

**A**lthough best known in the audio and music-to-picture industries, Cambridge-based CEDAR Audio has less well known links with the forensic science field. A small number of CEDAR systems and rackmount modules have been supplied to forensic laboratories in the UK, the US, Germany, Australia and New Zealand, including the National Audio Video Forensic Laboratory in the USA, the Australian Federal Police and the German Air Accident Investigation Bureau.

Ironic as it might seem, CEDAR Audio clearly has much to shout about — efficient noise removal being the pivot upon which the ongoing consummation of CEDAR's mission statement rests! But the use of CEDAR products by those latterly listed forensic agencies is no laughing matter. Managing Director, Gordon Reid: "The majority of

So far so good, but CEDAR opted to prematurely suspend their activities in this potentially lucrative market. Reid explained: "We decided not to proceed with that area of work at that time because we received one set of tapes that were extremely distressing to the audio engineer who was working on them. In addition, the client lost the case, so we didn't get paid for the job. We realised that we didn't really know the industry and we weren't comfortable with it."

Heading a viable business concern, however, 'Reid & Co.' could hardly let a supposedly dead dog lie — especially a profitable one. CEDAR was about to make some serious forensic connections. Reid continues: "Once we'd launched our systems, we realised that there was a market for people active in audio forensic restoration.



## CEDAR'S SECRET ADMIRERS

*CEDAR has many devotees worldwide within the mainstream record, mastering, film, broadcast and archiving communities. Not so well-known are its many admirers in the clandestine world of forensic audio. JONATHAN MILLER goes under cover...*

what we do, or are involved in at CEDAR is luxury — a cleaner-sounding CD or a movie without crackle — no lives are saved by the use of CEDAR or any other audio tool in that way. However, in the audio forensic field that may not be the case."

### *Close Encounters Of The Forensic Kind*

Admirable as Reid's sentiments may seem, the world of forensic audio was outside the original design brief of what became the CEDAR System. Reid continues: "It wasn't anticipated. Because my background is in the mainstream music industry, the kind of people I assembled around me were those whose backgrounds I understood: primarily music industry. We taught ourselves the audio-for-video, TV, and movie soundtrack side of the industry, but there was nobody here who had encountered audio forensic work."

Outsiders soon saw CEDAR's hitherto untapped forensic potential. "Although it didn't come as a surprise to us," claims Reid, "it was a new field. Initially we were approached by customers who were interested in cleaning up tapes for court cases. We had some people come to us with tapes that had a certain amount of background noise — relatively straightforward to remove — sometimes the voices on the tapes were completely inaudible and it was claimed that somebody was saying something. The customers wondered if we could see if there was actually a voice there and, if so, what was being said."

We quickly discovered that a CEDAR system, combined with the type of adaptive filters that are common in the audio forensic industry, provided an extremely powerful means for increasing intelligibility for transcription purposes. We also discovered that, if you take a tape with lots of background noise into a courtroom and play it to the jury, claiming 'The accused said this...', then the defence can obviously dispute that that was exactly what was said. But, if you play the same tape, at the same level of intelligibility, with all the noise removed, the prosecution has a much stronger case. So a lot of the work at that time was to clean up tapes for court, which proved to be of great assistance."

This was largely achieved in-house, CEDAR Audio having opened the Cambridge Sound Restoration Studio — purported to be the world's first commercial facility of its kind — in February 1989. In its current incarnation as CEDAR's Bureau Restoration Service, processes available to forensic audio clients are: broadband noise reduction (a spectral fingerprint-based noise reduction system permitting the user to identify the noise content within a signal and specify the amount of reduction at any given frequency); click removal (capable of removing a wide variety of impulsive noises with detection algorithms intelligent enough to discern the differences between genuine clicks and transient sounds such as a slamming door, the clicks themselves being replaced with a synthesised signal matching the surrounding audio);



- crackle removal (which removes a variety of audio degradations, whether irregularly spaced in time as crackles, regularly spaced buzzes, or distortion); azimuth correction (which can automatically identify and correct displacements of up to 20 microseconds); accurate time alignment of a stereo signal can, in some cases, lead to a 3dB improvement in signal-to-noise ratio when the signals are summed to mono); equalisation (CEDAR's I.I.R. Equaliser simultaneously supports up to ten stereo parametric equalisers in the form of high-shelf, low-shelf or parametric Q filters); and buzz removal (the buzz family of degradations including hums, drones and camera noise, all characterised by having a large number of strong, closely-spaced harmonics).

### **Murder Most Horrid**

Once news of CEDAR's 'miracle machine' spread — a fortuitous early appearance on BBC1's *Tomorrow's World* constituted many people's introduction to CEDAR, and the BBC coincidentally later used CEDAR, both in a *Panorama* documentary of the O.J. Simpson court case (CEDAR's noise reduction process being used to clean up an important 911 telephone recording of Simpson's ex-wife) and in a series of one-hour programmes investigating the infamous 'Watergate' scandal (with HISS2 likewise improving the intelligibility of historic phone recordings) — the sale of CEDAR systems to professional audio forensic customers was inevitable.

In December 1994, the Australian Federal Police were first off the mark, closely followed by their New Zealand counterparts. Graeme Kinraid, Senior Technical Investigator in the latter's Electronic Crime Laboratory:

"We first became aware of computer-based audio restoration equipment through the Audio Engineering Society in 1992: it's difficult and time-consuming to reduce some types of interference using traditional equipment," he says. "The invention of audio restoration systems has been a significant advance in technology for forensic audio experts."

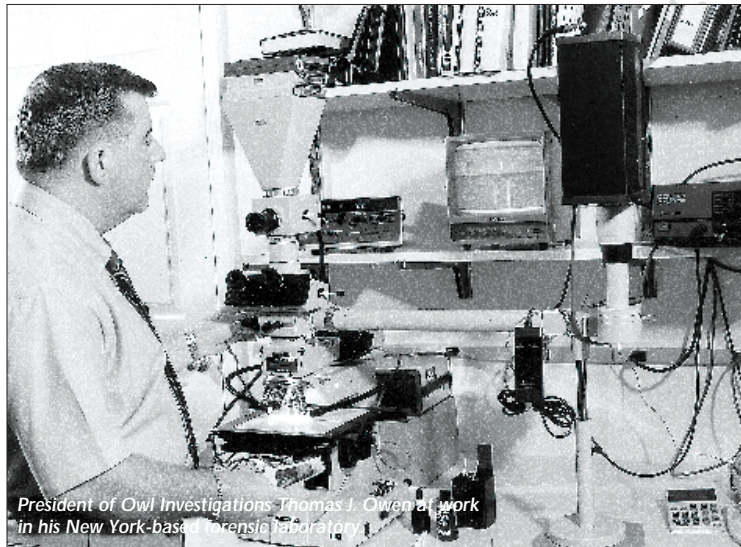
Kinraid is supportive of Reid, who concedes that the wildly varying combinations and configurations of specialist equipment found in places like the New Zealand Police Electronic Crime Laboratory are "all aimed at the same purpose — to increase intelligibility, where possible, which is largely done with equipment other than CEDAR, then improve the listenability using CEDAR. It's the combination of the two different pieces of equipment — whatever the other one is — that actually provides the best result, forensically."

Kinraid's often morbid line of work is far from luxurious: "We deal with a wide variety of recordings, many of which are of such poor quality that only the very slightest improvement

is possible," he proffers, "yet sometimes it's that difference which uncovers the vital piece of evidence. A good example of this happened soon after purchasing our CEDAR system: a recording we had processed earlier was further processed to gain that little bit extra. This assisted in building a case, ultimately leading to the successful prosecution of the offenders on major drug dealing and murder conspiracy charges."

### **And The Winner Is...**

At the 104th AES Convention in 1998 CEDAR Audio announced the inauguration of The CEDAR Awards with a dedicated category for Audio Restoration For Forensic Use. "The awards was our way of bringing a little bit of recognition back to our customers. The first forensic award was awarded to Tom Owen, of Owl Investigations in New York, because of a single case that he was involved with in which a company had been disenfranchising a large number of its workers. He used the CEDAR system to help demonstrate



President of Owl Investigations Thomas J. Owen works in his New York-based forensic laboratory

that the company had been acting both illegally and immorally, and there was a large settlement to a large number of people as a result."

Certainly Owl Investigations, Inc. President Thomas J. Owen's experience in the field is formidable: a nationally known expert, he served for many years on the Board of The International Association for Voice Identification. Currently serving as Chairman of both the Audio Engineering Society's Standards Group on Forensic Audio and the American Board of Recorded Evidence, and as Head Instructor for the New York Institute of Forensic Audio, Owen has appeared on US network television and on radio, has lectured in the US, Japan, China, Canada and the UK, and has authored over 25 articles in the *Audio Engineering Society Journal* and other publications concerning forensic audio and the restoration of sound.

With forensic consulting services including, but not limited to, audio and videotape authentications, tape enhancement and voice identification, Owen claims that Owl Investigations, Inc. offers one of the most sophisticated digital audio and video processing

laboratories presently available. Moreover, CEDAR plays an important role: "I have found that CEDAR is unsurpassed in hiss reduction."

### **Legal Eagle**

The previously mentioned award-winning case would appear to support this bold assertion. Owen: "Texaco, Inc. was involved in civil litigation with all of its black employees after a personnel meeting was tape-recorded by one of the participants. A class civil action was later filed, entering the tape as evidence. The tape found its way to me and I was able to eliminate the hiss using the HISS2 module of the CEDAR system. I was also able to make a satisfactory transcript that became the centre of the employees' case."

The USA represents CEDAR's largest market for forensic applications. Owen's system has undoubtedly paid its dues: "I purchased the CEDAR system in 1995, and since then I've processed several thousand tapes forensically using CEDAR HISS 1 and 2. I also utilise the CEDAR system to reduce obtrusive noise and hum using the I.I.R. filter, which is a separate module for the system."

### **Perles Of Wisdom**

Equally qualified to enthuse about CEDAR's adept audio forensic capabilities is Norman I. Perle, founder of the National Audio Video Forensic Laboratory in Northridge, California. He views CEDAR as "a very unusual and effective product!" An American Board of Recorded Evidence Nationally Certified Expert, with more than 20 years in the business, Perle played an integral role in the high-profile Rodney King Arrest Trial in Simi Valley, California, his being the only private facility to which the court had ordered the original 8mm

video recording be released. (King became a symbol of American racism and police brutality when George Holliday made an amateur videotape of four Los Angeles police officers beating King on the night of March 3, 1991.) Here Perle extracted audio from the video, filtering out helicopter noise to obtain intelligible words and sounds of the arrest, including what the arresting Police officers on trial had said.

Perle too claims that his laboratory has the most recent and most advanced computerised analysis and processing instruments for audio and video available, including a CEDAR system: "It was 1996 when I was first exposed to the system, at [Thomas J. Owen]'s laboratory. I heard about CEDAR a year earlier, but I thought I already had enough of an investment in sophisticated filtering and enhancement computerised devices. Intelligibility processing is the 'bread and butter' process here — seven days a week. A specific problem we all battle with is when there is one loud speaker — usually the informant — and the defendant sounds like he or she's across the street. Balancing them by amplification always produces an interference



hiss from the tape floor. When I was at Tom's Lab in New York being shown some of CEDAR's finer points, I announced that I wanted a real-time test! So we took a micro cassette tape recorder — the worst format for sound — and placed it on a table between us with a noise source nearby; an electronic hiss, similar to 'traffic', 'wind' or white static. We had a low-amplitude conversation, simulating a covert conversation with specific numbers, etc. The playback was as bad as expected; one couldn't hear most of the conversation, and experience told us that it was likely to be a very hard process to extract the information."

Enter Owen's CEDAR-20 DOS System into the fray and Perle was hooked, instantly: "He played the output through the CEDAR, hit a few buttons, and it came through like the noise source was next door! I rushed to put in my order. As a matter of fact, it's likely I'm going to upgrade to HISS3 shortly."

### Come Fly With Me

Preservation of life is of utmost priority within aviation circles — a concern affecting many people, as highlighted by the acclaimed Channel 4 documentary series *Black Box*, first broadcast in 1996. Here the implications of successful forensic audio restoration are frighteningly obvious. An aircraft's cockpit voice-recorder (CVR) captures conversation in the cockpit, as well as ambient sounds such as engine noise, and can be fundamental in rooting out the cause of unfortunate incidents or accidents. Although newer aircraft have so-called 'hot mics' — a permanently active boom microphone system worn by the pilots to minimise the risk of something critical being missed; for example when a pilot turns his head — the dynamic range and quality of recordings from those with a single microphone system, often placed behind pilots, is generally poor. It is in this capacity that Axel Thiel, Head of the German Air Accident Investigation Bureau's Flight Recorder Section, also uses a CEDAR-20 DOS System: "In many cases the signal derived from the mic which is installed in the cockpit is corrupted by noise and very often by the 400Hz spectrum of the 115V power supplies," he explains, "so we are using the CEDAR system to clean up those signals; one task being noise reduction; the other, removal of the offending 400Hz spectrum."

For Thiel, CEDAR's immediacy leaves many rival technologies wanting: "Due to the fact that the CEDAR system is operating nearly in real-time, you can immediately listen to the filtered version which saves a lot of time when compared to off-line versions of noise reduction and filter software like Sound Forge or Cool Edit Pro — reasonably powerful for their low price, but time-consuming to work with." And, where there is a risk to life and limb, time is of the essence.

Thiel was first made aware of CEDAR's existence through a magazine advertisement: whilst looking for an inexpensive computer-based noise reduction system: "I contacted CEDAR in the UK and they pointed me towards a German company called Mediacom who deal with CEDAR products. So we arranged a test in our lab with original CVR signals and were very impressed with the system." Thiel's employers invested in CEDAR soon after.

### 'Black' Box

Like Norman I. Perle's National Audio Video Forensic Laboratory, The German Air Accident Investigation Bureau are also planning to upgrade to the CEDAR for Windows system, an obvious move, at least as far as CEDAR's (arguably biased) in-house Audio Engineer, Tony Webster, is concerned: "With forensic recordings we tend to find that the actual sound you want is hidden below the noise floor, or partially obscured by noise. Now, especially with NR3, we can actually extract a lot of information that is below the

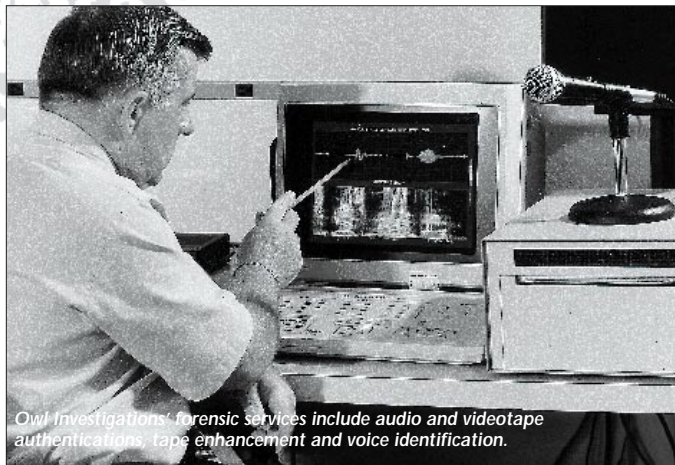
[Webster] was working on this we couldn't really hear what we'd achieved by simply removing a bit of noise from an already noisy recording of a rotor blade, but the Dutch were well pleased with the result."

For his part, Webster is enraptured by the discipline: "Often it's breaking new ground for us and testing CEDAR to its limits, or using it in a very unconventional manner," he enthuses. "Forensic audio restoration is always interesting; you're unravelling everything until you hear what's being said."

### Back To The Future

Where are we headed with audio technology's constantly changing environment? In the field of audio restoration, at least, Reid's master plan remains clear-cut: "It's very important to avoid complacency, in our dealings with existing customers and markets, and also with the products we currently offer. Research that we were doing ten years ago is now in the public domain and there are a lot of bright sparks with their Pentium computers developing \$500 plug-ins to do what we were doing then. So we have continuous programmes of research underway, both internally, within Cambridge University, and with some other companies we work closely with. The benefits of that for our existing customers are also on-going."

Reid's closing thoughts are disarmingly refreshing: "We're always looking for new opportunities where audio restoration can be of use. Forensics is the ideal example of this: we developed something that was initially considered as an aid in transcribing old 78s and cylinders in the National Sound Archive; which found broad use in the audio, film and video industries, and then more specialised use in the audio forensic industry. But I think there are still great improvements to be made in terms of how quick and simple the equipment is to use, and how good the results are in the difficult cases — where compromises have to be made, and user expertise and taste come into play. The Holy Grail of a box that takes all those decisions out of your hands and does the job automatically and perfectly is still fairly far away." □



Owl Investigations' forensic services include audio and videotape authentications, tape enhancement and voice identification.

noise floor; that's what makes it such a useful forensic tool, whereas other noise reduction systems effectively say, 'Everything below this level is noise; get rid of it.'"

Perhaps nowhere is Gordon Reid's appraisal of the forensic community being tightly knit more evident than in air crash detection, where effective dissemination of information is of paramount importance. The Netherlands Aviation Safety Board soon followed their trailblazing German consorts, recently visiting CEDAR's Bureau Restoration Service to restore a 'black box' recording from a non-fatal helicopter crash in the North Sea. CEDAR Audio's Sales & Marketing Director Clive Osborn picks up the story: "This helicopter had two mics picking up the pilot and co-pilot, the recording of which we cleaned up to help understand what had been said. But it was the third microphone in the ceiling of the cockpit, used for picking up any general noise, that the investigation team were most keen on having cleaned up, because they wanted to listen to the sound of the rotor to see whether its pitch changed prior to the crash so they could tell whether the accident was down to mechanical failure or pilot error. When Tony

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