

QC — and longterm archiving experience

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During the digitization of legacy archive material at ORF, the Austrian public-service broadcaster, hundreds of thousands of video cassettes will need to be converted to digital file formats over the next decade. To guarantee the sustainable usability of this file-based material, thoroughly-planned guidelines for Quality Control (QC) have to be worked out. Although some QC tools already exist, their detailed parameter settings as well as the exact requirements to test against, have not yet been determined and will be the main focus of the EBU QC group.

Besides giving some details of a migration project at ORF, this article discusses different proposals concerning the understanding of QC from an archival viewpoint, along with file format collateral effects and, finally, some data-tape library issues.

Long-term digital archiving means ingesting material – and, in special cases, also the migration of analogue and digital tape content to files – as well as maintaining the availability and manageability of the generated files over decades and even centuries! From that perspective, quality control seems to have a different relevance compared to the everyday use of programme material. What seems sufficiently high quality for edit and playout at present could lead to major problems in terms of unacceptable errors during material handling in the future – if standard compliance and audio or video consistency, as well as metadata correctness, are not ensured during the archiving process.

However, one of the most unpleasant jobs of archivists is weighing up the storage and handling costs against possible future value. Thus, special care must be taken to optimise every task of the archiving and de-archiving process, especially the time-consuming ones. One essential part to achieving a perfectly working archive which is usable for a long time to come is the planning and realization of a well-conceived QC workflow which is the main focus of the EBU QC group.

A short history of media formats

Fig. 1 outlines the history of the video carriers mostly used in ORF. Starting with black-and-white silent movie material from the 1890s (which is still usable if prepared specially) right through to high-quality HDTV file formats, there has been a long history of change. In the 1960s, the first magnetic two-inch video tapes were introduced. They brought a new quality in terms of material editing and processing ... but also a drawback in preservability because of the deterioration of the magnetization over time. The development goal of media carriers was to decrease their size, which goes hand in hand with reducing their life span and thus shortening the recycling interval. Around 1975, the one-inch tape was introduced, followed in 1979 by the UMATIC cassette format, which represented the all-time bottom of the quality level.

After the introduction of analogue BETACAM, a big step-up in quality was achieved by switching to the digital formats BETA DIGI and BETA IMX. The latter format is now used intensively within the recycling processes of SD material. Because the IMX carrier uses the same coding as an existing file format, no generation loss will occur when finally migrating the tapes to files. For the first time, these carriers have been used with both the 4:3 and 16:9 video formats.

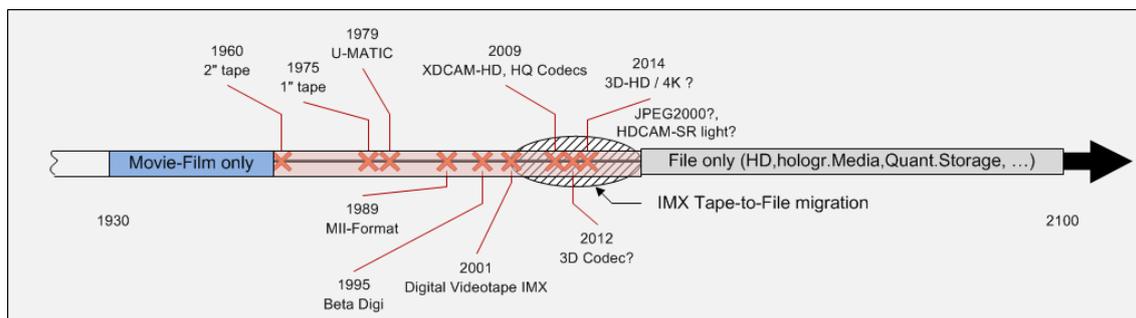


Figure 1
Changing media types over time

The launch of HDTV required new cassette types. Several television companies finally decided to switch to XDCAM-HD using the MXF wrapper [1]. From the archivist's viewpoint, this format has the advantage of the smallest HD bandwidth and therefore the lowest storage demand, but it also has the disadvantage of carrying relatively low video quality (LGOP, 8bit only ...) and more difficult handling than I-frame-only formats (in editing for example). As there is a demand for different video resolutions – from higher ones such as 4k material, to very low ones such as current internet-quality material, and also new ones such as 3DTV or interactive production formats – **a lot of new codec versions (and wrappers) can be expected over the next decades.**

IMX migration

During the last decade, lots of analogue magnetic video media such as MII have been migrated to the IMX (cassette) format during an attempt to recycle the media. The IMX tape format allows the recording of video and audio signals on behalf of a codec which can now be used as file essence without any loss of quality.

At ORF, around 360,000 hours of IMX along with DIGI BETA material (see Fig. 2) has to be transferred (migrated) into IMX files. Many of the collection tapes have several productions stored on one tape, which gives a total of more than a million files.

A short calculation shows the amount of data involved. IMX D10 as well as XDCAM-HD 4:2:2, using a 50 Mbit/s video codec (with audio and data overhead concerned) practically results in about $60/8 = 7.5$ MByte/s = 2.7×10^{10} Byte/h for each tape. For the complete archive of 360,000 hours, the storage capacity comes to a total of 9.7×10^{15} Bytes/h which rounds up to **10 PB (Petabytes)**.

As the focus of the group lies on quality control, material handling is not provided in full detail. Only the QC-relevant workflow items are mentioned here.

The migration process has been planned to start with selecting those tapes which are of most interest to the current programming schedules, as some content appears to be more relevant than others. During this selection process, a daily production list with cassette (barcode) numbers and their related technical metadata will be prepared. The final QC reports have to be checked against this



Figure 2
Part of ORF's Digi-Beta and IMX archive

list to be sure that the migration process was correct. Errors such as wrong aspect ratio or loss of audio channels could be detected by this procedure.

The next step concerns the cleaning of the tape. The cleaning machines report information about the quality of the tape, which could be valuable when attempting to migrate very old cassettes. Whether this type of information should be collected and handled by QC or not, is still a matter of debate. This kind of information, as well as the following reports, will have to be presented in a common form such as XML.

The main ingest process will be realized by several Sony E-VTR devices. Cassettes are ingested by robotics or also by hand. Implementations show that VTR robots have only a minor cost advantage over manual ingestion, so their implementation for the ORF archive process has not yet been decided. During this process step, some tape-related metadata information has to be gathered. Because of recording in more than real time, a monitoring of the video signal is not possible. The E-VTR-generated files contained in a (problematic) MXF header are stored in cache storage together with already-collected QC reports on the tape, in XML form.

The E-VTR-generated MXF container does not accord with the MXF standard and therefore has to be corrected using one or more already-developed solutions for that purpose. A wrapper check is applied to guarantee the correct syntax of the MXF container.

As there is no possibility of live video monitoring when ingesting faster than real time over E-VTR, a tailored software has to be applied which can analyse the generated video file for characteristic audio and video errors. The Joanneum Institute in Graz, Austria, for example, offers a monitoring system which, up to a certain point, is able to find most of these errors: the associated software delivers easy-to-configure XML reports as well as a human-readable display of the reported file segments with audio and video representation. Together with the now “standardized” MXF file, the XML report is sent to archive personnel to be sample-checked with the help of the generated QC file and compared against the daily production list.

A detailed refusal procedure for defective tapes or otherwise-failed ingests has yet to be determined. The cassette has to be ingested a second time, the material has to be restored by editing or the cassette has to be declared non-restorable and – as a consequence – has to be disposed of.

QC placing

QC is meant to report non-compliances of files to a given set of certain parameters. Common tools provide very detailed reports. Their interpretation is not easy to handle, because nearly every media coder has its own specialities (errors, problems and non-compliances against the common standard). Although there are error summaries and first attempts to abstract from the high number of error issues – such as red and green lamps (see Fig. 3) signalling a kind of go/no-go state – they very often show a red signal if the analyser has not been configured correctly: a general quality statement about the usability of a given file for archiving is not possible.

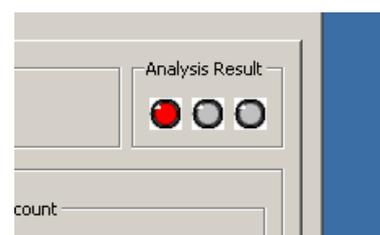


Figure 3
Error summary

Also, there arises the question about the actual location for QC. While this question is yet to be worked out, there are two basic approaches:

- The *first* proposal – for the archivist, the more pleasant one – considers the QC on the production side. All QC is done after the ingest process, there are no more “faulty” files in the workflow, and no problems arise when archiving or de-archiving files. However, this proposal demands a consequent and deep QC at every ingest process, which could lead to non-acceptable delays. Also for the production side, the QC is of minor importance. If files can be edited in edit suites and played out without errors over the (current) playout stations, there is no interest in an additional workflow item which only decreases working speeds.

- This leads to the *second* proposal, where deep QC rests mainly on the archive side. Again the delays play a role but they do not hinder the production process directly. On the other hand, QC would be performed unnecessarily because all of the files would be checked automatically, even though they would already have passed some lighter QC during production and ingest. Considering the huge amount of files which have to be archived, there are also costs in terms of the QC hardware and software involved.

Both proposals are not optimal per se. To find a feasible solution, a combination of both versions has to be developed. Besides, some technical issues such as “watch folder” technology or a decision for event-triggered QC have to be discussed.

QC variants and depths

Different places in the workflow will require different QC approaches. IMX migration touches several very different task areas for QC. Some important examples should be mentioned here:

- tape quality check;
- ingest process;
- check on analogue errors;
- loudness [4];
- metadata;
- wrapper (syntax) check;
- audio channels (Dolby-E, ...).

All items should be checked against some not-yet-defined common standard (also called “house standard”).

Additionally there are several file formats involved. Although the current ORF production format is XDCAM-HD 4:2:2 at 50 Mbit/s in the form of RDD9 (in two flavours), legacy formats also still play an important role (with declining importance over time). The lion’s share of archive files is represented by D10/IMX files which, since one year, are generated out of analogue material and put into a temporary storage. After solving some problems by updating older versions of our ingest system, our QC tools (and interpreting specialists) rated the generated file quality as acceptable for archiving (though still not perfect).

Other file formats delivered by older edit systems are less comfortable to deal with. Some of them even generate MXF files but they do not stick to the standard. To get these files into a correct form, severe converting effort has to be accomplished.

Another issue concerns “high-quality” codecs such as proprietary Apple ProRes or Avid DNxHD. As raw material they are archived in their original form, but for use in the common production environment they have to be converted into XDCAM-HD. The QC workflow concerning those codecs has not yet been established; the current emphasis lies on the standard production workflow.

Up to now, barely one of the available ingest systems generates a truly open-standard compliant file. No wonder that troubles are daily fare in a heterogeneous ingest / playout system. Hopefully the

Abbreviations

AAF	Advanced Authoring Format	MXF	Material eXchange Format
BWF	(EBU) Broadcast Wave Format	QC	Quality Control
HDTV, HD	High-Definition Television	SDTV, SD	Standard-Definition Television
IETF	Internet Engineering Task Force http://www.ietf.org/	VTR	Video Tape Recorder
IMX	(Sony) Interoperable Material eXchange	XML	eXtensible Markup Language, IETF RFC 2119

efforts within the EBU group to find a common reliable and automated QC can bring more transparency into these problem areas and finally lead to error-free playback, which also works reliably in the years to come.

Why stick with the D10/IMX format?

Sticking to a single standard codec and wrapper as a production format can only last a limited period of time. Thus, archiving material in its original codec (e.g. the D10/IMX format for recent SD material) is the only way to conserve its full quality and avoid generation losses due to repeated codec conversions. Although it seems inviting to convert the whole archive into the prevailing “working” codec (e.g. XDCAM-HD), a lossy re-coding procedure (D10 to XDCAM) as well as a reduction in video resolution must be taken into account. Converting from 4:3 to 16:9 for general use would mean converting into pillar box format. If resolution loss cannot be accepted for a special production, recourse to SD material and choosing the segment of interest at full resolution would be advisable.

Unwrapping

Another proposal for holding media files in the archive, without the hassle of retaining non-audio/video information, could be to extract the video and audio streams (MPEG and BWF [3] respectively) from the MXF wrapper using currently-available tools such as *MXF splitter* and storing the essences separately. Incompatibilities or even errors in the wrapper information could be avoided at the cost of a more complex handling of files, because of the need to recombine several audio channels with the video signal synchronously and to hold several files as one item in the library.

This method could be very efficient if a change of wrappers were to be decided in the future and all essence data could be wrapped into this successor wrapper. The AAF-derived [1] MXF-wrapper still seems to cope with current and foreseeable-future tasks but special requirements such as 3D or internet formats could arise which possibly could not be supported by MXF.

Checksum issues

The purpose of registering checksums for each file was discussed thoroughly. Certainly, there are some costs involved in the calculation time. As has been shown, the processing time for the two main candidates – MD5 and SHA-1 – lies well under real time and can thus be ignored.

At least three arguments for checksum generation can be proposed:

- to guarantee the originality of the material;
- to check that the cycling process did not insert new errors;
- to verify that no further long-lasting deep QC is necessary, once QC has been done and the checksum has been registered.

In several cases the originality of the material can be of importance. Modifications to the material after the archiving process can be detected easily and reliably. No audio comment can be modified or deleted, nor can parts of the video be removed or even new material inserted.

During the cycling process, checksums are a very useful tool to guarantee that the file which has to be transferred is equivalent to the original. On detection of a mismatch between the registered and the currently-calculated checksum, another source of the material has to be chosen which hopefully exists in the form of a backup copy.

Finally, calculation effort can be avoided if an already-executed deep QC has been done and registered into the archive database. Depending on the implementation of the general QC concept for

gathering a report or determining the applicability for a certain purpose, only a checksum has to be calculated and compared against the database entry. If the values match, the “old” QC report can be used.

Tape library concerns

Two main concerns of QC have to be standard compliance and correct metadata within the archived files because – especially when using tape libraries – **there exists no easy way to correct the whole archive in background processes!** The reason for it lies in the mechanical and logical limitation of tape robotics. They are designed for a “standard” archiving process; several files are written into the library concurrently, according to the dimensioning of the robots, and can be retrieved on demand providing only a limited number of files per hour.

There are two problem groups involved with modifying the whole archive. The first refers to the mechanical layout of the robot system (arms, bearing ...), which usually is not designed for such an intensive de-archiving process and the very limited number of tape read/write cycles. The second group refers to the fragmentation which occurs on the library tapes after deleting.

The intended tape library is unable to delete files to gain space effectively, such as on disks; files can only be marked as non-existent. New space on the tape or even a new tape will be chosen to write the corrected file back. Thus, a relatively high percentage of the files would have to be copied onto new tapes in a defragmentation process, which is expensive and additionally wears out the robotic system unnecessarily.

The next efficient chance, without an additional write attempt for a file repair, is opened during the cycling process. This infinite background process, with incidentally triggered copy activity, would lead to an unwanted mixture of corrected and non-corrected files over a period of decades.

The alternative – restoration during the de-archiving process – would delay the delivery process substantially. Following the repair process, an additional QC over the whole essence would have to be carried out. The repair process and the QC together lead to a delay of more than real time depending on the type of error (the file has to be read once, the corrections have to be made, the file has to be stored, read from the QC process again, tested and proofed).

Negative example

Fig. 4 represents a regularly-occurring frame of a video in a clip which was reported **as being perfect** in terms of video codec. Some combinations of small MXF errors lead to totally disrupted video frames when played out by a commonly-used video server. Detecting such errors occasionally after ingesting lots of material into your archive database leaves you in a disastrous situation. Only an **appropriate QC combined with a repair or denial strategy** can help to avoid this fate.



Figure 4
Problems during playback

Conclusions

QC in long-term archiving is very different from QC for everyday production: the archive can contain material from both known and unknown sources, with indeterminate quality. Even an upstream CMS cannot guarantee that the specified standard production format is in place. Production systems may very well leave ready-prepared files unprocessed and forward them to the archive system.

Furthermore, in addition to the transfer of correspondents' material via the internet or user-generated content – the opportunity to receive viewers' input in various formats – there is also the so-called “archive exchange”. In this way, material is received in various wrappers and codecs and often has to be tested and converted.

One is well advised to set clear-cut interface definitions between archive systems, the outside world and the production area,

and to see to it that these are also adhered to. One of the key cost-generating factors in the future will be the handling of files despite the clear setting of a “company standard” codec. It can be reported from experience that, in addition to the integration of high and low bandwidth codecs into the production system, already diverse “dialects” of the actual determined codec / wrapper combination cause predictable but also non-deterministic failures.

In order to maintain essences in the best quality possible over the long term, the content must be held in the original codec. Alternatively, it may be appropriate to archive uncompressed essences – something which, for financial reasons, can only be practical for a relatively small amount of high-quality material. The decision to exclusively provide the archive in the respective production format is short-sighted and leads to the essence quality continuously declining over time, due to small incompatibilities in the changeover from these old codecs to the current codec.

Fortunately, in the scope of the QC Group, the EBU is focussing on analysing the available devices and software for a suitable Quality Control and offers a platform for the comprehensive elaboration of necessary key parameters involving their use. On this basis, a framework is created which will guarantee that the original quality of the archive material is maintained in the long term, both in the case of forward and backward archiving.



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