RTT TECHNOLOGY TOPIC
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Camcorders and their impact on camera phone design

In last month's Hot Topic, we studied the impact of digital cameras on camera phone design.

We established that a mid-tier digital camera is typically now a 7 Megapixel device with good quality optics.

The launch at CEBIT of the Samsung V770 camera phone demonstrated that ' mid tier' digital camera phone capabilities can be packaged into a camera phone physical form factor

The 770 is a 7 Megapixel phone with interchangeable lenses. Note that, in common with many other camera phones, it also supports a basic camcorder capability.

In this month's Hot Topic, we are going to look at how digital camcorder performance expectations are changing and the related impact on camera phone form factor and functionality. In particular, we set out to review the impact on memory requirements.

Digital camcorders as a quality and functional performance reference

The picture below shows two digital camcorders,one from Hitachi, one from Canon, both are priced at around £600 to £700, the same price point as the mid tier digital cameras we looked at last month.

Canon Mv6iMC	Hitachi DZ-MV580
	

Note that camcorders do not need to have the same resolution as still image cameras(our eyes cannot resolve fine detail in a moving image). These two products use 800,000 and 1.2 Megapixel CCDS. The default resolution (DV video) is usually 720 by 480 pixels (345,000 pixels). The additional pixels are used for image stabilisation, digital zoom and still photography. Camcorders with 3 or 4 megapixel CCDs are sold on their ability to produce quality still images in addition to video. However this also has an impact on memory functionality. Video images are recorded on tape or disk and still images are recorded on plug in memory.

The Canon camcorder uses Mini DV cassettes and an 8 MB SD card. The Hitachi camcorder uses a DVD-R/DVD Ram and an SD card.

Points to make:

Resolution expectations
The top of the range Samsung 770 seven Megapixel camera phone can 'only' handle QVGA 320 by 240 pixel video (76000 pixels). Users of camcorders expect to have 720 by 480 pixel DV resolution (345,600 pixels) which is more or less equivalent to 640 by 480 pixel VGA (307,200 pixels). This gives adequate quality when displayed on a computer monitor.

The other format found in video phones presently is 176 by 144 pixel QCIF (25,344 pixels) which is derived from 352 by 288 pixel CIF(101,376 pixels) which is one quarter the size of a standard 704 by 576 pixel PALTV image known as 4CIF (405,504 pixels).

Note that CIF (common intermediate format) is a standard originally from the TV industry, whereas VGA (video graphics array) was introduced in 1987 as a standard for describing computer monitor resolution.

The VGA standard does however now include 1920 by 1080 pixel High Definition TV (2.073 Megapixel).

Frame rate expectations
The 770 produces 15 or 30 frames per second. 30 frames per second would normally be considered adequate for video (cinema film runs at 24 fps, PAL at 50 and NTSCC at 30 fps) but a number of streaming applications in 3G networks are now being trialed at 35 fps (the faster frame rate hides some of the quality issues).Some of the higher tier camcorders can shoot at more than 240 frames per second.

Audio quality expectations(and the impact on memory bandwidth)
DV audio provides a choice of 2 channel 16 bit stereo or 4 channel 12 bit stereo with a 32 KHz, 44 KHz (same as CD) or 48 KHz sampling rate. Phones such as Motorola's recently launched E680i targeted at the mobile music market have up to 2GB of memory just for audio storage.

Memory expectations
The V770 has 32MB of internal memory and an MMC Micro card slot.

The Canon Camcorder has 11 GB of memory on it's DV cassette plus 8 Mb on the SD card.

The Hitachi camcorder has 9.4 GB of memory available on the DVD plus the SD card.

Tape or DVD are both capable of storing half an hour of DV quality video and audio.

It might be argued that camera phones can only aspire to providing camcorder functionality if they can provide similar functionality or at least a similar user experience to (equivalently priced) camcorder devices.

Memory options

Tape

The Mini DV tape used in many camcorders including the Canon product above, has a number of advantages - relatively reliable and robust, a good low cost (less than 4 dollars for 11 GB) storage medium.

However there is a mechanical process involved. The tape moves at 18.9mm a second over a read/write head rotating at 9000rpm. The head lays down tracks diagonally across the tape, 12 tracks per frame for PAL and 10 tracks per frame for NTSCC.

This means that the tape is quite bulky (the cassette is 12.2mm by 48mm by 66mm) and the recording is sequential - i.e. random access requires the tape to be mechanically wound forward or back. It is thus not suitable, (if used on its own), for mixed media (video, audio and data) applications.

Optical storage

DVD's in comparison can be configured for random access (DVD-RAM), or sequential access (DVD-RW and/or DVD+RW).

DVD's come in three sizes, four and a half inch, three inch mini DVD's and Sony's two and a half inch Universal Media Disk.

Data is stored in a spiral of pits (up to 48 kilometers long for a double sided DVD) embedded within the disk. The reflectivity of the pits can be changed by the application of heat from a red (640 nanometer) laser which is also used to read the data.

A DVD RAM can be re written about 10,000 times, a DVD-RW or DVD+RW can be rewritten about 1000 times (the whole disk gets erased on the write cycle).

The disks rotate at between 200 and 500 rpm. Although DVD-RW and DVD+RW are optimised for sequential storage, there are zone storage and search techniques that mean they can be used for storing and reading a mix of video, audio and data. The spin speed changes to keep the read speed constant as the laser moves out from the centre of the disk. The transfer rate is typically 10 MBPS. The seek time on a DVD RAM disk is typically about 75 milliseconds.

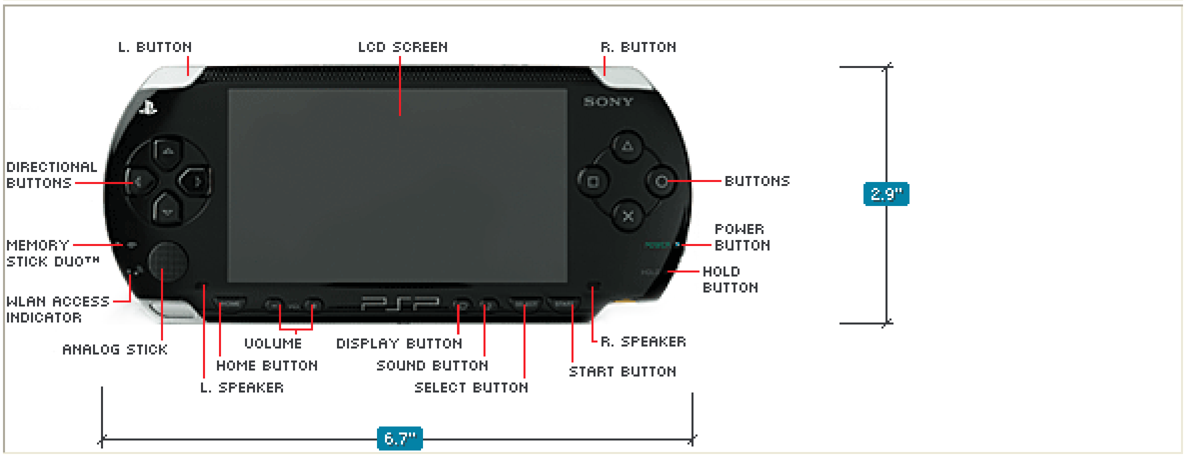
A standard four and a half inch DVD holds 4.7 GB of data, (9.4 GB on a double sided disk), a mini DVD holds 1.4 GB and a Universal Mini Disk holds 1.8GB.

One proposal is to use a blue laser at 405 nanometers rather than a red laser. The present track pitch of 0.74 microns would be reduced to 0.32 microns. A blue laser UMD would hold about 9 gigabytes (9GB).

The Universal Media Disk is used (as a read only device) in the Play Station Portable which shows that Sony at least are confident that optical disks are sufficiently robust and sufficiently light weight (10g) and sufficiently slim (1.2mm) to be used in small form factor hand held devices. The slow spin speed means that it is more power efficient to use DVD's for sequential access rather than hard disks. The random access seek time is however much slower. Interestingly, the write power budget is also quite low. The laser power is typically just a few (highly focused) milliwatts.

The Play Station Portable is also of course one of the first (possibly **the** first?) mass market example of a portable hand held product with a DVD **and** WiFi connectivity.

Sony Playstation Portable with Universal Media Disk and Wifi Connectivity



Hard Disk Storage
A desk top hard disk is typically now a three and a half inch diameter device spinning at between 10,000 and 15000 rpm with a capacity of 100 GB or more. The power budget of these devices (8 to 10 watts) precludes their use in portable products.

Lap tops typically use two and a half inch diameter hard disks offering between 20 and 100 GB of capacity. A spin speed of 10000 rpm produces a seek time of under 5 milliseconds but power consumption is still over 5 watts. Reducing the spin speed to 5000 rpm increases the seek time to about 15 milliseconds but reduces the power to about 3 watts.

iPOds use 1.8 inch hard disks with between 20 and 60 GB of storage and a 3990 to 4200 rpm spin speed. Power consumption is about 1.3 watts.

For cellular phone applications, vendors are promoting either 1 inch drives (Hitachi) or .8 inch 'microdrives' (Toshiba and Samsung).

Hitachi 4GB Microdrive

The one inch drives fit into a Type 2 PC card form factor (5.2mm) and weighs 16g. Microdrives have a depth of 3.3mm and weigh 10g. One inch disks now typically hold about 8 to 10 GB and microdrives are either 2 or 4 GB. Both have a spin speed of 3600 rpm giving a seek time of 12 to 15 milliseconds and a transfer rate of 4 or 5 M/bytes per second. A one inch drive has a power consumption of just under one watt, a .85 inch drive, about 700 milliwatts.

There are some cellular handsets now available with hard disks (the Samsung V5400 for example and the 3GB SGH-i300 being launched in the UK). Toshiba have brought forward the availability of their 4GB 0.85 inch hard disk with mass production starting this month so it is reasonable to expect an increasing number of phones to be launched with hard disk based camera phone, camcorder and audio functionality.

Samsung V5400 with integral hard disk drive

DV tape versus DVD versus Hard Disk Cost and Performance Comparisons

A mini DV tape costing 4 dollars implies a storage cost of less than 0.04 of a cent per megabyte but the memory medium cannot be used for random access applications.

An optical disk could potentially offer similar cost/performance ratios with the added benefit of sequential storage and random access capability.

A 4 GB microdrive can provide sequential storage and fast random access (15 milliseconds rather than the 75 milliseconds of a DVD) but presently costs about 10 cents per megabyte.

Hard Disk Shock Protection and memory back up

A number of manufacturers (Toshiba for example) have MEMS based accelerometers built in to hard disk drives to detect when a product is being dropped. The head can then be kept clear of the disk to prevent damage. Analog Devices (low-g iMEMS) and ST Microelectronics have digital accelerometers targeted at hard disk protection.

The fact that mobile memory including hard disk storage can be physically lost in a number of ways (including theft) does of course add value to network operator based back up services

Given that operators already offer back up for SIM based information such as phone numbers and contact data, it makes sense to have auto save capabilities for hard disk devices. These services intrinsically increase in value as hard disk capacities increase over time.

Solid state storage

Flash (Nor and Nand), SRAM and SDRAM
Which brings us to solid state memory. Flash based solid state memory can of course be configured to look and behave like a hard disk (given its ability to retain data in power down) and has the big advantage of not having any moving parts. It is however, more expensive (between 20 and 40 cents per megabyte) and comes in a bewildering range of form factors.

Embedded non volatile(FLASH) memory in a cellular handset is typically a mix of NOR for code storage and NOR and NAND for data storage. NOR sets the input memory state at 0, NAND sets it at 1. NAND costs less than NOR because it takes a number of memory capacitors and matches them to a smaller number of switching transistors. NAND is more error prone but the cost benefits make it a preferred option for most embedded data storage applications. Wear levelling techniques have also increased the number of write cycles to typically 100,000 or more even on extreme geometry devices.

Flash memory, originally developed by Intel, works on the basis of having two transistors separated from each other by a thin oxide layer- one transistor is known as the 'control gate', the other is the 'floating gate'. The floating gate can have it's state changed by a process known as tunneling. An electrical charge is applied to the floating gate transistor which then acts like an electron gun, pushing electrons through the oxide layer. A cell sensor measures the level of charge passing through the floating gate. If it is more than 50% of the charge, the state value is 1, if less than 50%, the value is 0. The gate will remain in this state until another electrical charge is applied. In other words it is non volatile. It will retain its state even when power is not applied to the device.

The embedded (non volatile) Flash memory sits alongside (volatile but lower cost) SRAM (Static Random Access) and DRAM memory.(Dynamic Random Access).

Random Access means just that, the memory is optimised for fast random access rather than steady sequential access.

SRAM offers very fast read/write cycles (a few nanoseconds) but the data is held in a volatile 'floating gate'.(a volatile flip flop). It does not need refreshing as often as DRAM (hence the description static) but is still relatively power hungry .SRAM is used for temporary cache memory.

DRAM memory holds data in a storage cell rather than a flip flop (which is why it is called dynamic). DRAM offers the lowest cost per bit of the available solid state memories. A typical DRAM device will store up to 64 MB (512 Mb). SDRAM is synchronous DRAM - synchronous means the device synchronises itself with the CPU (central processing unit). Clock speeds of 133 MHz would be quite typical.

DRAM products are inherently power hungry in that the storage cells leak and require a periodic refresh to maintain the information stored in the device. There are techniques such as temperature compensated refresh, partial array self refresh and deep power down which help reduce power drain . These products are sometimes described as mobile DRAM or mobile SDRAM. The volatility and related power drain issues of these devices and their optimisation for random rather than sequential access makes them unsuitable for storing large amounts of video requiring sequential access.

It has therefore now increasingly common to supplement embedded memory with plug in memory. Most plug in memory consists of a NAND Flash device(or multiple devices) on a die with a dedicated microcontroller.

In the context of a cellular handset, plug in memory can be summarised in terms of when the technology was introduced.

FLASH based plug in memory

The SIM Card

The SIM card (subscriber identity module) became an integral part of the GSM specification process in the mid to late 1980's. The original idea was that it should be used embedded on a full size ISO card (the standard form factor for credit cards) but as phone form factors became smaller through the 1990's it became normal to use the device on its own. The device is 0.8mm high which apart from the Smart Media Card (see below) makes it the thinnest of any of the plug in memories and one of the smallest (26mmx15mm). Early SIM's consisted of an 8 bit microcontroller, 8K of ROM, and 250 or so bytes of RAM and were used primarily to store the user's phone number (IMSI/TMSI) and to provide the basis for the A3/A5/A8 challenge and response authentication and encryption algorithms. Early SIMS also had a limited amount of data bus bandwidth, typically 100 k/bits/second.

A modern SIM still has the same mechanical form factor but uses a 16 bit or 32 bit microcontroller. Most of the vendor product roadmaps suggest that one gigabyte of data storage should be technically and economically feasible within 2 to 3 years coupled with a faster bus (up to 5 M/bits/s) and faster clock speed (up to 5 MHz). These devices are known as HC SIMS (high capacity SIMS), or MegaSIMS or SuperSIMS depending on the vendor and are being targeted at the image storage market .A SIM used with a UMTS phone is known as a USIM (Universal Subscriber identification. An ISIM is a SIM optimised to work with the IP MultiMedia Subsystem and is intended to provide the basis for IPQOS management and control.

Although the SIM is a mandated component within UMTS and a mandated part of the 3GPP1 and 3GPP2 standardisation process, it's longer term role in managing authentication, access and service control is being challenged by microprocessor and memory manufacturers.

ARM11 microprocessors for example are promoted in terms of their ability to manage user keys and as a mechanism for providing network virus and M commerce protection.

ARM/TI dual core microprocessor /DSP's are promoted in terms of their ability to provide end to end security, multi media and digital rights management.

Intel promote 'Bulverde' on the basis of it's built in hardware based security capabilities (DES, triple DES and AES encryption) and conformance with IT industry (EAL4+/EAL5+evaluation assurance levels) rather than telco industry security standards.

The SD card and MMC cards covered below promote enhanced security and authentication features as part of their future network operator focussed value added proposition. Smart card/SIM/storage card combinations such as MOPASS (a Hitachi led consortium working on SIM card/memory card functional integration) strengthen this story. These products are sometimes described as 'bridge media' products.

Thus it is possible that some of the functionality proposed for the USIM/ISIM will migrate on to competitive device platforms particularly in markets with no prior SIM/USIM experience (TDMA/IS136 based networks for example). The 1 gigabyte capacity of the SIM may also be insufficient for many of the evolving imaging applications, particularly video storage and movie image management (the Camcorder effect).

Compact Flash (www.compactflash.org)
In 1994, SanDisk introduced Compact Flash, a 4MB Flash card with a depth of 3.3mm (type 1 PC card) by 36.4 by 42.8 mm, and a weight of 11g. Compact Flash is compatible with the Integrated Device Electronics standard which means that the Flash looks like a (small) hard disk to the operating system. Capacities range from 16MB to 12 GB and the products are widely used in digital cameras. The devices will withstand a shock of 2000 G's equivalent to a 10 foot drop and are claimed to be able to retain data for up to 100 years. The latest specification revisions include an increase in data transfer rate from 16 MB/sec to 66 MB/sec.

Smart Media (www.ssfdc.or.jp/english/)
In 1995, Toshiba launched Smart Media, an 8 MB device. This is the slimmest of the plug in memories with a depth of only 0.76mm but has the disadvantage of being dependent on the host controller to manage memory read/writes (it has no built in controller but is just a NAND chip on a die). This, and a relatively high pin count, has limited its application in smaller form factor devices although it finds its way into a number of digital cameras and camcorders (for still image storage).

Multi Media Cards (www.mmca.org)
Introduced in 1997 by Siemens and Sandisk, multimedia cards were targeted from the start at small form factor cell phones and (not surprisingly, given their name), multi media applications. Standard MMC cards have a depth of 1.4mm and are 24mm long and 32mm wide. An MMC micro card is18mm long.

There is an MMC Plus and HS (high speed) road map with a variable bit width bus (1 bit, 4 bit, 8 bit), a 52 MHz clock rate (a multiple of the GSM 13 MHz clock), a 52 M/byte per second transfer rate and a search time of 12 milliseconds (as fast as a hard disk). Storage footprints go from 32MB to 2 GB. A standards group working with the Consumer Electronics Advanced Technology Attachment standards body **www.ce-ata.org** has addressed how an MMC card interoperates with disk drive memory and is looking at future optimisation of MMC devices for audio and video stream management.

Memory Stick (www.memorystick.org)
The Memory Stick was introduced by Sony in 1998 . It has a depth of 2.8mm, a width of 21.5 mm and is 50mm long (the same length as an AA battery). The 'top of the range' model at the moment is the Memory Stick Pro which provides up to 2GB of storage with a maximum transfer rate of 20 MB/s and a minimum write speed of 15 mbps. A thinner version, the Memory Stick Pro Duo, has a depth of 1.6mm and a capacity of up to 512 MB. These devices are optimised for video (and other types of media including images, audio, voice, maps and games). The high transfer speeds needed for video do however have a cost in terms of power drain - a Memory Stick used at full throttle will be using upwards of 360 milliwatts. Sony have a product road map showing 4 GB devices being available by the end of 2005 and 8GB devices by the end of 2006.

SD (Secure Digital) Cards (www.sdcard.org)
Introduced by a group of manufacturers including Sandisk, Toshiba and Panasonic in 2000/2001, the SD card was developed to be backwards compatibility with (most) MMC cards but with a reduced pin count (2 rather than 9 pins), and (as the name implies) extended digital rights management capabilities.

The standard SD card is the same width and length as the standard MMC card (24 by 32mm) but is thicker(2.1mm) and therefore able to support slightly more storage with a road map of 2 to 8 GB devices. The device weighs 2gm and has a smaller cousin known as a Mini SD card which is 1.4mm by 21.5mm by 20mm and weighs 1 gm and a Micro SD card which is 1mm by 11mm by 15mm and weighs virtually nothing. As you may have noticed, Mini SD cards and Micro SD cards are not compatible with MMC micro cards. Seek times are similar to MMC. Rather like the memory Stick, the SD card has separate file directories for voice (SD voice), audio (SD audio) and video (SD video).

An SD card is used in tandem with a SIM and a GPS receiver in the Gizmondo Game Player **www.gizmondo.com.**

xD PIcture Cards (www.fujifilm.co.uk)
Introduced by Toshiba, Fuji and Olympus in 2002, Picture Cards have a depth of 1.7mm, a width of 20mm and a length of 25mm, weigh 2 gm and are presently

available in capacities up to1 GB with a 2 to 8 GB product road map similar to the memory stick. A 1 GB card will store about 18 minutes worth of Quick Time movie at VGA resolution (640 by 480) at a frame rate of 15 fps including sound or 9 minutes at 30 fps. Given that we said that a camcorder user expects a minimum of half an hour of record time then this corroborates the thinking behind getting the memory footprint up to 8 GB within the next 18 months to two years and to optimise transfer rates and read speeds (and power consumption!).

USB Flash Drives/Portable hard drive (www.usbflashdrive.org)
Slightly different in that they are specifically designed for moving data files on to or from a hard disk, USB Flash drives plug straight into the USB port. This does mean that you have to have a 12mm by 4mm USB port in the host device but delivers flexibility in terms of plug in I/O functionality (hot swapping, USB hubs and all those other nice things that USB ports deliver). The objective is to have devices that are compatible with the USB2.0 standards (**www.usb.org**) for high speed USB which includes transfer rates of up to 480 mbps

The USB standard includes support for MPEG2, MPEG4, MJPEG and DV video - in other words all existing camcorder compression and streaming standards. There are of course some issues (apart from the mechanical size) of putting a USB connector into a small form factor hand held device, in particular the power drain implications of supporting these higher transfer rates.

The mechanical issues could potentially be overcome in the longer term by having a UWB (ultra wide band) wireless USB connector though the donor device would then need to be self supporting in terms of power.

There are also some vendor sponsored initiatives trying to encourage a standardized size and format for USB Flash through an association known as the Universal Transportable Memory Association (**www.fishmemory.org)** and similar standardisation initiatives aimed at digital camera and audio player devices by the USB Flash Drive Alliance. Typical products available today have up to 2GB of storage and sustained read speeds of 19 MB. Some devices have a built in MP3 player.

The table below shows comparisons of plug in memories by date of introduction, size and capacity. Note that in general, the thicker the device, the more capacity.

Memory	**Date**	**Thickness**	**Width**	**Length**	**Capacity**
SIM card	1990	.8mm	15mm	26mm	Up to 1GB
Compact Flash	1994	3.3mm (Type 1PC card)	36.4mm	42.8mm	Up to 12 GB
Smart Media	1995	.76mm	37mm	45mm	8MB
Multi Media Cards	1997	1.4mm	24mm	32mm	2GB
Memory Stick	1998	2.8mm	21.5mm	50mm	2GB(8GB by 2006)
SD Cards	2000	2.1mm	24mm	32mm	2GB
xD Picture cards	2002	1.7mm	20mm	25mm	2GB

USB Flash Drives	2002	4mm (USB port size)	12mm	28 or 33mm	2GB

What this tells us is that adding imaging capability and, in particular adding camcorder functionality to cellular handsets has moved the market very quickly towards accepting 2GB as a typical plug in memory form factor and that this is likely to increase to 6 or 8 GB within the next 18 months or so.

The present problem is the disparity of form factors available which adds significantly to the complexity of selling and supporting these devices through traditional cellular phone distribution channels.

The Camcorder effect on network memory bandwidth
Even with 8GB of plug in solid state memory it can be argued that imaging bandwidth in the handset is growing faster than memory bandwidth which suggests in turn that network based storage or web based storage (or web based storage provided via the network) may evolve as a significant revenue opportunity.

Summary

Adding camcorder functionality to camera phones implies a rapid increase in both embedded and plug in memory.

Optical disks offer attractive price performance ratios but with an awkward form factor for handheld devices.They can be configured to provide sequential or random access.

Miniature hard disks also offer attractive cost and performance ratios (and can be configured for sequential or random access) but like optical hard disks, are inherently more fragile than solid state storage.

Solid state storage can be configured to provide either sequential or random access but is relatively expensive. The slimmer form factor devices are capacity constrained when compared with optical or hard disk storage. The wide choice of form factors also introduces 'hidden costs' into the sales and product support process.

The capacity constraints of solid state storage and the form factor issues of optical and hard disk devices suggest that memory in the device will lag behind the increase in imaging bandwidth. This will be particularly true for camera phones with camcorder capabilities.

This will create new opportunities for network based storage or web based storage or web based storage accessed via the network.

Deja Vu

Our HOT Topic of January 2000 '3G memory - Memory Bandwidth Added Value' identified the shift that would occur from a business added value model based on on handset resident and network resident and/or web resident storage bandwidth.

We talked then about miniature disk drives in cellular handsets and how DVD performance would drive consumer experience expectations.

The Hot Topic is archived on our web site or can be downloaded by highlighting the link above.

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