Information Appliances—New Toys and New Business Models

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The disciplines of computing, communications, and consumer electronics converge in information or Internet appliances. Today, wristwatches have built in cameras, still cameras record audio, and cellular phones play MP3 files. Consumers use free hardware, buy data subscriptions, and hire digital plumbing consultants. Audio and information technologies have collided, creating both opportunities and challenges for technologists and businesses.

IS THE SKY FALLING?

One day, Chicken Licken was playing under the Internet tree when, suddenly, a portable MP3 player fell on his head. Mr. Licken cursed the lump on his head, and prophesied the end of the audio industry.

Others among us might choose a more optimistic conclusion from the Internet audio downpour. As acorns logically fall from oak trees, audio information appliances (IAs) may logically result from the Internetworking of digital audio.

Is the merging of audio and the Internet a revolution? Or is it better classified as evolution? We will be happiest if it is after all a revolution, as we want to tell our grandchildren heroic stories of our part in creating it. ("Then, in the winter of 2001, your battle-scarred Grandpa bravely crossed the perilous, icy cold Bit Stream, with only a packet of severely-compressed melodies for sustenance…")

But a quick look back at other "evolutionary revolutions" might help us prepare for success, without requiring a complete rewrite of our embellished memoirs. After all, how many times must we be hit in the head with acorns before we start anticipating them?

Once we understand the past as it relates to the current context, we can look at the technologies, products, and business models thrust upon the early adopters, and set our sights on the future.

Convergence is the blending of computers, communications, and consumer electronics. When designing information appliances, the communications engineer may occasionally miss what any audio engineer would find glaringly obvious. The experienced audio engineer may misinterpret a computer interfacing protocol.

Although the Renaissance is long past, there is a great need for Renaissance-style attempts at pulling together the knowledge of these diverse specialists to direct the development of future audio products, and products with audio features.

WHAT IS CHANGING, REALLY?

"Suppose time is a circle, bending back on itself. The world repeats itself, precisely, endlessly."

- Alan Lightman, *Einstein's Dreams*

While inventions such as radio broadcasting and audio recording were arguably revolutionary, others can be looked at as history improving itself. More than simple analogies, the following connections can teach us a lot.

Broadcast

As AM radio gave way to FM, so now we have two competing digital satellite radio systems. In addition, we have streaming Internet radio. Where AM and FM radio have occasional tuning problems (drift), Internet radio has occasional dropouts caused by undernourished buffers. The audio quality of the broadcasts is similar, as are the business models. Indeed, most Internet radio stations today are merely streaming Internet versions of the regular broadcast. To the consumer with a DSL connection, the Internet radio is as familiar as the radio they grew up with.

Prerecorded Music

Compact discs overtook vinyl LPs, and have now been around long enough for us to see the long-term reliability problems of the format. CDs are more fragile than perhaps we were led to believe, leading to a growing industry of products to counteract scratches and other error-inducing problems. Currently, DVD-Audio disc players are coming to market, meeting Super Audio CD (SACD) players. The Internet has been connected to CD players, as a way to bring up liner notes and graphics for any prerecorded CD.

MP3 files (and other formats) allow us to sample full-length recordings. While nobody argues that MP3

audio sounds better than CDs, both formats are booming. To the consumer, the portable MP3 player is as familiar as the portable cassette player before it.

Home Recordings

The audio quality of home recordings has always lagged that of prerecorded music. When they first appeared, cassette tapes did not sound as good as record albums, and MiniDiscs did not sound as good as CDs. Today's MP3 files suffer as well. History shows that with personal recordings, convenience and portability rate higher than audio quality.

The big difference is that, back then, it was a lot of work and expense to make 20 cassette copies of your new record album for your friends. But now a trivial effort and near-zero expense allows you to share the same via emailed MP3 files. The Internet brought us MP3s, and Napster taught us to share. To the computer literate consumer, the CD "ripper" is as familiar as the cassette deck.

Live Interactive Music

Most kids grow up with a garage band in their neighborhood. Any kid who believed they could play an instrument brought it to the garage to jam. In college, this was replaced with Open Mic nights at the local pub. Today, the neighborhood has expanded to the entire world through the work of Rocket Network and others [1]. To the musician, the peer-to-peer jam session is rather odd, but in some ways as familiar as jamming in the garage with eyes closed.

DEFINITIONS

Like many words in the English language, marketing and public relations campaigns have successfully taken well-defined words and turned them overnight into formless, ambiguous terms.

Convergence

We know it has something to do with computers becoming consumer electronics. But it also applies to the future of personal transportation, when automobiles are given out to service subscribers, like cable TV set top boxes and mobile phones.

For the purpose of this discussion, convergence is what we are all living through. The computer engineer is here to learn about audio. She is sitting next to the audio engineer sent here to learn about computing devices. Between them sits a wireless communications expert. One plans to stay competitive by adding audio playback features to a cellular phone. One is adding cellular phone functionality to a portable music player. All are trying desperately to copy each other's notes.

Convergence refers more to what is happening among professional disciplines than it does to what is happening to product feature sets. To be sure, we have seen similar situations before. The first audio-for-television broadcast systems, not unlike most video systems designed since then, were designed by video experts. Television audio, somewhat of a necessary evil, remained monophonic for many years. Even long after stereo broadcasts were common, most people listened to their television program using small, inferior monophonic speakers inside their set.

Over time, this system evolved into what is today one of the fastest growing audio product segments: the all-in-one home theater system. Simply pull it out of the box, connect to your DVD player or television, and audio-for-television has come of age. (These audio systems are addressing a primal need for simplified home entertainment systems, perhaps the biggest barrier to overall quality of digital media in the home. This is not likely to be overcome until IEEE-1394 connectivity is commonplace at home.)

Audio-for-IA systems need to address the same two barriers: connectivity, and ease of use/set up.

Broadband

Like *convergence*, the term *broadband* also has no singular definition. Broadband, or perhaps more accurately *broader-band*, is seen to be the Holy Grail of Internet audio enthusiasts and investors. What is broadband? Is it here, now that we have DSL and cable modem connections? Can we stop searching?

The word is presented to us in business plans and media ads as if it were an invention. On the contrary, broadband identifies an evolutionary process, like Moore's law, that has been ongoing for quite some time. And it shows no sign of stopping at any time in the future.

In the earliest days of television, viewers had one choice. The number of broadcast channels then grew from one to three. Cable TV appeared with packages of a dozen channels. Digital satellite and cable systems came along, broadcasting hundreds of channels of television and pay-per-view (PPV) programs. It is easy to extend Internet radio's thousands of channels to the future concept of Internet television.

With 100 televisions and 100 tuners, we could watch 100 different programs simultaneously, all thanks to

one small coaxial cable. Thus, most of us are already familiar with, and users of, a broadband connection.

Those of you with hundreds of channels of television programs are thinking: "What more could I possibly want." Well, humans seem to have an insatiable appetite for personal freedom and choice. Therefore, for every **n** channels of programming, some among us will want **n+1**. Thus, as long as one among us remains unfulfilled, *broader-band* will continue to be the Holy Grail.

The Internet, broadly taken as a single cable with unlimited programming, represents the broadest of bands, as long as the connection is fast enough to deliver the program with the quality we desire.

The Internet

We grew up in a world where every house had a phone that could connect to all the other phones in the world. Why then did it surprise anyone when, 20 years later, all home computers were connected together? Absent the media, we might all have come to understand the Internet as logical, wondering what took it so long to arrive.

Now that it is as ubiquitous as the worldwide telephone network, what attributes of the Internet have caught our attention?

The Internet is the superstore of superstores, a place where you can buy everything.

The Internet is the world's largest hard drive. If you can digitize a signal, you can store it somewhere on the Internet. This brings up interesting concepts such as the virtual storage unit, eliminating the need to rent a physical storage unit to store your photo albums, vinyl records, and home videotapes.

The Internet is the world's most powerful computer. Peer-to-peer computing applies near-infinite parallel processing power to the world's most difficult equations. When not used to crack genetic codes and extraterrestrial communications, it can be used to interactively make music.

The Internet is the world's longest RCA cable, connecting my music collection (and my friends') to my amplifier. Today, I connect my music collection (CD changer) to my amplifier using an RCA cable that I own outright. A simple one-time buyout allows me unlimited use of this cable to carry my data from source to destination. With the Internet, this simple business model diverges greatly. There are many cables, translators, switches, routers, and multiplexers between my music collection (i.e., peer-to-peer, large RealAudio servers, personal music storage site) and my amplifier. And you can be sure that the owner of each bit-carrying cable wants you to pay a toll.

Let's assume that the desired audio file is stored on a server at an online music retailer, located somewhere on the Internet. This server is connected to an Ethernet local area network within their facility. This LAN is connected to a regional Internet service provider (ISP) via a T1 line (fiber or copper). The regional ISP is connected to my local ISP via the Internet (a complex web of fiber and copper backbones). My local ISP connects to a DSL Access Multiplexer located in the telephone company's central office. The DSLAM connects to a DSL modem in my condo via my telephone line. The DSL modem connects to the network interface card in my computer via Ethernet. The network interface card in my computer connects to my computer's CPU via its PCI bus. The CPU is also connected to a sound chip via the PCI bus. The sound chip is connected to audio speakers via an old fashioned RCA audio cable.

THE FORCES AT WORK

"'I've gone through hell,' Ignatius slobbered, pulling Myrna into the hall by the sleeve of her coat. 'Why did you step out of my life you minx? Your new hairdo is fascinating and cosmopolitan.'"

—John Kennedy Toole, *A Confederacy of Dunces*

The romance between Audio and the Internet has moved to the front page. The union has created a comeback of sorts for the prerecorded music (and audio) industry. The emergence of Internet radio, maturation of Internet commerce CD sales, and the infection of MP3 songs into every low-income teenager on the planet are all helping make believers out of skeptics, and millionaires (or low-income grown-ups) out of entrepreneurs.

The familiar formula looks something like this:

$$\mathbf{E=mc^2},$$

where **E**=Engineering, **m**=Marketing, **c**=Consumer.

What Engineers Make

Perhaps it is the need to create job security, or perhaps simply the creative artist in all of us; engineers are only happy when creating something new. Left alone in the lab, audio data formats and interfacing specifications would never be completed, merely forever tweaked and extended. This drive is essential for innovation, but needs to be balanced by the cold economic reality of staying in business.

Why have one when we can have many? If cultural diversity is a virtue, why not data format diversity? Storage media diversity? Digital interface diversity? This is what engineers do.

What Marketers Sell

Marketers want defined products that meet the needs and desires of consumers. Somehow, they must draw lines around specifications and plan products that can not only be built, but also sold over and over again.

When competing companies deliver the same product, the business model often becomes the differentiator. Thus, one company sells video movies, while the other rents them out. Advertisers fund one radio station, while subscribers fund the other. One company gives away the hardware and charges a subscription for services; the other gives the services away but bills you for the hardware.

What Consumers Want

Often overlooked by companies (no longer in business) that created and sold products (that are no longer sold) is the lowly consumer. Many business executives and marketing books believe that consumers can be simply told what to purchase, using persuasive ads and magic spells.

While some consumers do indeed walk through life doing as they are told, most like to at least feel like they have a say in the grand scheme of things.

Many people are surprised (appalled) that consumers are willing to "settle" for the inferior audio quality of Internet audio. This is not a surprise to anyone with a "digital" cellular phone, whose quality is markedly inferior to wired telephones. Cellular telephones have many audio dropouts, yet we do not stop buying them and using them. Here, convenience and portability clearly win out over audio quality. Much is the same for today's portable music players. Like cellular phones, nothing new is required to learn how to use them—they are functionally equivalent to a portable cassette player.

Never-before-seen features such as time-shift recording are big hits with early adopters of personal video recorders (PVRs), but sales growth is much slower than portable music players, which came to market at approximately the same time. This is an example of a valuable feature that will one day become ubiquitous. But since there is no obvious equivalent today, it will take much more time.

Beyond convenience and portability lies a quality threshold, to be sure. The successful design of a new digital video product depends less on technical specifications and more on the simple fact that it has to be at least as good as what the consumer stares at for hours on end today: broadcast television. Broadcast television has no video dropouts, no missing frames, no pixelization. On the living room sofa, the convenience of a remote control sits along side a basic expectation of quality. Couch potatoes will not put up with cellular phone-like dropouts occurring consistently and constantly, and they won't put up with the interruptions associated with streaming Internet video today.

With IA audio, there is a similar, subjective threshold that must be crossed with regards to audio quality. Portable music players would have not gotten out of the starting gate had the audio quality been equivalent to an AM radio. Clearly, there exists a marketing concept called "good enough".

Contrary to what we were told, CDs can be scratched. And the stuttering loops created are perhaps even more annoying than a skipping vinyl record album. Dropouts caused by buffer problems in streaming Internet audio are equally unacceptable to the listener. All three cases result in the listener discarding the program material altogether.

In any event, early IA product designers must decide to promote convenience, while achieving the subjective standard of "good enough" audio. Like all emerging audio technologies before this, IA audio quality will improve over time.

THE EARLY STATE OF THE ART

"Eva Hesse thought that art was not obligated to be pretty; she was instead committed to the natural evolution or process of things."

- Margaret Steele & Cindy Estes, *The Art of Shapes*

Data Rates and Formats

Unfortunately, with the proliferation of information appliances, audio quality has arguably taken a step backwards while traditional audio product formats continue to improve. The "Redbook" compact disc format, introduced nearly 20 years ago, delivers 1.4122Mbit/s of audio data, with 20kHz audio bandwidth and 96dB of dynamic range.

DVD-Audio delivers 9.216Mbit/s, with up to six 24-bit audio channels each with sample rates up to 96kHz. It also supports two 24-bit channels at a sample rate of 192kHz and 144dB of dynamic range.

The DVD-Audio format supports linear PCM, Dolby Digital, DTS, and MPEG coding.

Information appliances, on the other hand, are incapable of supporting these staggering data rates. Consequently, they utilize various data compression techniques to lower the data rate of program material. Formats such as Real Audio [2], Windows Media, MP3, AAC, and ATRAC3 typically deliver 128kbit/s over broadband connections, and 32kbit/s over modems [3].

In comparison with the 1.4Mbit/s and 9.6Mbit/s data rates of CD and DVD-Audio disks, it is obvious that compromises must be made to audio quality. The 15kHz bandwidth and noise characteristics of good but compressed audio sounds strikingly similar to FM radio; bad compressed audio can sound as bad as AM radio or even a telephone. Compression technologies are improving, but it is unlikely that a compressed 128kbit/s program stream will ever sound as good as an original recording that was encoded with at least a 1000% advantage over that data rate.

Storage Formats

1.44MB 2HD floppy disks have been around forever, but in recent years they have been replaced by higher density formats. The SuperDisk by Imation holds 120MB on a disk the same size and shape as the old 1.44MB floppy disks. SuperDisk drives can read and write both formats. Matsushita Kotobuki Electronics Industries (Panasonic) recently announced the development of a new technology that can increase the capacity of 2HD floppy disks to 32MB. Other magnetic removable storage formats include the Jaz (up to 2GB), Orb (2.2GB), ZIP (250MB), and PocketZip (40 MB).

CD-ROM disks typically store 650MB-700MB of data, while their successor DVD-ROM supports 2.6GB (single sided) or 5.2GB (double sided). These disks are getting smaller; DataPlay has developed a half-dollar-size, write-once DVD disk that stores 250MB of data per side.

By far, Flash is the most popular high-density removable media today due to its shock resistance, small size, and low cost. Flash is packaged into Compact Flash cards (up to 256MB today), Multimedia and Secure Multimedia Flash cards (up to 64MB today), and Smart Media cards (up to 64MB today). Not to be left out of the Flash memory format war, Sony introduced its Memory Stick. Smaller than a stick of gum, the format stores up to 64MB, with 128MB Memory Sticks promised soon.

Hard drives continue to grow in capacity and shrink in size. Toshiba has developed a PC Card hard drive that holds 2GB of data, and even greater capacities are promised for the future. The 5-by-3-by-0.5-inch Pockey external drive connects to a PC via USB, and holds up to 20GB. LaCie markets a similar drive, the PocketDrive, which holds up to 10GB. But the undisputed champion in the hard drive miniaturization race is IBM's Microdrive, measuring only 0.2 inches by 1.4 inches by 1.7 inches and weighing half an ounce. This drive is available in capacities up to 1GB, and is four times cheaper per MB than Flash memory.

Finally, exotic new forms of storage are on the horizon. Scientists are working on holographic storage technologies that use lasers and a doped crystalline medium. When this storage becomes practical, perhaps within a couple of years, its capacity (measured in terabytes) and bandwidth will make today's magnetic memory as obsolete as punch cards.

Even cellophane tape is destined to become a digital storage media. European Media Laboratory and Stanford University are working together to exploit the fact that the polymer structure of adhesive tape is well suited as a holographic data medium. A technique similar to burning a CD modifies the optical properties of the tape using a laser. It can store data on any individual layer of the tape without unwinding the roll or disturbing other layers, meaning as much as 10 gigabytes of data can be written on a single roll.

Watermarking

Watermarking is a process for embedding inaudible digital information within program material. Watermarking technology has been applied to audio, video, and still images. In particular, audio watermarking has recently emerged as a solution to the difficult problem of protecting music copyrights. In this application, watermark data may indicate the publisher, creator, owner, distributor, or authorized consumer of an audio recording.

Digital watermarking involves two processes: watermark insertion, which adds the digital data to the original program material, and watermark extraction, which recovers or verifies the digital data. Techniques for encoding digital watermarks into program material include least-significant-bit replacement, spread-spectrum, and perceptual masking.

In least-significant-bit replacement, one or more of the less significant bits of a digital audio sample are replaced with the watermark data. This method is easily circumvented by stripping off the least significant bits, so it is not used in applications in which unauthorized copying is to be prevented.

Spread-spectrum techniques use the entire spectrum of the program material to embed the watermark and boast a low probability of circumvention by an attacker.

Perceptual masking, such as that used by the Digital Harmony PAWS system [4] and others, takes advantage of the time and frequency masking properties of the human auditory system to embed information in spectral or temporal zones that the ear will not detect.

Watermarking techniques are commonly judged by the following criteria:

- Transparency - the watermark is inaudible.
- Survivability - the data is not detectable after the audio has been subjected to signal processing during broadcast, audio compression, and/or recording.
- Security - the data is resistant to attempts at forgery, alteration, erasure and decoding by unauthorized users.
- Data Throughput - the more data that can be hidden in the program material, the better. It is also desirable to embed multiple "layers" of watermarks without corruption.

Portable Music Players

Thanks in part to the Napster phenomenon, the MP3 format has become part of the mainstream. Webnoize estimates that sales of portable players increased about 150 percent during 2000 [5]. Companies are falling all over each other to introduce MP3 players in all shapes and sizes. The Diamond RIO portable MP3 player was the first to hit the street, and it has been followed by dozens of models from other manufacturers. These players come in all shapes, sizes, and price points. Players support a variety of removable storage media, most commonly Compact Flash and Smart Media.

Recently, MP3 (and other IA audio formats) players have been built into other types of devices:

- In-dash, hard drive players for automobiles such as MTE's Neo and Aiwa's CDC-MP3
- Personal digital assistants (PDAs) such as InnoGear's MiniJam MP3 Player for the Handspring and PocketPyro's Pyro for Palm
- Cellular telephones such as the Samsung Uproar SPH-M100
- Casio's MP3 Wrist Watch Audio Player
- Portable CD players that play MP3s, such as the D-Link DMP-CD100 and Pine Technology D'music MP3 CD Player SM-200C+
- Digital still cameras such as the Kodak MC3 and Fujifilm FinePix 40i
- Clocks radios such as the Nakamichi SoundSpace2
- Vending Jukeboxes such as the SongPro Party Machine
- Internet Radios such as the 3COM Kerbango and Philips FW-i1000
- Add your own idea here (go ahead, we know you have one).

Indeed, it seems likely that any device that emits a sound may become an MP3 player in the future, as companies jump on the bandwagon and attempt to capitalize on the MP3 hype.

Business Models

The music industry could use MP3 song files much like it used 45 RPM singles in the early days of rock and roll. Both are song-based formats, rather than LP based. Both have no liner notes, and limited information. Both get listeners in the mood to hear more from the particular artist, and could lead to sales of the LP/CD. Indeed, many record labels are starting to sell MP3 singles for $2-4 each.

Historically, radio stations and record labels were independent. If a listener heard a song they liked, they had to write down its name, run to the record store, ask for it, buy it, and bring it home. Internet radio today is, for the most part, just copies of regular radio broadcasts. Will this always be the case? Not likely. Indeed, at least one major label is conducting field trials to stream all songs in its library to subscribers, for a monthly fee of around $10.

Another way to attract music buyers would be to watermark retail music system content (i.e., the music you hear at Starbucks and Toys R Us). Any store customer with a PDA could automatically get a readout of song information and stock number, with a one-button BUY NOW feature for any PDA with a wireless Internet connection.

Other mainstream and innovative business models for IA audio devices and content include:

- Brick and Mortar - the purchase and download of copy-protected MP3 files [6]
- Pay Per Play – the purchase of each play of streaming music
- Pay for Box, Get the Service Free – typical Internet radio business model
- Pay for the Service, Get Box Free – a copy of the cable TV set top box model
- Publishing on Demand – purchasing self-directed compilations on CD-R
- Pay per Byte – common unofficial music download model, paying the ISP and phone/cable company.

THE PERSONAL MEDIA ASSISTANT (PMA)

There remain a number of barriers that must be broken down in the next generation of information appliances. A futuristic example of this is the Digital Harmony Composer [7], a demonstration software package that controls devices connected to the Internet, and those connected locally via an IEEE-1394 bus. The *personal media assistant* (PMA) will have many advanced attributes:

Audio Formats

As sure as Seattle's sky will be gray tomorrow, engineers and committees will continue to create new data formats. Accepting this does not mean that we must accept the status quo of audio decoding techniques and business models. One day soon, someone will start packaging decoder algorithms in the audio data packets. Until then, smart personal media assistants (PMAs) can ignore any non-decodable content.

The consumer does not care what data format is used, and the ideal PMA will make data formats transparent to the user. If the user's system cannot decode a file format, the file will simply not appear in the user's library.

Storage Locations

The music you want to listen to may be found in your home CD changer, on a streaming media server, on a peer's local hard drive, on an Internet server in India, on a Memory Stick in your camera, or in a Bluetooth telephone. With information appliances connected to all of these devices, we can also eliminate the location (as irrelevant to the user) from the media library.

Again, the consumer does not care where the music is located. The only need is the need to listen to the desired song, and the end result is the same whether the song is streaming from the Internet or playing from a local CD changer.

Number of Audio Channels

As audio devices become interconnected and interoperable using interface specifications such as IEEE-1394 and HAVi, it becomes a simple matter to add any number of loudspeakers to any home entertainment system. Indeed, the number of audio channels becomes arbitrary, after years of stereo and 5.1 channel systems. The intelligent home entertainment systems will automatically sense the number and location of loudspeakers.

Content-Specific System Presets

Every music recording was mastered in a unique environment with unique signal processor settings. Each venue (e.g., your home, your automobile) has its own unique environment. The optimized system settings for one recording will likely be different for the next. With a PMA and a digital home entertainment system, presets can be created for *every song in your library*, each preset automatically called up by the PMA when the song is selected.

Mobility

The mobility of portable IA devices, and other storage devices such as bus powered 1394 hard drives, allows great flexibility. For example, a 1394 hard drive can easily contain an entire music library in MP3 format. This drive can be carried in a shirt pocket from the living room, to the automobile, to the office, and then back again. Wireless LANs can be used to load music to/from vehicles while the driver sleeps, all under the guidance of a PMA.

CONTENT IS KING

"In one row, orangutans were blowing into gleaming trumpets, on their shoulders sat merry chimpanzees with accordions."

- Mikhail Bulgakov, *The Master & Margerita*

When the day is done, all that matters is the music played, the melodies sung, the words spoken, the sounds defining a subtle mood, the ability to evoke strong emotions. Without good music, we are left with merely good audio. Without art, our best technologies end up being nothing more than productivity enhancers and intellectual exercises, providing all the convenience of a corner market.

A good microphone cannot make you a good singer. MIDI did not turn bad musicians into good musicians. DV camcorders with FireWire PCs enable desktop movie editing, but cannot guarantee good movies. Publishing on demand saves trees and gets

more authors published, but cannot improve literature. Paint-by-numbers never transformed fine art. Technology provides the patterns and instructions, the tools of a trade. True inspiration has to come from somewhere else.

Perhaps then, the best job security for all technologists is to drag our children away from the computers and game players long enough to learn to play the cello, listen to a recording of Ella Fitzgerald, watch Dave Matthews' play live. Don't forget this. The remaining barrier from today forward, the weakest link in the chain, is quality content.

Without it, what good are a million channels?

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