



Scientific Working Group on Digital Evidence

SWGDE Best Practices for Forensic Audio

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SWGDE Best Practices for Forensic Audio

Introduction

The purpose of this document is to provide forensic audio practitioners recommendations for the handling and examination of forensic audio evidence in order to successfully introduce such evidence in a court of law.

Audio is an auditory perceptual phenomenon. Most courts use some version of the "fair and accurate representation" standard as a measure of acceptance. The same general principles apply regardless of the format or media in which the audio is recorded. This document will describe best practices for the receipt, documentation, handling and examination of audio evidence, regardless of the tools and devices used to perform the examination.

This document is not intended to be a training manual nor a specific operating procedure. Nor does this document intend to describe best practices for the collection of surveillance or other investigative material. This document will comment on only those matters that may affect the forensic examination process. This document is not all inclusive and does not contain information relative to specific commercial products. If dealing with technology outside your area of expertise, consult with an appropriate specialist. For recommendations on forensic audio training, refer to the document "SWGDE/SWGIT Guidelines and Recommendations for Training in Digital and Multimedia Evidence." For recommendations on developing standard operating procedures refer to the document "SWGDE/SWGIT Recommended Guidelines for Developing Standard Operating Procedures."



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1 Audio Laboratory Considerations

When building and configuring a forensic audio laboratory there are several factors that must be considered to ensure an optimal environment to produce the best results.

1.1 Environment

The physical environment, independent of equipment, in and around a forensic audio lab can have profound effects on the quality of work products.

1.1.1 Acoustics

The acoustic environment of a forensic audio lab is the collection of ambient sounds and influences (e.g. resonances, echo) which can affect the quality of a forensic audio analysis. Eliminate or minimize sound distractions in the audio laboratory to prevent confusion as to what sounds are present on a recording. Distractions may come from:

- Background conversation, TV, radio, and music.
- Computer and equipment cooling fans.
- Air conditioning units and airflow.
- Vibration.

Steps can be taken to mitigate external noise in the laboratory such as:

- Using acoustic foam or other materials to absorb reverberation and echo.
- Designing the laboratory with acoustic traps.
- Rerouting unnecessary HVAC ducts.
- Using acoustic baffling within the HVAC ducts that are present.
- Using heavy wooden doors that seal tightly all around when closed.

Audio studio or facility design is a complex task and comprehensive references should be consulted.

It is recommended headphones should be used during examinations to reduce extraneous sounds and maximize the audibility of the signal being examined.

1.1.2 Temperature & Humidity

Ensure the temperature and humidity of the laboratory is within the manufacturer's specifications of the equipment. Equipment itself generates heat and requires adequate ventilation to prevent heat buildup which could affect the signal.

1.1.3 Electromagnetic Interference

Interference from a variety of electromagnetic sources can affect signal quality.



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- Alternating current (AC) sources, such as power lines, motors, lamp dimmers, fluorescent lights, and uninterruptible power supplies can create magnetic pickup loops that can induce noise into improperly routed signal cables. Separate transformers and power lines from signal lines. If power and signal lines must cross, have them cross at 90° to one another.
- Improper grounding can create ground loops. Many factors contribute to this phenomenon. Properly ground equipment and racks to minimize ground loops. Grounding is a complex task and comprehensive references should be consulted.
- Items that generate magnetic fields strong enough to affect the integrity of any magnetic media nearby, such as loudspeakers, should be kept as far away as possible from evidentiary recordings or removed from the laboratory.
- Cell phones, pagers, radios and other RF transmitting devices may interfere with cables or equipment and should be turned off or removed from the laboratory.
- CRT video monitors.

1.2 System Configuration

The quality and arrangement of equipment, cables, connectors, and interfaces directly affects the audio signal.

1.2.1 Signal path

The signal path is the complete route of the audio data from the source through all of the connectors, interfaces and cables to the destination. Design signal paths with the least amount of degradation. Use cables and connectors of sufficient quality and minimal length to minimize signal loss and reduce the opportunity for interference. For analog audio runs, maximize the use of balanced lines over unbalanced lines. Avoid stacking adapters to interconnect equipment. It is preferable to use a cable designed for the particular interfaces involved. Be aware of the impedance and level of analog interfaces.

Documentation

- How equipment is interconnected during exam.
- Signal formats used.
- New or temporary equipment.
- Verification tests done on new equipment.

1.2.2 Signal format

Choose the signal format that transmits the audio data with the least amount of degradation, loss or attenuation. This decision depends upon what formats are available on the equipment being used. Minimize the number of digital to analog and analog to digital conversions.

1.2.3 Equipment

Choose equipment suitable for the task at hand, using professional and broadcast grade equipment where possible.



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1.2.3.1 Protecting Digital Media

For evidence received on writeable digital media, it is recommended to use a read-only media reader to prevent modification of media content. If no such reader is available, use write blocking hardware or software to prevent modification.

1.2.3.2 New or Temporary Equipment

Some submitted exhibits will require equipment that is not a regular part of the laboratory. This new or temporary equipment can include:

- Submitted devices.
- Equipment or codecs acquired to support the format of submitted media.
- Older or archived equipment.
- Newly acquired equipment.

Optimizing the playback of audio exhibits may require interfacing this equipment to the system. Refer to any available user manuals to ensure proper use of unfamiliar equipment. Take reasonable precautions when installing unknown or untested software onto the system, such as backup and virus scanning. Due to the instability within or incompatibility between third-party codecs or utilities, it is recommended that the use of these programs be limited to a stand-alone computer. Test any new or unfamiliar software or equipment on known data before use on examination materials.

1.2.4 Computer and Network Systems

Process evidence on a system isolated from people not authorized to access the evidence.

1.3 Calibration

Any equipment or tools requiring calibration, such as signal generators and spectrum analyzers, should be calibrated according to the manufacturer's specifications. Typically, this would be at least annually, after any significant maintenance or repair, or if it fails a control test.

1.4 Maintenance

Equipment with moving parts, subject to wear, or periodically updated by the manufacturer should undergo maintenance. Records should be kept to ensure that this task is performed regularly and according to the manufacturer's specifications. Maintenance can include but is not limited to:

- Cleaning and demagnetizing electromagnetic heads in tape decks.
- Cleaning and checking the capstans and rollers in tape decks.
- Updating anti-virus software and performing a virus check on computers.
- Updating computer operating systems as necessary.
- Defragmenting hard drives.



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- Azimuth alignment.

1.5 System Verification

Once the equipment and interconnections are configured, run test signals through the various components to verify that everything is operating as expected.



2 Comments on Audio Collection

As stated above, this document is not intended to detail the best practices for the collection of audio evidence. However, during the collection and submission process there are considerations to be mindful of as they directly impact the forensic examination and recovery process. It is always desirable to collect audio evidence using the highest-quality recording speed/mode, bit depth, and sampling rate subject to limitations of the case and available equipment. If the audio collection is uncontrolled, identify and collect the original source recording or as close to it as possible. Alert submitters to these issues even if it is too late to affect the case being submitted as it may improve the quality of future submissions.

Documentation

- Note any conversations with the submitter.
- Record your efforts to obtain the original evidence and peripheral items.
- Efforts to preserve volatile memory.

2.1 Volatile memory

Digital devices may use volatile memory. Volatile memory is lost if the power supply to the device is interrupted. Before the submitter ships an unfamiliar device, determine if constant power must be maintained to preserve the integrity of the evidence. Only if the device is capable of running off of battery power for a sufficient amount of time to transfer the item to the lab should this option be used. If this is not possible, the examination or data extraction may have to be performed in place or via remote access.

2.2 Importance of original recording

An original recording is the first manifestation of sound in a recoverable stored format be it a magnetic tape, digital device, voicemail file stored on a server, optical disk, or some other form. Duplication processes and format conversions can introduce artifacts or alter the signal characteristics of the audio content. These alterations can degrade the performance of enhancement algorithms and make authentication impossible. Consequently, insist that the original recording be submitted for analysis. If the original is not provided, document that fact and inform the submitter of the limitations imposed on the examination.

2.3 Peripheral items

Some audio devices require specialized or proprietary software and/or accessories (power adapters, cables or connectors, manuals, batteries, etc.) to properly interface with processing equipment. If it is determined that this is the case, instruct the submitter to seize or procure these items and submit them with the recording apparatus or media to be examined.

2.4 Write protect

Instruct the submitter to enable whatever appropriate mechanism that will preserve the recording (safety tabs, write protection, etc.) before transferring the item to the lab. Ideally, this should be done as soon as the recording is finished. If the submitter is not certain how to do this and the



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transfer process poses minimal risk to the evidence, have them submit the item to the lab and perform this operation upon receipt.

2.5 Working copies

If the submitter wishes to retain a working copy of a recording to be submitted to the lab and it poses no harm to the evidence, instruct the submitter to have a qualified technician make one or more working copies to keep for investigative review before transferring the original evidence to the lab. Instruct the submitter not to overlay original tape media as the accumulated effects can damage the tape over time.

The use of high speed duplication equipment is discouraged due to increased chance of tape breakage from physical stress and the risk of over-recording the original information due to the lack of safeties on this equipment.

2.6 Shipping

Instruct the submitter to ship evidentiary items using a trackable method and using the care and materials appropriate for the medium. For example, CDs and DVDs should be protected from scratches and breakage, and magnetic tape cassettes should be protected from breakage and strong magnetic fields.



3 Receipt of Evidence

3.1 *Receiving a request for service*

Follow your laboratory's records retention policy or quality assurance program regarding requests for forensic services, shipment receipts, and chain of custody. The request for forensic services should include at least the following:

- The type of examinations requested. Pay particular attention to whether the request includes examinations by other disciplines. Consult with examiners in the other disciplines to determine an appropriate sequence of examinations and precautions to take.
- Safety hazards, if present (sharp objects, poisons, bacteria, blood borne pathogens, etc.). Follow your laboratory's policies for handling such situations.
- Pertinent details about the recordings and/or designated areas of the recordings.
- The identity of the party requesting the services and the date of the request.
- A description of each evidence specimen with each item assigned a unique identifier.
- The shipping documentation of the evidence, including tracking numbers, dates shipped and received, identity of persons shipping, receiving and/or processing the received evidence before receipt by the forensic examiner.
- Chain of custody documentation to account for all individuals handling and/or processing the evidence from receipt until return shipment.

Documentation

- Note condition of the evidence.
- Photograph, photocopy or scan damage to items submitted.
- Evidence receipt and marking.
- Shipment records.
- Communications.
- Write protection actions.
- Safety hazards.
- Areas of interest.

3.2 *Physical inspection*

The exhibits submitted with the request should be inspected to ensure that the physical items match those described on the inventory. Take appropriate precautions based on any safety or special handling issues identified in the request for forensic service.

An inspection should consider the following:

3.2.1 Damage

Inspect the items for physical damage which may impact the proper function of the media or device. If damaged, document and photograph the condition in which the item was received.

Consider:

- The cassette housing.
- The tape reel.



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- Scratches and cracks on CDs and DVDs.
- The presence of contaminants or water damage.

Follow your laboratory's policies for handling such situations or execute standard operating procedures for repairs, etc.

3.2.2 Power source

If a submitted device needs constant power to preserve evidence stored in volatile memory, take all necessary steps to ensure there is no interruption in power.

3.2.3 Write Protection

If the submitted media has a mechanism designed to preserve the recording (safety-record tabs, jumper, software setting, etc.), document its state upon receipt. If not already engaged, activate the mechanism unless there is a clear reason not to. Refer to the user's manual, the appropriate published standard, or talk to the manufacturer about unfamiliar media.

3.3 Marking exhibits

Uniquely identify each examined item as per laboratory policy. Be aware of how and where the audio is stored on the media to avoid damaging it with your mark. If the media itself cannot be marked without interfering with the contents, mark its container.

For devices that do not contain internal removable media, document the make, model, and serial number of the specific device. Refer to laboratory policy regarding marking the device.

Some suggestions for common media are:

3.3.1 CDs and DVDs

- Write only on the disc label side, never on the readout surface. If possible, write only within the inner hub of the disc, an area where no data is written.
- Use a felt-tipped marker, never a ball point pen or other sharp-pointed writing instrument, to mark optical media. The top layer of the disc could be scratched or otherwise damaged which could cause data loss.
- Do not apply adhesive paper labels to CD and DVD media. They can cause delamination and create the risk of spin imbalance.

3.3.2 Magnetic tape

- Mark the cassette housing.
- If marking the tape is required by laboratory policy, mark magnetic tape on the backing (non-oxide) side using a felt-tip pen.

Documentation

- Note the description of each exhibit.
- How non-physical exhibits were handled.



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3.3.3 Non-physical recordings

As digital technology advances, it is possible that multimedia content can exist without ever residing on easily identifiable or removable physical media, such as voicemail, e-mail attachments, and on-demand technology.

When working with these recordings, one needs to maintain integrity of the data and also demonstrate that the steps taken were effective, such as transferring the data to physical media and marking as above or using a hashing algorithm. Refer to your laboratory's procedures or the SWGDE document "Data Integrity Within Computer Forensics" for more information.

3.4 Check for originality

At the time of receipt, note whether items are originals or copies as described on the request of forensic service. Initially and as the examination process progresses, continue to inspect each item for obvious indications of originality. This could include:

Documentation

- Note whether each exhibit is an original or not.

- How the media is labeled.
- Whether the tape has been reused.
- Consistency between the provided media or file format with the purported means of production.
- Metadata. See the document "SWGDE/SWGIT Digital and Multimedia Evidence Glossary".
- Indications of conversion processes.

If a copy is received, request the original from the submitter. Consider that the "best evidence" rule is dependent upon the availability of the original and that an imperfect duplicate, analog or digital, can have deleterious effects on enhancement or other examinations. An analog duplicate is usually inferior to the original by having added noise, higher distortion and altered frequency response. Digital copies may not be identical to the original if the format was not preserved.

3.5 Evidence Storage

Preserving evidence during examinations and while in storage requires taking the necessary steps to safeguard the evidence from alteration (physical, electronic, magnetic, etc.), deletion, or damage. Ensure that devices requiring constant power have it and be aware of sources of magnetic fields, such as loudspeakers, that can affect magnetic media located in the laboratory and in any storage areas.

The temperature and humidity normally maintained in an office environment are suitable for most audio media. Ensure that any audio evidence storage locations have the same controls. Refer to the documents "SWGDE Recommended Guidelines for Developing a Quality Management System," "SWGDE Data Archiving," and "SWGIT Best Practices for Archiving Digital and Multimedia Evidence in the Criminal Justice System" for further recommendations.



4 Preliminary Evidence Exam

This section describes best practices common to all examinations that should be followed in preparation for a more specific procedure. The native media, format, and intended use of the audio data will determine the available options for playback or transfer. Also, consider the desired output format when making these determinations.

4.1 Preparing for analog audio exam

The following factors need to be considered to optimize the playback of analog media:

- Format.
- Track configuration.
- Azimuth.
- Speed.
- Signal levels.

Determine the proper equipment for playback based on the above factors. Using the frequency response and channel separation of the audio signal, adjust the playback device to optimize the output signal quality. To limit the introduction of noise or transport problems, use professional quality devices if possible.

4.2 Preparing for digital audio exam

Audio can be stored in a wide variety of digital formats on a variety of physical media. Determine the details of the source exhibit.

For digital files, appropriate computer software applications may be needed to ensure proper playback. If the digital audio data is in a format that can be transferred to the system without conversion, that is the preferred method.

A virus scan of evidence should be done on a stand-alone system with updated virus definitions. This is to prevent possible contamination of evidence files on the forensic workstation. If possible, digital exhibits should be virus scanned before any files are opened.

4.2.1 Conversion

Transferring the digital audio data may require a conversion. Conversions may affect the audio content (aliasing, compression, etc.). Minimize the degradation of the audio by limiting unnecessary conversions. The following factors need to be considered when performing a conversion:

- Format (file or signal).

Documentation

- Equipment used.
- Azimuth adjustments made.
- Playback speed.
- Number of recorded channels.
- Existence of audio on each side.
- Bit depth.
- Sampling rate.
- File Format.
- Proprietary codec.
- Format conversions.



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- Sampling rate. Use anti-aliasing to avoid adding audible artifacts that are not part of the original signal.
- Quantization.
- Compression scheme. Convert only to an uncompressed format (e.g., PCM), whenever possible.
- Proprietary decoding software.

4.3 Controls

A control is a known audio test signal that is run through a system to ensure that the system produces the expected result. This gives an examiner confidence that the system will perform as expected when processing evidence. In forensic audio, the system is the complete signal path including playback, processing, and recording equipment, cables, and connectors. A control test should be run on the complete signal path before processing evidence.

Documentation

- When controls were run.
- Results of control.

The interval at which controls are run should be appropriate for the specific equipment used. Specifically, controls should be run:

- Whenever a system configuration change occurs.
- Regularly for equipment that experience wear.
- When infrequently used equipment is put into service.

If a control test fails, evidence should not be run through the system until it behaves properly. When failure occurs:

- Notify other examiners of the failure.
- Troubleshoot the system to isolate the failed component. Recognize that the failure could be in a piece of equipment, a cable, a connector, or in an interconnection itself.
- Take the failed component out of service until it can be replaced, repaired or recalibrated, or it otherwise demonstrates reliable performance.



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5 Forensic Examination

This section describes general guidelines for the following common forensic audio examinations:

- Duplication.
- Repair & Recovery.
- Enhancement.

A forensic audio examiner should be specifically trained in the procedures performed. Refer to the “SWGDE/SWGIT Guidelines & Recommendations for Training in Digital & Multimedia Evidence” for recommendations on forensic audio training. Do not attempt an examination on evidence without training, experience, and meeting laboratory qualifications.

Procedures that are outside the scope of this document are:

- Authentication. An audio authentication examination seeks to determine if a recording is original, unaltered or continuous, and/or consistent with the manner in which it is alleged to have been produced. Consequently, there is no catch-all means of declaring a recording “authentic” without having a clear understanding of what claims the creator holds true about its nature and what specific allegations are being levied against the recording. SWGDE recognizes that audio authentication is a complex examination that requires specific training. Best practices for this type of examination are reserved for a future document.
- Other specific signal analyses. Signal analysis uses engineering principles to identify audio characteristics of the recording. The analysis of the contents of a recording requires independent knowledge, training and experience in the phenomena under study. Best practices for these types of examinations are reserved for future documents.
- Audio transcription.
- Speaker Comparison and Identification – a subject matter expert should be consulted as speaker comparison and identification go beyond the technical aspects of audio and are considered outside the scope of SWGDE.
- Video - audio and video are frequently recorded together. Forensic audio examiners not qualified to process video should consult a video analyst or the Scientific Working Group on Imaging Technology before proceeding to ensure best practices are followed when handling the video portion of the recording.

5.1 Duplication

The goal of duplication is to produce copies as close to or equal to the quality of the source. This objective applies to both copying to the same media type and format as well as format conversion. Refer to Section 4.2 for guidance on format conversion. When performing a format conversion, ensure no part of the process is degrading the quality of the

Documentation

- Original format.
- Final format.
- Number of copies.



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source content.

When making multiple copies simultaneously from a single source, verify the all copies are equal quality.

Using devices such as high-speed cassette duplicators that stress the original tape and produce copies with increased noise and lower bandwidth is highly discouraged.

All copies should be produced on new, high quality blank media.

5.2 *Media Repair/Recovery*

Repair of damaged media is a complex and critical task. A policy or program of instruction should outline the step by step cleaning, drying, and, if necessary, ironing processes for different situations. Any damaged evidence should always be photographed or photocopied.

5.2.1 **Media housings**

Inspect the housing for cracks, dirt, and debris that may interfere with playback. If the media housing is cracked or broken in such a manner that it may affect playback, the media should be transferred to a new housing. If there are any cracks, inspect to determine if any pieces or dirt may have contaminated the media.

Determine if any parts of the housing are not in their proper position (e.g., a cassette felt pad) and repair or replace as necessary.

Ensure that the new housing has its write protection enabled and that both housings are properly marked. Return the old housing with the repaired media.

5.2.2 **Contaminants**

Media should be cleaned of contaminants such as cola, mud, dirt, and other contaminants. Use lint-free materials and distilled water or another solvent if appropriate for the materials in the media.

5.2.3 **Magnetic tape and reels**

Look for evidence of the following and take appropriate actions:

- Sticky shed.
- Binding.
- Pack slip.
- Torn or wrinkled tape.
- Damage to tape reel.

Documentation

- Photos of damage.
- Problems identified.
- Procedure performed.
- Final status of all original pieces of the exhibit.



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5.2.4 CD/DVD Scratches

First try reading the disk with a different drive. If that fails, use of a commercially available disk polisher may allow the data to be recovered. Caution should be used as polishing could further damage the disk.

5.2.5 Unfinalized CD, DVD or unfinished tracks

Unfinalized tracks and sessions can be recovered using software dedicated to this purpose. Although it may be possible to recover some data by finalizing in the lab, some data may not be recovered by this process. If unsure about the process, consult a computer forensics examiner to recover data from the disc.

5.2.6 MiniDisc

Slug discs and maintenance mode may be exploited to recover unfinalized tracks and minidisks. If unsure about this process, consult the equipment manual of the player.

5.3 Enhancement

The goal of audio enhancement is to increase the intelligibility of voice information or to improve the signal to noise ratio of a target signal by reducing the effects that mask it. Audio enhancement begins with critical listening to assess what signal characteristics are limiting intelligibility. Once those characteristics are identified, a strategy should be developed to rectify them, if possible. This strategy should include:

- Analysis tools to identify the limiting characteristics.
- Selection of filters that address the limiting characteristics.
- An appropriate signal path.
- The sequence of filters to be applied.
- Selection of playback and processing equipment or applications.
- Identifying whether regions require different filtering approaches and minimizing any boundary effects of regional processing.

Documentation

- Problems identified.
- Equipment and filters used.
- Sequence of filters or steps.
- Number of copies produced.
- Regions processed independently.

For speech enhancement, improved intelligibility means more words can be understood. To determine if intelligibility has been increased, compare the original recording against the processed recording, repeating as frequently as necessary. This continued comparison will help avoid over-processing. For lengthy listening sessions, take breaks to avoid listener fatigue.

The limitations of the source recording may prevent meaningful improvement. Exceptional situations may require unique solutions. Validate these solutions on known data if possible.



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6 Results of Examination

Once the forensic audio examination is complete, the results of the exam should be returned to the submitter per your laboratory policy.

6.1 Output Media

The format of output media should be chosen to preserve signal quality and meet the needs of the submitter. Normalize signal levels to a nominal value and consider format, track configuration, and speed. A submitter may not be aware of the effects that different formats have on the audio. Use or include an uncompressed format when applicable. If a compressed format is requested or required, it should be noted in the documentation and the consequences of that choice should be explained.

Enable whatever write protection mechanism is available for the output format selected. Use write-once digital media and finalize or close to prevent alteration. Output media should be marked for identification. Return the results in proper packaging to prevent damage to evidence specimens and to the output media being shipped. Refer to section 2.6 for more information.

Recommend the use of good quality equipment and headphones to review the results.

6.2 Documentation

Documentation should be returned to the submitter that confirms his request was completed and explains what is being returned to him. Often this takes the form of a formal report for analysis but may not for duplications or other processes.

Notes should be kept throughout the examination process to document how exhibits were handled and what processes were performed. The notes should be detailed enough to allow a comparably trained examiner to explain the results or derive similar conclusions. Refer to the sidebars in this document for suggested elements to be included in the notes.

Documentation

- Date of return.
- Shipment method.
- Media returned.
- Copy of final chain of custody.



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7 Administrative and Technical Review

A written policy should be established outlining protocols for technical and administrative review. A written policy should determine the course of action if an examiner and reviewer fail to reach agreement.

Documentation

- Date and initials of Admin Review.
- Date and initials of Tech Review.



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History – Best Practices for Forensic Audio

Rev	Issue Date	Article Section	History
1.0	01/31/2008	Final	Drafted by SWGDE Audio Committee