in February 2019.

**Sidebar: State of implementation of practices for the capture or creation of data and metadata beyond picture and sound**

The assessment, capture, and/or creation (when warranted) of the payload elements listed in the following sections (D.1.4.2.1 through D.1.4.2.5) is *not* part of the established practice in many archives, including the archives that are home base for some IASA-TC 06 authors. To a degree, what is written here is aspirational: the IASA-TC 06 authors are convinced of the value of these payload elements for long-term preservation and have included the descriptions that follow in order to heighten awareness of the topic and to encourage the continued development of practices and tools.

To what degree can this payload data be carried in the same file that carries video picture and sound? The ability varies from one target format to another, as described in the comparison tables in section B.3 and that section's appendixes. Although the file wrapper usually carries ancillary and associated information, in the case of the FFV1 picture encoding, data like frame-level fixity information is carried in the picture-essence stream.

When the preservation master file does not offer the means of carriage, what options exist? Some data, notably captioning and subtitles, can take advantage of well-established "sidecar" files, as described in section B.1.3.2.1.2. Other information, even if fragmentary, can be documented in a note or text-data element in an archive's collections-management database, as a kind of provenance information. Since the same facts may obtain for a batch of source tapes, it may be possible to inscribe this information on a batch basis.

### D.1.4.2.1 Time code

#### *D.1.4.2.1.1 Retain legacy time code*

Documenting the source-video's original time code (or time codes) is often important for an archive. To summarize the argument made in section B.3.3.2.1, legacy time code can have many different uses: for example, synchronisation between different formats such as film, magnetic video tape, and magnetic audio tape. Time-of-day time code may have been recorded to document legal proceedings, parliament sessions, or sporting events. Time code could be linked with accompanying information such as oral history transcriptions. EDL (Edit Decision Lists) style metadata that includes descriptive information for later segmentation, such as news or program compile tapes, could have time code information that could be used with digitised files in a Media Asset Management system.

Legacy time code may be discontinuous or fail to maintain integrity for reasons connected to the initial creation or to the playback of older media. Issues can arise with LTC (longitudinal or linear time code) if there is a drop in the replay level, either due to a dirty replay head, a misaligned replay head, or poor signal originating from a deteriorated tape. Keeping playback machines clean and well aligned is one way to minimise loss or corrupt time code data. If there is an issue with time code, error detection tools should be applied on either the source VTR or the preservation master file during the encoding process.

Some encoders have trouble with handling playback signals with loss or jumps in time code. Explore and test the encoder's time code handling, to prevent loss of code before digitisation. Time code can be regenerated from original code in two ways, either by only replacing missing time code, or by restriping entirely from the moment of loss. Legacy time code regenerators are also available where time code is damaged.

If time code is recorded on an audio channel, select that as the LTC source on the encoding device. If not, decoding time code as audio within the preservation master file would require decoding specialist software.[57]

As noted in the next section (D.1.4.2.1.2), the IASA-TC 06 authors strongly encourage that new, high integrity time code be added to digital preservation files at the time of production. Assuming this is done, the legacy time code is retained as reference, in effect, as a form of added metadata to serve future researchers.

The legacy time code may be multiple: it is, alas, not unusual to encounter older recordings whether the LTC and VITC (vertical interval time code) are both present with completely different numerical sequences. Choose the most relevant time code to use as the source. Most encoding devices should give you the option from where to select the original time code.

Some digital target formats have "places" to carry legacy time code within the file; for others, information about legacy time code must be carried in a "sidecar" file of some kind (no standard formats exist), or as abstracted information for future researchers. If an archive deems it important to retain legacy time codes, this may govern the selection of the target format. For more information, see sections B.1.3.2.1.1, B.1.3.2.2, and B.1.4.1.2.

57 One example of a specialized time code tool is *LTC Convert (AUXTC)* from Videotoolshed, https://www.videotoolshed.com/product/ltc-convert-auxtc/, accessed 17 December 2017.

**Sidebar: Time Code Characteristics for Selected Carrier Formats**

*This sidebar provides information about time code carriage by various types of videotape. Because it was convenient to do so, some of the following bullets provide information about time code carriage in a few digital videotape types that are not otherwise discussed in the initial version of IASA-TC 06. These videotape formats will receive discussion of matters beyond time code carriage in future editions of IASA-TC 06. Some information in this sidebar was provided by a useful reference to the topic, J.D. Ratcliff's* Timecode: A User's Guide (Ratcliff: 2015).

- U-matic: Originally U-matic was not designed to accommodate time code. Time code was first recorded in the field on one audio track. LTC was later supported in a time code track positioned on the inside of the two audio tracks. Originally VITC was not included for U-matic, due to lack of bandwidth resolution.
- 1-inch type C: 1-inch C has a few options for audio and time code support. One option is to use the third audio track which can support LTC, or another option is to have a fourth audio track to carry either LTC, or cue audio. SMPTE proposed for PAL VTRs that VITC should be on lines 12 and 14 for C format with sync head, and lines 16 and 18 for C format without sync head.
- Betacam Oxide, Betacam SP, and Panasonic MII: All three formats support LTC. Betacam Oxide originally did not support VITC, although modifications became available to support it. Even so, most machines that support Betacam Oxide would not be able to read it. Betacam SP format supports VITC.
- D-1 Component: D-1 supports LTC with a dedicated time code track, or recorded on an audio channel, however not VITC.
- D-2 Composite and D-3 Composite and D-5: D-2, D-3, and D-5 support LTC with a dedicated track running along the edge of the tape. D-2 and D-3 and D-5 support VITC.
- Digital Betacam. Digital Betacam has a dedicated LTC track on the outside of the tape and supports Digital VITC.
- DVCAM DVCPro. DV and DVCPro does not have a dedicated LTC track, however LTC is still supported. VITC is also an option. LTC is recorded in the subcode tracks between video and audio tracks.

*D.1.4.2.1.2 Time code: provide coherent master time code*

As outlined in section B.3.2.2.2, the final master file must carry high integrity, continuous time code. Such a time code may be present in the source video and thus will be inherited by the new digitised file. Often, however, this is not the case and a new *master time code* (aka *synthetic time code*) should be created when digitising. An archive should develop a policy for master time code specifications: non-drop-frame, dropframe, reflecting actual time-of-day, "starting at midnight" (00:00:00.00), or "starting at 1 am" (01:00:00.00), and so on. The digitisation system must have the capability to provide the underlying data via a time code generator, genlock support.[58]

58 *Genlock* refers to the use of a specific reference signal from a signal generator (or even a video output of "another" source) to synchronise the time code in video signal.

*D.1.4.2.1.3* ***Time code: label multiple time codes***

The digitising system (or human intervention) should provide a means to tag the various instances of time code so that users of the file can identify each one; see also section B.3.3.2.3. Some digital target formats have "places" to carry time code tags within the file; for others, tagging metadata must be carried in a "sidecar" file of some kind (no standard formats exist), or as abstracted information held in an archive's collection files for future researchers.

## D.1.4.2.2 Captions and subtitles

*D.1.4.2.2.1* ***Retain and provide carriage for existing captions and subtitles***

*Captions* and *subtitles* consist of binary, non-XML text intended for display in synchronisation with image and sound essence; see also section B.3.3.2.4.[59] Teletext is an ongoing feed of information that may or may not be relevant to the active picture. Any and all of this textual information could potentially be very useful to archives and their users to enrich search and discoverability.

Closed Captioning and Teletext requires a special reader to decode information from the vertical interval and as originally displayed as subtitles on the active picture. Captions in some video formats, like NTSC and its successors, may be found as binary data in picture-data line 21 or in packets referred to as CEA-608 and/or CEA-708. In EBU areas (PAL and SECAM format), binary captions may be found in the EBU-STL format, sometimes as sidecar files (originally distributed to broadcasters on floppy disks). Newer digital video formats—not the subject of this initial edition of IASA-TC 06—may take the form of XML text that adheres to the SMPTE or EBU Timed Text specifications.[60]

A decode process could also be performed on digital preservation files at a later date but this, in addition to a dependency on the continuing availability of decoders, would be a slow, CPU-intensive real-time process. For that reason, the moment when an old recording is being digitized—also a real-time process—is a perfect opportunity to decode Closed Captioning or Teletext.

The IASA-TC 06 authors recommend that the captions be retained as encountered, i.e., retain line 21 in the picture data and/or carry CEA-608 or CEA-708 data packets in some way, e.g., for MXF files, the carriage is governed by SMPTE standard ST-436-1:2013 *Mappings for VI Lines and Ancillary Data Packets*.

*D.1.4.2.2.2* ***Create and capture captions and subtitles as Timed Text***

As noted in section B.3.3.2.4, however, binary captions and subtitles are a poor choice for the long term, since they depend on the continued availability of decoding tools. For this reason, the IASA-TC 06 authors recommend that the digitising process employ a decoder to convert the captions or subtitles to XML Timed Text. At this writing, however, such tools are neither widely available nor well implemented in typical digitisation tools, and it may not be possible for an archive to follow this advice.

If the wrapper selected by an archive for digitisation is not capable of carrying embedded caption data—especially XML-formatted data—then a sidecar file can be made part of the preservation bundle. The SMPTE and EBU standard formats for captions

59 *Free TV Australia Operational Practice Op42:* Distribution, Transmission, and Monitoring of Closed Captions on Line 21/334 (Free TV Australia: 2012) offers an excellent introduction to this topic.

60 *Timed Text* carries captions and/or subtitles in compliance with either the SMPTE or EBU Timed Text XML schema: SMPTE ST 2052-1:2013 *Timed Text Format (SMPTE-TT)* and EBU Tech 3350, EBU-TT Part 1: *Archive & Exchange*; EBU Tech 3360, EBU-TT Part 2: *STL Mapping*; EBU Tech 3370, EBU-TT Part 3: *Live Contribution*; EBU Tech 3380, EBU-TT-D, format for the distribution of subtitles over IP; EBU Tech 3390, EBU-TT Part M, EBU-TT metadata elements.

generally employ the filename extension *.ttml*. In addition, there are a number of industry and ad hoc structures for captions and subtitles. Although not specified by standard setting organizations, some of the following are widely adopted and reasonably interoperable: Caption Center, Captions Inc., Cheetah, DFXP, LRC, MPSub, NCI, Scenarist Closed Caption (*.scc*), SubRip (*.srt*), SubViewer, Timed-Text Markup Language (*.ttml*), Videotrol Lambda, and WebVTT.[61]

**D.1.4.2.3 Documenting audio tracks, captions, and subtitling**

The documentation described in the subsections that follow pertains to information that will be useful to future users or researchers. In many cases, the information is simple and straightforward, e.g., for recording with monaural or stereo sound, lacking captions or subtitles, with all spoken word content in a single language. In contrast, another recording may have multi-track audio, perhaps with French narration on track one and Spanish on track two and carrying subtitles in English.

It is a good practice to document the features of a recording and, in some cases, the same facts will apply to batch or run of recordings, "boilerplate" as it were. The documentation, like many other types of specialized metadata, can be maintained in a number of locations, and there is always a preservation argument for redundant storage in more than one location. Options include the archive's collection management (asset management) database, embedded in the preservation master file (some of the target format options allow for this; see section B.3), or as sidecar files that are stored in the same location as the master files.

It is worth noting that much of the needed documentation is best developed by an analysis of the content prior to digitisation and, if destined for embedding or sidecar files, provided to the reformatting facility (internal or outsourced) when the conversion of a batch begins.

***D.1.4.2.3.1 Identify and label audio track layout and content***

As noted in section B.3.3.2.5, audio tracks in source video recordings vary: silent, monaural, and multi-track as stereo, surround, or multi-channel (e.g., Spanish and French). Some broadcast recordings carry Descriptive Video Service (DVS), Second Audio Program (SAP), annotations (like a director's commentary for a dramatic program), as well as other types of multiple language content or other versioning elements. Sound tracks on certain videotape formats may also carry time code data, e.g., the carriage of LTC on track three of the 1-inch type C format.

When retained in the digital preservation master, these audio tracks ought to be labelled. Depending upon the target format selected, this tagging may follow a standard or industry convention, e.g., SMPTE's Multi-Channel Audio,[62] the EBU track allocation templates specified by EBU R 48 or EBU R 123, or by an industry convention promulgated by a broadcast network, such as the PBS Audio Configuration specification cited in the MXF application specification AS-03. Existing tagging should be retained in archive or preservation files.

61 DFXP (Distribution Format Exchange Profile), ".ttml", and WebVTT are related formats associated with the important W3C Timed Text initiative; for specification information, see https://www.w3.org/TR/ttml1/, https://www.w3.org/TR/ttaf1-dfxp/, https://www.w3.org/TR/webvtt1/, and https://w3c.github.io/webvtt/, all URLs accessed 20 June 2020.

62 SMPTE ST 2035:2009, *Audio Channel Assignments for Digital Television Recorders (DTRS)*.

In order to provide the tagging metadata, the digitising process must employ a tool to make a record of the tags, which will generally require human intervention. The data may be embedded in the digital preservation masters if this is supported. If the wrapper selected by an archive for digitisation is not capable of carrying this metadata, then the information can be recorded in a sidecar file or in the archive's asset management system.

*D.1.4.2.3.2 Tag the languages in soundtracks*

Archives may wish to tag primary and secondary languages in soundtracks using IETF RFC 5646 and/or the coding approaches that underpin it; see also B.3.3.2.8.

*D.1.4.2.3.3 Retain language tagging for binary caption or subtitle data*

As noted in B.3.3.2.7, language tagging may be present in caption and subtitle source material, e.g., as implemented via CEA-608, and -708 (called *caption service descriptors*), EBU STL, and SMPTE and EBU Timed Text. This language identification information should be retained in the output from a digitisation process.

*D.1.4.2.3.4 Tag the languages in Timed Text captions or subtitles*

Archives may wish to tag primary and secondary languages in Timed Texts. In addition, primary language tagging is required by SMPTE RP 2057:2011 (Text-Based Metadata Carriage in MXF), including Am1:2013. As noted in section B.3.3.2.6, broadcasters often rely upon IETF RFC 5646 and/or upon the coding approaches that underpin RFC 5646, especially ISO 639-2. Luckily, collections are often relatively homogeneous in terms of language, and many organizations will employ default language values in tags. In the U.S., for example, this will often be the code value for American English ("en-US").

**D.1.4.2.4 Capturing, creating, and retaining associated data**

The data types described in the subsections that follow have to do with "good housekeeping" and/or the retention of information that will be useful to future users or researchers. The associated data discussed in the three subsections that follow were introduced in sections B.3.3.2.9 through B.3.3.2.12, which also sketched in their value to archive administrators and future researchers. This associated data should be considered as "at the archive's option," that is, a given archive, for a given set of original materials, may or may not find it useful to consider capturing, creating, and retaining these types of added data. The strongest case can be made for the first, supplementary textual metadata. The arguments in favour of capturing and retaining the types of binary data described below are less strong but are still worth considering.

Associated data can be maintained in a number of locations, and there is always a preservation argument for redundant storage in more than one location. Options include the archive's collection management (asset management) database, embedded in the preservation master file (some of the target format options allow for this; see section B.3), or as sidecar files that are stored in the same location as the master files.

#### *D.1.4.2.4.1 Supplementary metadata (text-based data)*

Supplementary metadata is described in section B.3.3.2.9; as explained there, this is metadata that is supplementary in terms of the technical requirements for playback. Examples include additional technical metadata about the production or digitisation activity, sometimes called process-history metadata, information about the source item, about quality review outcomes, and preservation metadata, e.g., PREMIS. One example of process metadata is provided by the SAMMA digitising system in use in several IASA member institutions: an XML-encoded, frame-by-frame record of the metrics associated with each tape transfer. Many organizations wish to maintain process metadata and some see value in embedding such data in files, as it the case with process history metadata in the EBU Broadcast WAVE audio format.

Although boilerplate information when digitising analogue videotapes (the facts will always be the same), archives may wish to consider embedding Active Format Description (AFD) codes, especially if producing MXF files (see B.1.4.2.1.1 and D.1.3.1.9.2).

#### *D.1.4.2.4.2 Preservation file manifest (text-based data).*

The concept and value of a file manifest is discussed in section B.3.3.2.10: a manifest provides a high-level inventory of the parts including their identifiers, data description, MIME type, size and location. This information can help the user to better understand the composition of the file and it will also provide machine-interpretable information for content processing in later phases of the life cycle. Manifests are included in several formats ranging from the digital library community's BagIt specification[63] to the Interoperable Master Format (IMF).[64]

As is the case for supplementary metadata, depending upon the target-format wrapper selected, a manifest may be embedded in the main preservation file or may instead be maintained as a sidecar file.

#### *D.1.4.2.4.3 EBU STL, still images, and documents (binary data).*

EBU subtitles and other forms of binary are described in section B.3.3.2.11. Some archives will want to embed these types of associated materials in the preservation file along with the main content item. Other archives will prefer to maintain these types of materials as a part of the preservation file bundle.

### D.1.4.2.5 File- and frame-level fixity data

Fixity data is described in sections B.3.3.1.4 and B.3.3.2.12, which also make note of its value in preservation. With video, a case can be made for the creation of both *file-level* and *frame-level* fixity data. Regarding file-level data, digital files destined for long-term preservation are generally stored in data management systems that monitor these values, and in order for the audit trail to point back as a far as possible, fixity data should be created when the file is created or, at the latest, when files are held and inspected in an interim storage system (D.1.3.10.2).

63 Wikipedia, BagIt, https://en.wikipedia.org/wiki/BagIt, accessed 17 December 2017.
64 IMF Forum, http://www.imfforum.com/IMF_Forum/, accessed 17 December 2017.

The value of frame-level fixity data reflects considerations like the following pair. First, if you wish to obtain a more detail examination and repair the file, a mismatch in a whole-file checksum (the alarm) only takes you "to the neighbourhood" without identifying the specific "house" (frame or group of frames) that is damaged. Frame-based data gets you to the house.[65] Second, frame-based fixity data also serves broadcasters, who often employ what is called partial file restore to pull a single segment from a longer archived recording that is needed for insertion in a new program.

As described in section B.3.3.2.12, some target formats embed frame-level fixity data in the file, generally in the wrapper but occasionally in the encoded essence bitstream. The BBC Archive Preservation File Format specified in BBC White Paper 241 employs frame-level hash values, carried in the MXF wrapper. The digital cinema approach is standardized in *SMPTE ST 429-6:2006, D-Cinema Packaging – MXF Track File Essence Encryption*. In the latter example, fixity data is conjoined with data pertaining to encryption. Meanwhile, other target formats carry frame-level fixity metadata in a sidecar file that accompanies the main preservation file. This is generally the case with the hash values produced by the ffmpeg software's *framecrc* and *framemd5* capability,[66] related to the FFV1 video encoding specification.[67]

65 The fire brigade metaphor is borrowed from Dave Rice's article "Reconsidering the Checksum for Audiovisual Preservation" (Rice: 2012).

66 See "Reconsidering the Checksum for Audiovisual Preservation," ibid.

67 FFV1 Video Coding Format Version 4 [main specification], draft-ietf-cellar-ffv1-v4-03 (draft version 03, 18 October 2018, expires 21 April 2019) in various formats: https://tools.ietf.org/html/draft-ietf-cellar-ffv1-v4/; related to earlier version FFV1 Video Coding Format Version 0, 1, and 3 (draft version 06, 18 October 2018, expires 21 April 2019) in various formats: https://tools.ietf.org/html/draft-ietf-cellar-ffv1/. All preceding URLs accessed 19 January 2019; updating of all specifications continues; to identify latest versions, consult https://datatracker.ietf.org/.

**Sidebar: What about a version of the recording for digital dissemination today?**

This is a parallel discussion to the sidebar that follows section B.1.3.1.3, titled *Colour and tonal specifications for digital video, and related matters*. That sidebar sketched the differences between ITU-R Recommendation BT.601 (for standard definition, SD) and ITU-R Recommendation BT.709 (for high definition, HD), *Rec. 601* and *Rec. 709* for short. It noted that, in principle, digital copies of SD video ought to conform to Rec. 601, while also observing that today's end users are likely to view the recordings on the web, via streaming services like Netflix,[68] Blu-ray disk players, or via computer-based systems, using monitors likely to have been adjusted to present colour and tonal range as if the signal conformed to Rec. 709, and as if the scan were progressive with square pixels. (Some display systems are smart enough to recognize and properly display signals identified as Rec. 601.) Reassuringly, the colour and tonal differences between Rec. 601 and Rec. 709 are subtle; the video specialist Glenn Chan offers some illustrative examples on his web site (Chan: n.d.).[69]

What is required for an archive to produce a "digital dissemination" version of the recording, i.e., one that conforms to Rec. 709 (or one of the other recent digital colour/tonal standards listed in the sidebar that follows section B.1.3.1.3)?[70] Such a conversion requires appropriate filtering to produce the best colour and tonal outcomes, and may require additional technical transforms, such as de-interlacing (which may use methods called bob, mean, and linear). Dropping a field to convert to a progressive format is not advised, as half of the vertical information is lost. To ensure that temporal artefacts are not baked in to the picture, high quality sophisticated adaptive motion compensation[71] ought to be employed and thoroughly tested on a variety of content. If the up-conversion transforms SD (with a 4:3 aspect ratio) to HD (with a 16:9 aspect ratio), most archives will prefer to use pillarbox framing, as the alternative is what is called "scan and pan," with a consequent loss of picture information. Depending on the archive's perception of its user community, there might also be a bit of clean-up: adding a watermark or logo, cropping unwanted blanking or analogue artefacts such as head switch error, removal of non-program content such as bars and tone, black, and so on.

68 Netflix provides an overview of its ingestion and dissemination systems at https://medium.com/netflixtechblog/high-quality-video-encoding-at-scale-d159db052746, accessed 8 December 2017. Regarding ingestion, the document states that Netflix's "preferred source type is Interoperable Master Format (IMF). In addition, we support ProRes, DPX, and MPEG (typically older sources)".

69 Chan, Glenn, n.d., "Rec. 709 Versus Rec. 601 Luma Coefficients," http://www.glennchan.info/articles/technical/rec709rec601/rec709rec601.html, accessed 13 November 2017.

70 IASA-TC 06 author Andy Martin reports that, in Australia, this type of adjustment is sometimes called *presentation conformance*.

71 Motion compensation is critical to high quality video format conversions; for example, in promoting its conversion devices, an InSync Corporation document states that "motion compensation is concerned with preserving the consistency and resolution of moving content," and makes note of problems related to the conversion of "slow horizontal pans" and scenes made by a "stationary camera with descending objects" like airplanes, http://www.insync.tv/documents/Efficient-motion-compensation.pdf, accessed 8 December 2017.

While acknowledging the necessity of producing digital-dissemination copies of older, interlaced video recordings, specialists tend to characterize the quality of the outcome in "glass half full, glass half empty" terms. Andy Martin, a video specialist in Canberra and the main author of IASA-TC 06 section D, sees the glass as half full, and calls attention to a few of the tools that seem like reasonably good bets for the task (there are more):

- ffmprovisor: a tool from the Association of Moving Image Archives (AMIA) that guides end users in the effective use of the powerful open-source application *ffmpeg*[72]
- Teranex Standards Converters, marketed by Blackmagicdesign[73]
- Motion Compensated Converters (MCC model numbers) from InSync Technology[74]

Franz Pavuza, a video specialist now retired from the Austrian Academy of Sciences, reminds us of the half-empty glass and the risk of image degradation, albeit slight: "at the moment [there is] no 'perfect' de-interlacing method for the older interlaced material that would justify a complete transfer to progressive data and a subsequent removal of the originals . . . . [I have tried] many de-interlacing routines. All of them do a reasonably good job, but they are far from perfect. . . "[75].

The IASA Technical Committee embraces one implication of Pavuza's comment: the digital dissemination versions of recordings, resulting from the actions outlined in this sidebar, will not qualify as *preservation* copies that follow the guidance of *The Safeguarding of the Audiovisual Heritage: Ethics, Principles and Preservation Strategy: IASA-TC 03* (IASA Technical Committee, 2017). The committee echoes Pavuza's recommendation that archives not discard interlaced originals for the foreseeable future "even when a de-interlaced version seems to satisfy most of the scientific work on the material"[76].

72 The main GitHub page for ffmprovisor is https://amiaopensource.github.io/ffmprovisr/, while de-interlacing is described at https://amiaopensource.github.io/ffmprovisr/#deinterlace, both accessed 8 December 2017. Application downloads and related resources for ffmpeg are shared at http://ffmpeg.org, accessed 9 December 2017.

73 Promotional materials for Teranex highlight a variety of capabilities including "pixelMotion-based de-interlacing". In 1999, Jed Deame, Teranex's director of product development, described the technology in "Motion Compensated De-Interlacing: The Key to the Digital Video Transition" (Deame: 1999).

74 See *Motion Compensated Converter MCC-4K* (InSync: n.d.) and *How more efficient motion processing can save you money* (InSync: 2014). The MCC-4K device is associated with InSync's joint venture with the For.A Company, https://www.for-a.com/, accessed 8 December 2017.

75 Pavuza, Franz, private communication, 30 November 2017.

76 Pavuza, ibid.

### D.1.4.3 Critical control factors: operating a digitising facility and system

#### D.1.4.3.1 Quality control and the digitisation production line

Video digitising includes a series of distinct process steps and there are multiple points in the series that would be good "spots" for quality control actions. These QC actions should be autonomous from the standard digitisation process to allow for an independent and objective view. Checks should be applied to all parts of the process chain including conservation practices,

VTR playback, signal path quality and cabling, analogue-to-digital-conversion tests, audio and video monitoring checks, file creation, and archiving infrastructure. All tests should be scheduled, evenly distributed and logged throughout all practices. It is also the case, however, that the feasible "spots" to make quality control assessments vary from setup to setup. Especially for full-extent and comprehensive systems (informal terms defined in section D.1.3.1.9.1 above), the technology often consists of a complex integrated system, typically from a commercial vendor. It is generally impossible to infiltrate such systems in order to check the signal at theoretically desirable points. In these instances, a sensible quality control approach will combine (1) actions taken upstream, like those outlined in D.1.2.2 and D.1.3.2 above, (2) quality control capabilities that are part of the digitising system as provided by the vendor, and (3) some additional quality control actions that can be taken downstream of the digitising system, e.g., in an interim storage system (D.1.3.10.2) before the preservation master files are moved to a long term preservation repository system.

The vagaries and nuances of video transfer and digitisation are complex, specifications are sometimes unclear, and the performance of conversion systems and devices may be less than perfectly reliable. For an example of this phenomenon, see Dave Rice's 2017 report *Audiovisual Adherence*, for the Tate Museum in London (Rice: 2017). The authors encourage archives to embrace the mottos "check your work" and "using any QC tool is better than using none".

### D.1.4.3.2 QC applications: for preservation and for current-day dissemination

The category of tools available for quality review is extensive and varied: when drafting this guideline in 2018-2019, the authors identified more than 20 automated tools in the ever-evolving marketplace.[77] Given the small community of archives engaged in digitisation to support long-term preservation, why are there so many tools, with some commercial examples commanding high prices? The answer is that the QC market is also driven by the requirements pertaining to current-day dissemination of digital content. One part of this has to do with broadcast rulemaking (see section B.1.1.3): the signal or bitstream that is transmitted "over the air" or via cable must meet a number of requirements.

It is also the case that non-broadcast streaming-video providers impose strict technical-quality requirements on those who provide programs.[78] One of the TC 06 authors is associated with a pair of video-technical companies whose services include assessing and, when needed, correcting shortcomings in program material on its way to streaming dissemination; one company is certified as a Netflix Preferred Fulfilment Partner. Service providers like these are constantly looking for the best set of pass-fail parameters for file-based checks to ensure well-formed files, as well as fine-tuning checks for anomalies such as video and audio dropouts, audio clicks or hum. "These anomalies," the author writes, "should be flagged as an alert for an operator to check, just in case the error is a false positive. There is real benefit when mass digitisation is underway, and QC operators are 'under the pump'".[79]

### D.1.4.3.3 QC applications: types and categories

The two purposes for QC applications outlined in the preceding section—archival preservation and conformance to dissemination requirements—help account for the diversity of offerings in the application marketplace. Although the following list of categories is rough and ready, it can be helpful to consider QC applications in terms of four dimensions:

77 This "working-draft" list of video QC applications was assembled during 2018 and 2019 to support the writing of TC 06; readers are reminded that any or all applications are subject to replacement by newer versions or removal from availability. Application names are followed by the source company or organisation and a relevant URL: Aurora, Tektronix, https://www.tek.com/aurora; BATON+, Interra Systems, http://www.interrasystems.com/workflow-qc.php; DV Analyzer, AVP, https://www.weareavp.com/dv-analyzer/ (discontinued as of June 2019); ffprobe (format identification), FFmpeg.org, https://www.ffmpeg.org/ffprobe.html; FrameLector and Video Migration QC, NOA, http://www.noa-archive.com/products/archive-transfer-technology/video-transfer/framelector/; IMS120 Multiviewer Monitor, Mividi Inc., http://mocomsoft.com/en-US/products/MultiViewMonitoring.aspx; Iris, GrayMeta, https://www.graymeta.com/iris/; MDQC (Metadata Quality Control), AVP, https://www.weareavp.com/products/mdqc/; MediaConch, MediaArea, https://mediaarea.net/MediaConch/; MediaInfo, MediaArea, https://mediaarea.net/MediaInfo/; Mkvalidator, Matroska.org, https://www.matroska.org/downloads/mkvalidator.html; MXF Legalizer, Cube-Tec, https://www.cube-tec.com/en-uk/products/video/mxf-legalizer; MXFixer, Metaglue, http://www.metaglue.com/website/mxfixer.php; Pulsar and Quasar, Venera Technologies, http://www.veneratech.com/; QCTools, Dance Heritage Coalition and the Bay Area Video Coalition (BAVC), https://github.com/bavc/qctools and https://sustainableheritagenetwork.org/digital-heritage/qc-tools-manual-2016-printable-version; QScan Video Quality Check, Quales.tv, https://qscan.editshare.com/solutions/overview; Quadriga Video, Cube-Tec, https://www.cube-tec.com/en/solutions/video/quadriga-video; QualityChecker, NOA, http://www.noa-archive.com/news-and-events/news/noa-qualitychecker/; SdEye, Dektec, https://www.dektec.com/products/applications/SdEye/; Vidchecker, Telestream, http://www.telestream.net/vidchecker/overview.htm and http://www.telestream.net/vidchecker/specs.htm; videoQC suite, Drastic Technologies, https://www.drastic.tv/productsmenu-56/videoiosoftwarelist/videoqc; VidiCert Essence QC, Joanneum Research Forschungsgesellschaft mbH, http://www.vidicert.com/en; Vrecord, Association of Moving Image Archivists (AMIA), https://github.com/amiaopensource/vrecord. This list does not represent a recommendation or endorsement by the IASA Technical Committee.

78 One thorough-going example is Netflix; see the technical guidelines linked from this page: https://partnerhelp.netflixstudios.com/hc/en-us/categories/202282037-SPECIFICATIONS-GUIDES, accessed 20 June 2020.

79 Andy Martin, private communication, 3 June 2019.

- Motive for development
  - Support archival video digitisation for preservation
  - Support professional production, broadcast, and online content disseminators, may be adapted or employed in preservation digitisation

- Cost, dissemination fee
  - Open source applications, with no cost licenses
  - Applications from non-profit organisations, fee for license
  - Commercial applications
  - Commercial applications with integrated open source tools

- Hardware or software dependencies
  - Applications that are independent of specific hardware or systems (e.g., other applications)
  - Applications that are integrated with hardware and/or other systems
  - Applications that depend upon and "work with" specific hardware or systems (e.g., other applications)

- Actions: assess transfer process, assess files and/or metadata only, reports only, fix problems
  - Applications that inspect finished files and generate reports
  - Applications that inspect finished files, generate reports, and are capable of correcting errors
  - Applications that monitor signal (in this context, analogue, more or less) and/or bitstreams (e.g., in an SDI interface) as playback and transfer proceeds

### D.1.4.3.4 Preservation master file profiles

Quality review depends upon what might be called a profile for the preservation master file. These will change from job to job, depending on the types of original source materials and the archive's preference for the treatment of a given job. In effect, the job profile is a list of the specified features that review processes use to guide their monitoring of production processes and when checking the final delivered files.

Subsection D.1.4.3.4.1 provides a hypothetical, illustrative example of a profile for a master file for an item from a collection of recorded television broadcast. Subsection D.1.4.3.4.2 offers comments on what might be important to include in profiles for other types of source material, including born-digital.

#### *D.1.4.3.4.1 Illustrative profile for a preservation master file*

D.1 Table 4 presents a digital master profile for a video recording that will be digitised as uncompressed 4:2:2 video in MXF-file form. This hypothetical example is meant to illustrate the idea of a profile, not to recommend a particular set of specifications (although the example does fit this guideline's target format recommendations in section B.3.1.2.) In this case, we have imagined a memory institution that has received older recordings from a broadcaster. The video payload is complex with many significant features to retain. This recording may be requested for reuse by the television station and the preservation master ought to maintain sufficient quality to meet that requirement.[80]

80 The authors acknowledge that few broadcasters today wish to ingest uncompressed 4:2:2 video for their production archiving and, if requested for reuse, this preservation file would be digitised into the requesting station's current "working format," which today might be one of the MPEG-family formats, DVCPro50, or some other high quality lossy compressed format.

D.1 Table 4. Illustrative profile for a digital preservation master file

| **Parameter** | **Job specification** |
|---|---|
| **Wrapper** | |
| File wrapper format | MXF |
| File wrapper spec conformance | Relevant MXF features might include such things as Operational Pattern, KAG size, Essence Wrapping, Source and Material Package Time codes (master synthetic time code, legacy time code documentation), Index Table Segments, Header Partition Status, Body Partition Status and Count, Footer Partition Status, RIP Presence, Essence Location, Picture Essence Container Label, Picture Offsets, and Active Format Description. Values for the preceding from: Minimum: SMPTE ST 377-1 and other relevant SMPTE standards<br>Extended with constraints: SMPTE RDD 48 specification<br>Details omitted from this illustrative table |
| **Picture data stream** | |
| Picture encoding, compression type (includes uncompressed) | uncompressed |
| Picture encoding, if compressed, bit rate type (CBR, VBR), bit rate | n/a |
| Picture encoding, chroma subsampling | 4:2:2 |
| Picture encoding, bits per sample | 10 |
| Frame rate | 29.97 |
| Frame size (raster in pixels) | 720x486 |
| Pixel and frame aspect ratios | 720:486 (pixel)<br>4:3 (frame) |
| Field order | 1, 2 [or "same as source"] |
| **Picture quality measures (selected)** | |
| Blanking information | Black level (10 bit) set to 192 (theoretical 64, tolerance to allow for noise) |
| Luma levels | 64-940<br>Also conforms to EBU R 103 *Video Signal Tolerance in Digital Television Systems, ver. 2.0*<br>Tolerance +/- 2% |
| Chroma levels | 64-990<br>Tolerance +/- 2% |
| Freeze frames | Duration of frozen frames to fail (trigger QC alert): +/- 12 frames |
| Analogue dropouts | Isolated light or dark lines; tolerance sensitivity = medium |
| Digital dropouts | Block artefacts; tolerance sensitivity = medium |
| Stripe errors | Lines offset horizontally from correct positions; tolerance sensitivity = medium |
| Corrupt frame | Corrupt or unexpected frames; frames out of place in a sequence; tolerance sensitivity = medium |
| **Picture data as written to file** | |
| Picture file-data format | V210 |

| Parameter | Job specification |
|---|---|
| **Sound data stream** | |
| Audio encoding, compression type (includes uncompressed) | LPCM |
| Audio encoding, if compressed, bit rate type (CBR, VBR) | n/a |
| Audio encoding, if compressed, bit rate (average, if VBR) | n/a |
| Audio encoding, sampling freq | 48 |
| Audio encoding, bits per sample | 24 |
| Audio: number of audio channels | 2 |
| **Sound quality measures (selected)** | |
| Digital silence | All programs carry sound on 2 tracks; no digital silence for entire recording<br>Programs should have 30 seconds silence preceding colour bars and tone |
| Audio clipping | Avoid successive samples of equal value; tolerance sensitivity = low |
| Clicks and pops | Avoid transients or sudden changes in amplitude; tolerance sensitivity = low |
| Phase coherence | Stereo recordings must be in phase for mono compatibility; tolerance sensitivity = medium |
| **Duration** | |
| Duration (minutes) range | 25-35 |
| **Ancillary and associated data** | |
| Master (synthetic) time code | Serves as main TC in MXF wrapper |
| Legacy time code documentation | Documented in MXF wrapper |
| Captions/subtitles retained | Retained as found (line 21, ANC packets, etc.) |
| Captions/subtitles as Timed Text | conform to SMPTE ST 2052-1:2010; carried in MXF Generic Stream Partition |

*D.1.4.3.4.2 Illustrative example of relevant features for other profiles*

The preceding section outlines an illustrative profile for a professionally produced video recording. More modest recordings intended for more modest venues, however, may be successfully digitised and represented by digital preservation files that would fail quality control tests designed to validate content against the preceding profile.

Imagine a university, where a lecturer recorded a number of classroom presentations with an unattended camcorder, marked by jumps in autofocus, low audio levels, and segments of distorted sound. Nevertheless, the recordings have pedagogical value and the university wishes to retain and reuse them. As indicated in section B.3.7.1, these recordings are members of a class that can comfortably use, for example, the target format options of AVI or QuickTime file wrappers, with an uncompressed or lossless-compressed picture encoding. For this type of recording, quality review should check to be sure that the file format and encodings are valid, with the picture- and sound-quality measures focusing on problems that suggest such incidents as head-clogging during the playback of the tape and dropouts that would interfere with future digital-file playback.

### D.1.4.3.5 Quality control tools: general

Basic checks of facts about the formatting of the wrapper and encoding are important and useful. This is the type of information extracted from file headers, stream-embedded metadata, and value-calculation by free open-source applications like MediaInfo.[81]

In the illustrative profile above (D.1. Table 4), facts about formatting are listed under these headings:

- Wrapper
- Picture data stream
- Picture data as written to file
- Sound data stream
- Duration

The most thorough review of digitised content, however, will include monitoring and/or testing of baseband picture and sound. It is not unheard of to find that the metadata in, say, a file header does not agree with what is actually carried as baseband data. In addition to verifying the "facts," this kind of review will also check the quality of picture and sound.

Automated QC applications generally examine "facts" and, to varying degrees, they also check baseband picture and sound, and assess essence quality to the degree possible via computer algorithms. In some cases, these tools respond to the thresholds or aim points in a profile, as illustrated in the profile above (D.1. Table 4) under these headings:

- Picture quality measures
- Sound quality measures

In other cases, QC applications are set up to analyze and provide assessments along the lines of good, acceptable, poor, or pass or fail. And some tools provide even more in the way of evaluation and correction.

Some QC applications are in operation during the production process and monitor the content as transfer proceeds. This approach requires more in the way of systems and equipment and is more often provided by commercial systems, especially those developed to serve broadcasters.

What about corrective actions, when needed capabilities are not offered by the quality control applications? In many cases, an archive will choose to retransfer the source recording, often using different settings on the digitising system. In addition, there are applications designed to correct flaws by adjusting or altering files, but we have not surveyed this category for this guideline.[82]

Additional discussion and illustrative lists of "what to check" is provided in part D appendix A.

81 The MediaInfo application is hosted at GitHub: https://github.com/MediaArea/MediaInfo, accessed 15 June 2019.

82 Here is one illustrative example, to stand for the category: Jan E. Schotsman has created six tools to adjust digital video: Deinterlacer, Video Cleaner, Clips Cleaner, Movie Tools, Extensifier, and Audio Channel Tool. One of these has been recommended for use by Netflix: Extensifier, used to correct flaws in QuickTime files such as incorrect time code data, aspect ratio flag, clipping, and gamma. The Netflix reference page is at https://partnerhelp.netflixstudios.com/hc/en-us/articles/214928598-JES-Extensifier, accessed 7 June 2019; as of this date, the application was offered for download at multiple sites.

#### D.1.4.3.6 Manual quality control: play the file

As a safety extra, there is always value in producing a few sample files "as if " in a real operational job, and then playing these back in the actual systems that will serve future researchers or other consumers of an archive's output, i.e., those who will study or re-purpose the preservation files that have been created. In effect, this verifies the content stored in the file back to baseband SDI video to ensure there is the most minimal loss or introduction of noise during the process. This kind of real-life playback and processing can help ensure interoperability or expose issues that might not be obvious when played back within the creation system. Add sentence at end of paragraph: Information about some unwanted artefacts is provided in section D.1.4.1.1 above.

## D.1. APPENDIX A Digitisation QC: what-to-check

### D.1 Appendix A.1 Digitisation QC: more than just picture and sound

Although the central role for digitisation QC is to monitor essence quality ("picture and sound"), it is also the case that--depending on the job--attention should also be paid to ancillary data, digital file format structure, and associated metadata. Readers are encouraged to consult the European Broadcast Union's identification and description of QC dimensions.[83] Meanwhile, the setup and operation of QC applications may benefit from reference to an archive-created profile for their desired preservation master file; see section D.1.4.3.4.1 (*Illustrative profile for a preservation master file*).

### D.1 Appendix A.2 Monitoring signal and bitstream during digitisation

Some tools monitor video signal and bitstream during production, i.e., as digitisation proceeds. Often, these tools are subsystems within a larger application that executes the overall digitisation process. The dynamism of the process and the variables in play mean that the selection of features to check is, to a degree, a matter of strategy. As the following illustrative examples suggest, planning this phase of QC depends upon a both well-understood science and wisely considered art (see also section D.1.1.5, *Quality control: how much science, how much art?*).

Specialists in the field report that as many as 90 percent of archived videotapes are nonproblematic and can be efficiently transferred, especially in "factory" production lines. In many cases, the QC tools (often subsystems) that check production-in-process include warning features that can stop the transfer process in the face of severe errors. This approach means that the approximately 10 percent of videotapes that are rejected during in-transfer screening can be shifted to a non-factory production line to receive custom treatment.

The following bullets represent a starter list of illustrative examples of features that may be monitored during transfer by built-in QC tools. This list tilts toward aspects of the incoming signal, usually but not always *analogue*. A starter list of *digital-bitstream* features-to-check is provided in the following section.

- SONY ISR data reporting (when playback VTRs permit; see sections D.1.3.1.4.5, D.1.4.1.3.2)
- RF data reporting (when playback VTRs permit; see section D.1.4.1.3.3)
- Dropouts (identification often supported by ISR and RF monitoring)
- Video level and defects, analogue
- Audio level and defects, analogue
- Linear and Vertical Interval Time Code (legacy TC is usually reported as data; many transfer systems also generate new synthetic time code to govern future playback; see section D.1.4.2.1)
- Other ancillary data anomalies (e.g., captions/subtitles)
- Field dominance (aka field order), cadence (aka colour framing)

It is worth noting that sometimes analogue signal from one or another VTR will present in an anomalous way to generic QC check, e.g., a VHS-tape-format head switch error may report as an analogue dropout. In addition, there is always value in having human eyes and ears spot-check materials as work proceeds. In support of this, some production applications offer operatorobservation capabilities to supplement automated tools. For example, some systems provide visual monitors that display the vertical interval (ancillary data) scan lines along with active picture and/or provide a split-screen display to increase the visibility of the anomalies that may appear in individual fields, anomalies that may be obscured by full-frame picture display.

83 https://ebu.io/help/qc/, accessed 24 May 2019; see also section D.1.1.6.1 in this document

## D.1 Appendix A.3 Monitoring or assessing digitised bitstream in progress or in file

Many production systems with built-in QC also monitor the "downstream" (post-digitisation) digital bitstream. As an alternative, of course, downstream components can also be analysed by QC tools that assess files after production is complete. Either way, here's a starter set of digital bitstream features to monitor:

- Luma and chroma values, black level
- Ancillary data anomalies in digital stream (e.g., time code, captions/subtitles)
- Broadcast range conformity (e.g., not super white)
- Audio level or loudness
- Dropouts (may be detected by repetition of picture lines)
- Noise, video and/or audio (may be identified by measuring peak signal to noise ratio)
- Sample rate, bit depth

## D.1 Appendix A.4 Assessing encodings and file wrappers

Multiple specialised commercial and open-source tools exist to check encodings and file wrappers to verify that they are *valid* and *well-formed*. Evaluations of validity and well-formedness are familiar to digital library specialists: this is the kind of assessment provided by the well-respected JHOVE2 tool which, alas, does not yet have modules for most moving image formats.[84]

As noted in section D.1 Appendix A.2 above, strategic planning is required when defining QC checks for picture, sound, and ancillary data, whether the checking is applied during production or to finished files after production is complete. In contrast, there is a bit more clarity about whatto- check with encodings and wrappers; these are generally digital structures that are specified in standards documents. Nevertheless, some variability remains: (a) an archive may judge that some features are more critical than others and (b) both encodings and wrappers are specified in ways that offer multiple *profiles* (aka *application specifications*), each of which may offer a range of defined levels. For many moving image specialists, this profile-and-level phenomenon is most familiar from MPEG video specifications.[85] For example, the pass-fail conformance of an MPEG file or an MPEG player will be articulated in terms of, say, "conforms to the MPEG-4 *High Profile* at *Level 3*."

Section B.3.7 in this guideline indicates the preference of the TC 06 authors for two encodingwrapper combinations for video preservation: (1) FFV1 wrapped in Matroska and (2) lossless JPEG 2000 or uncompressed video wrapped in MXF. What ought to be included when QC checking these target formats? The lists of features that experts may select are lengthy and the following illustrative lists are intended only to suggest the range of interest. An archive that wishes to develop a thorough QC plan for one of these target formats should start with lists like these and seek added advice about the features and possible tools that would make a good fit for a given project; see the "tailoring" discussion in D.1. Appendix A.5 below.

84 https://bitbucket.org/jhove2/main/wiki/Home, accessed 16 June 2019.

85 For example, the Library of Congress description of the lossy compression format nicknamed MPEG-4 AVC (MPEG-4, Advanced Video Coding, Part 10), also known by its ITU-T designation H.264, offers links to descriptions of seven profiles (there are more), and each profile may be produced at various levels. (See https://www.loc.gov/preservation/digital/formats/fdd/fdd000081.shtml, accessed 29 May 2019.) "Higher" profiles and levels are more complex and/or carry more data: they offer better picture quality but require more capabilities from encoders and decoders, as well as increased network capacity. (See https://en.wikipedia.org/wiki/Advanced_Video_Coding#Profiles and https://en.wikipedia.org/wiki/Advanced_Video_Coding#Levels, accessed 20 June 2020.)

Illustrative what-to-check list for FFV1 lossless picture encoding[86]

- header
- version (and version 2)
- micro_version 2
- coder_type
- state_transition_delta
- colorspace_type
- bits_per_raw_sample
- h_chroma_subsample
- h_chroma_subsample
- v_chroma_subsample
- v_chroma_subsample
- QuantizationTables
- initial_state_delta
- ec
- intra
- crc_parity
- end of header
- slice x / y / width / height
- quant_table_index
- picture_structure
- sar_den
- slice_size
- error_status
- crc_parity
- end of slice
- end of frame

Illustrative what-to-check list pertaining to the Matroska wrapper[87]

- Extension Test
- EBML Element Start
- EBML vint efficiency
- Element ID Registered
- Element Size 0x7F Reservation
- Element Size Byte Length Limit
- Level 0 Segment
- EBML Header
- EBML (various features)
- DocType (various features)
- Top Elements Coded on 4 Octets
- CRC (various features)
- Single Segment Composition
- Seek-Presence
- SeekID (various features)
- SeekPosition-Presence
- Segment-Info-Presence
- SegmentUID (various features)
- SegmentFilename-Type
- PrevUID (various features)

86 Derived by paraphrasing the list in *Conch: Appendix: Conformance Check Registry and Expression Snapshot*, http://www.digitalmeetsculture.net/wp-content/uploads/2015/04/MediaAreaConch_Appendix_ConformanceCheckRegistry.pdf, dated 2015, accessed 27 May 2019. See also https://mediaarea.net/MediaConch, accessed 30 May 2019.

87 Derived by paraphrasing from the MediaConch "appendix" document, identified in the preceding footnote.

- NextUID (various features)
- NextFilename-Type
- SegmentFamily-Size
- SegmentFamily-Type
- TimecodeScale-Presence
- Duration-Range
- Duration-Type
- DateUTC-Type
- Title-Type

Illustrative what-to-check list pertaining to the JPEG 2000 picture data that conforms to the ISO/IEC-standardized lossless Broadcast Profile[88]

- Reversible discrete wavelet transforms using the integer 5-3 filter
- SIZ marker segment, Rsiz profile indicator and tile data
- RGN marker segment not used
- COD/COC marker segment for specified decomposition levels, layers
- COD/COC marker segment for reversible discrete wavelet transforms (integer 5-3 filter)
- Progression order
- Reversible color transform (RCT)

Illustrative what-to-check list pertaining to the MXF wrapper as profiled by SMPTE RDD 48.[89]

- Operational Pattern
- KAG size
- Essence Wrapping
- Source Package Timecode
- Material Package Timecode
- SDTI Timecode Continuity
- Index Table Segments
- Index Location
- Header Partition Status
- Header Fill
- Body Partition (various elements)
- Footer Partition Status
- RIP Presence
- Essence Location
- Picture Essence Container
- Label
- Picture Element Key
- Picture Essence Coding
- Signal Standard
- Picture Offsets
- Active Format Descriptor

88 A set of three JPEG 2000 Broadcast Profiles, including one that is lossless, were first published as Amendment 3 to JPEG 2000 Core Coding standard (ISO/IEC 15444-1:2004/Amd 3:2010, Profiles for broadcast applications). These profiles were subsequently incorporated in the revision of the main standard (ISO/IEC 15444-1:2016, Information technology – JPEG 2000 image coding system: Core coding system).

89 This illustrative list emphasizes features associated with the wrapping of picture essences; similar features associated with sound essences have been omitted. The list has been derived by paraphrasing documentation provided to users of the Vidchecker QC application from Telestream Inc., and with reference to SMPTE RDD 48. A general description of the Vidchecker application is offered on Telestream's promotional webpages (http://www.telestream.net/vidchecker/overview.htm#vidchecker, accessed 30 May 2019). Readers should note that a number of sources offer MXF QC tools; the IASA Technical Committee has not evaluated these applications and this listing does not imply any type of endorsement.

- Colour Range (metadata check)
- Chroma subsampling (metadata check)
- Component Depth (metadata check)
- Frame Size (various elements)
- Aspect Ratio
- Edit Rate
- Reference Levels
- Video Descriptor
- Video SubDescriptor
- 608 Closed Captions
- 708 Closed Captions
- EBU STL or teletext
- Timed text

### D.1 Appendix A.5 Tailoring QC application to workflow systems and delivered digital files

QC applications should be tailored to an archive's workflow, whether the work is performed in an archive's own facility or by a contractor carrying out an archive's requirements. With qualified in-house staff, an archive can tailor a "what to check" QC list for a given project. But what might support archives whose staff does not include specialists with video engineering experience? One option is to engage an expert consultant to support project planning. A second complementary option may emerge from the process used to select and engage contractors, as described in the section that follows.

### D.1 Appendix A.6 Procurement process may support refinement of a "what to check" list

A second option for the assembly or refinement of a QC "what to check" list may arise in the course of a procurement (aka contracting or acquisition) process. Such processes typically feature Requests for Proposal (RFPs, a term frequently used in the United States) or Invitations to Tender (ITTs, or "Tender" for short, a term frequently used in Europe and elsewhere). RFPs or Tenders can be designed to launch a dialog between the archive and potential vendors (contractors) for such activities as a) designing a facility, (b) building a facility, or (c) outsourcing digitisation services.

Many organisations, notably government agencies, have established rules for drafting RFPs and ITTs. Often these rules discourage requiring a vendor to use a specific tool, i.e., *stating the solution*. Instead, the RFP/ITT should *state the problem* and, to the degree possible, performance requirements, asking prospective vendors (aka *offerors*) to propose how they would meet the requirement and their reasons for choosing those methods and tools.

This type of RFP or ITT might include some QC features—like the ones in the illustrative lists above—presented as "such as" or "along these lines" examples. Offerors would be encouraged to articulate a fully realized QC plan and rationale. Even if not expert engineers, the archive staff evaluating the resulting proposals will benefit from the offeror's narrative. And, as noted above regarding project planning, an archive can sometimes engage an expert consultant as a guest reviewer to assist in the evaluation.