



It's Happening Now: This is the Tera Era

Table of Contents

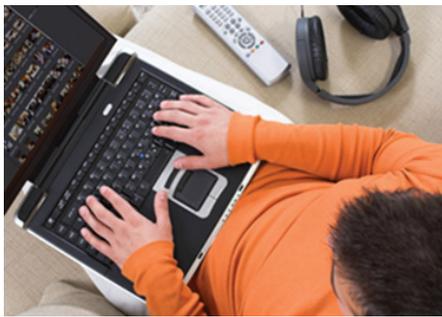
The Content of the Tera Era	1
Email and the Internet	2
Digital imaging	2
Digital audio	3
Digital video.....	3
Capacity in the Tera Era.....	4
The cost of storage space.....	5
Tera Era culture.....	5
Summary.....	7
Endnotes.....	8

It's perhaps not terribly revelatory to say that there has been an explosion in the amount of digital data recently. After all, in the decades since the term "Information Age" was first coined back in 1971, uninterrupted, unrelenting data growth has been perennial.

In the 1980s, the new Mac OS® and Windows® layout-rich documents and spreadsheets replaced simple ASCII-based files, invoking the transition from the temporary storage of the day, the 360 kilobyte (KB) 5¼-inch floppy, to much higher capacity 1.44 megabyte (MB) 3½-inch floppies. In that same decade, IBM introduced the 3380, the world's first gigabyte (GB) capacity hard drive, and it was time for our language to march forward as well. Soon, gigabyte supplanted megabyte as the common vernacular measure for storage capacity.

And the march continues. New visual and audio file types and increased computing power continue to drive storage capacities upward. But today's digital data explosion is, indeed, very different.

This is a new era of increasing storage capacity. The Information Age has given way to the Internet Age. Digital data now permeates much more of our lives and lifestyles. It spans our laptops and desktops, of



course, but also a new host of broadly used consumer devices like digital cameras, mobile phones, digital video camcorders, car navigation systems, gaming devices, digital video recorders (DVRs) and handheld audio players, each wholesaling in comparatively huge file types. And while some of these devices have internal solid state storage, many more also have hard drives. Moreover, virtually all of these devices ultimately interact with a larger hard drive storage system for the ability to access, network and share files, songs and games, video footage, digital movies or photos.

Today's digital data explosion is more of a chain reaction of explosions ignited by the needs of millions of individual digital content producers, be it photographers, gamers, music lovers, movie enthusiasts or knowledge workers. Each of these individuals contributes their files, images, music, entertainment, hobbies, curiosities, research and electronic content to the "digital shoebox" in the closet. Except now the digital shoebox reaches beyond the virtual closet doors through an Ethernet cable and out across the Internet, allowing their colleagues, friends and family—or anyone else they may choose—to share their information and interests and to communicate in unprecedented ways. And with each shared slice of life, or emailed presentation for that big meeting, digital data is copied from one hard drive to another, adding to the ongoing explosion of bytes filling the individual's hard drive and the corporation's servers.

More eye-opening still, the large files we have now are clearly just the beginning. A peek into the near-term future reveals even larger file types from uncompressed digital audio, digital television (DTV), downloadable high-definition movies and even interactive 3D video, are all on the way.

So while uninterrupted, unrelenting growth in data storage may not be a revelation, something bigger is happening underneath. At the center of this powerful story is an intersection of three points. It's a crossroads where *Culture*, *Capacity* and *Content* are colliding to create a whole new world view of data. And, once again, it has become time for our language to change.

It's now time to say goodbye to the gigabyte and hello to the terabyte.

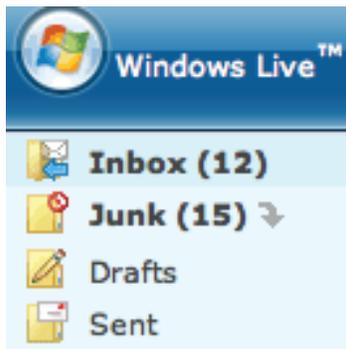
It's happening now. This is the Tera Era.

The Content of the Tera Era

In terms of raw numbers, IDC, a leading market intelligence and research firm, estimates the volume of digital data in the world at 2.81 exabytes (EB), or 2.81 million terabytes (TB) as of 2007¹. It's a volume, IDC notes, that is larger than the number of stars in the universe. More astoundingly, IDC also estimates that the amount of digital data will grow by a factor of 10 every five years, thereby surpassing the number of atoms in the universe in about 15 years.

Admittedly, those are hard numbers to internalize when looking at something as close to home as the free space on an individual computer's hard drive, TiVo® DVR hard drive or the drive in your car's onboard navigation system. Here's a different way to think about it: to the earth-bound, digital-age individual, that growth rate for digital data means that in five years their computer will need a hard drive with 10 times the capacity of their current drive. In other words, a typical 500GB internal hard drive today will likely be a 5TB drive by 2013.

Where is this explosion in digital data coming from in the Tera Era? The continued growth of traditional business data—including documents, spreadsheets and presentation slides—is steady and adding to the volume of data, of course. And that growth is augmented, often doubled on a daily basis, by today's business convention of regularly backing up and archiving it as part of corporate or personal record keeping. But that's just scratching the surface.



Email and the Internet: Take a look at something as straightforward as digital communication in the Tera Era. Email has been widely used for a couple of decades and we rarely think of it in terms of terabytes. After all, a typical piece of attachment-free email is pretty small, perhaps just a few kilobytes depending on the length of text and any graphics or other added data types. However, sign up for a Gmail™ account and Google™ will reserve roughly 6.7GB worth of storage for you at no charge (premium service with more storage is available for a fee). That's more than 600,000TB worth of tiny emails, based on Google's estimated 90 million users.

Admittedly, few of Gmail users actually fill that space. But that's Google's goal and enough Gmail users retain email correspondence records so that Google has seen fit to increase that capacity more than sixfold since February 2007. Amazingly, given that volume of email data, Gmail currently ranks only a distant third in registered webmail users behind Windows Live Hotmail® and Yahoo® Mail, both with roughly 250 million users and millions of terabytes of email data. And, of course, it's all backed up for security and redundancy, thereby generating literally millions of terabytes worth of tiny emails.

Still, email is just a small fraction of the digital data flowing over the Internet, moving from one hard drive to another. *The New York Times* reported in March, 2008² that digital traffic on the Internet is growing at a rate of 50% per year, leading to a cumulative quadrupling of digital traffic over just the next three years. It's a result of the increasing amount of rich media that has made the World Wide Web so visually engaging and diverse.

Digital Imaging: Digital photography has, for all practical purposes, replaced film and it has made sharing photos and images, whether for pleasure or commerce, as easy as a mouse click. IDC reports³ that in 2007 the total number of digital cameras and digital photo-capable cellular phones in the world has now surpassed

one billion units and that fewer than 10% of all still images were captured on film. IDC's *Worldwide 2008-2012 Digital Camera Forecast*⁴ shows that digital camera sales in 2007 reached 131 million units, up 24% from the previous year, and that 2008 sales are expected to hit 146 million units.

Naturally, a single digital photograph is much larger than a typical email, but still generally less than a megabyte or two from a consumer-oriented camera. But, just one picture a year from each of those one billion cameras adds up to some 1,000TB, averaging 1MB per photo. Indeed, just one image each week from each of the 146 million newly purchased cameras generates a weekly need for new storage of roughly 146TB, or more than 7,500TB in a year.

Digital Audio: Digital audio has created both an explosion in digital data and a shockwave through the once enormously powerful music industry. NPD Group, a leading global provider of consumer and retail market research, reports⁵ that in the U.S. in 2007 “twenty-nine million consumers acquired digital music legally... representing an increase of over five million from the previous year.” That’s actually good news for the music industry, according to NPD, because the pay-for-download model seems to be gaining popularity, while no-revenue peer-to-peer digital music sharing reached a plateau in 2006. However, physical CD sales have plummeted, along with the music industry’s former distribution model and control of the product in general.

Yet whether consumers download MP3 files or purchase a CD, digital data increasingly and ultimately resides on a hard drive. MP3 downloads go straight onto a computer’s hard drive before being uploaded to a digital audio player, but consumers do the same with purchased CDs. Ripping CDs to a hard drive in a laptop or desktop makes the music available for transfer onto the built-in solid state storage of a digital audio player, but also to popular home media centers that play music throughout the house and for accessing remotely and sharing music with friends over the Internet.

If we look into the future of digital audio, the demand for storage gets even larger. MP3 files are, by definition, compressed digital audio files that save hard drive space, but also diminish the audio quality, most overtly in the highs and lows. That’s been an acceptable trade-off over the last few years in exchange for portability, online availability and convenience. However, the audio quality does not compare with that of stereo audio CDs, and particularly not with the uncompressed surround sound audio on Blu-ray Discs™. As the temporary storage in digital audio players and the hard drive capacity both grow, consumer expectations are likely to grow with it, yielding enhanced compression technologies, more audio data and, again, a need for more storage.

Digital Video: There is no greater bandwidth and storage hog than digital video: even individual video clip files can generate gigabytes. With its report of the 50% growth rate of the Internet, *The New York Times* also reports⁶ that YouTube™ alone now uses more bandwidth than the entire Internet did in 2000. It’s a statistic that illustrates how digital video streams can be larger than just about any other type of data.

Yet YouTube files are highly compressed video and don’t come close to representing the storage needs of other types of digital video. For example, video streams recorded by a TiVo or Sky+ Box device or some other digital video recorder can eat up about 1GB of the device’s internal hard drive space for each hour of programming, even at the lowest quality setting. At higher quality settings, the recorded video can use up to four times the storage space, even for standard definition (non-high definition) material. Record a program in high-definition and you’ll use about 10 times the space of the lowest quality setting, or about 9GB per hour. Today TiVo’s highest-end recorder can capture only 30 hours of HDTV



programming, while the base model records 80 hours of standard television. Certainly that will change as HDTV reaches more homes with the U.S. transition to Digital TV (DTV) which occurs in February 2009. Not surprisingly, there is already a U.S. after-market for TiVo expansion hard drives.

Consumers with standard “DV” format or high-definition “HDV” format camcorders record video together with audio and metadata at roughly 36Mbits or 4.5MBytes per second. That’s about 270MB per minute or 16.2GB per hour, sixteen times that of a TiVo device.

These are huge capacity numbers, but hardly unapproachable by the average consumer recording just an hour of video per week or acquiring a collection of movies. Just as physical CD sales are giving way to downloaded audio, several websites — Netflix®, Blockbuster™, CinemaNow™, etc. — now afford the ability to download full-length feature films to a local hard drive. With each few minutes of camcorder footage and each movie measuring in the gigabytes, it doesn’t take much for the average home’s video collection to reach the reality of the Tera Era.

Capacity in the Tera Era

Not surprising given the proliferation of large media file types and new consumer devices that create them, the demand for the fixed storage of hard drives has never been greater. In the same report mentioned above⁷, IDC estimates that at some time during 2007 the volume of digital data exceeded the entire capacity of all available data storage.

Does that mean that that data is being lost? The answer is both “no” and “yes.” IDC notes that not all data has the same long-term storage value. For example, much of the data that flows across the Internet from web pages to browsers is either not stored locally at all or stored only as temporary files in the browser’s cache folder. Those cache files ultimately make the web faster and create a better experience for the end user.

Similarly, different email messages, images, audio files and songs or video clips all have varying degrees of long-term value. Limited storage space often forces the issue of long term value, causing users to delete files with questionable future relevance. In the Tera Era, it’s generally easier and more cost effective to simply increase storage capacity than make difficult, time-consuming choices about what data, documents, images, songs, emails and other records might be valuable in the future. The new financial and accounting disclosure requirements put forth by the Sarbanes-Oxley Act and healthcare privacy rules, like HIPAA in the U.S. make these choices even more pronounced for some of today’s corporations. Many opt to increase storage capacity to play it safe — and why not?

HGST estimates that the hard drive industry will ship more than 550 million units this year alone. Given IDC’s forecast for the rapid growth of digital data, unit shipments will continue to grow and so will the capacity of individual hard drives. Fortunately, storage industry history has shown consistent, if not remarkable growth in areal density; that is, the number of data bits per square inch of storage surface. Over the last 50 years, areal density has increased from 2,000 bits per sq. in. when IBM introduced the first hard drive (RAMAC) in 1956 to nearly 100,000,000 times that density today. Remarkably, the growth rate for areal density is growing steadily at 40% per year.

In early 2007, HGST released the first 1TB hard drive; the 3.5-inch Deskstar 7K1000, with an areal density of more than 178 gigabits per square inch. Later in 2007, HGST’s Tokyo R&D labs demonstrated a new type of nanotechnology that shows the promise of enabling 500 gigabits per square inch areal density, which is expected to quadruple current storage capacity limits resulting in a 4TB desktop (3.5 inch) hard drive and a 1TB notebook (2.5 inch) hard drive.

One of the most important technological advancements that's yielded these huge, steady jumps in areal density is Perpendicular Magnetic Recording (PMR). This replaced the prior method called Longitudinal Recording. The difference in the two approaches is the magnetic orientation of data bits on the drive's physical surface. With Longitudinal Recording, the magnetic orientation of the data bits is aligned horizontally, parallel to the surface of the disk. By re-aligning those data bits perpendicular to the disk surface—imagine dominos standing up on end as opposed to lying flat on a table—HGST has been able to fit more small crystalline grains on the same surface area. What's more, the new orientation has allowed for the use of smaller crystalline grains, as well. The result is larger and larger storage capacities on hard drives—hence, the steady migration from gigabyte to terabyte.

Looking out at the future roadmap, technologies such as Discrete Track Media (DTM), Bit Patterned Media (BPM) and Thermally Assisted Recording (TAR) all show impressive potential to allow these already tiny grains to become even tinier—which, again, will mean hard drive capacities can become even bigger. Initial forecasts show that DTM could produce a two times areal density increase, while BPM shows the potential to deliver a tenfold increase in areal densities.

The Cost of Storage Space: Why the need for such a massive hard drive as 1TB? That, too, is a question that's been asked before many times as storage capacities have increased. In the past, even a 1GB drive seemed preposterously large for the average computer user, but that was before digital photography, high definition broadcasting and MP3 players. However, early digital video users had a clear glimpse of the future. Perhaps they didn't know that consumer digital video camcorders would be ubiquitous a decade later or that YouTube would double the size of the Internet in less than a decade, but it was easy to see how quickly video could eat up a gigabyte. Was 100GB too big for the average consumer? Today, you can scarcely buy a new computer with a system drive as small as 100GB—not with a billion digital cameras, or digital audio players usurping the entire music industry, or digital camcorders generating more than that amount of data in a few hours.

Two 500GB hard drives or four 250GB hard drives would serve the same purpose as a 1TB drive, but would not have the same physical space and power requirements. There's a cost associated with the physical space of storage, whether it means needing a larger computer chassis with multiple internal bays or the physical size of a file server and the room in which it sits. More physical drives require more space, more cooling, more connections, and more power. And, of course, at the other extreme, a notebook has room for none of the above.



Tera Era Culture

By all measures, the rate at which the Internet continues to grow is astounding. Large numbers of new Internet users are now originating from nations such as Brazil and China. And between 2000 to 2008, the Middle East had an Internet user growth rate of 1,176.8% according to www.internetworldstats.com. Around the globe, from Africa to Australia, thousands of new users are flocking to the Internet every hour.

Many worldwide studies indicate that the most prevalent activity online is still email, though search—whether that's for news, sports scores, weather, driving directions, products to buy, travel information or health advice—is also a massive driver of Internet usage.

And while booking travel online is, today, a fairly mature Internet application, the relatively new Internet activities such as watching, sharing or downloading videos are steadily growing in popularity. Many believe

that social networking sites such as FaceBook™, MySpace.com®, Friendster and others have only just begun to demonstrate their true potential for driving Internet engagement, communities and activism.

As Internet usage continues to grow, and exponentially, on a daily basis, the shapes, sizes, colors and capabilities of the devices we now use to connect online are also growing and morphing at an unprecedented pace. In turn, this evolution is having a huge impact on the volume and value of data being created, accessed, shared and stored as we move throughout our wired world.

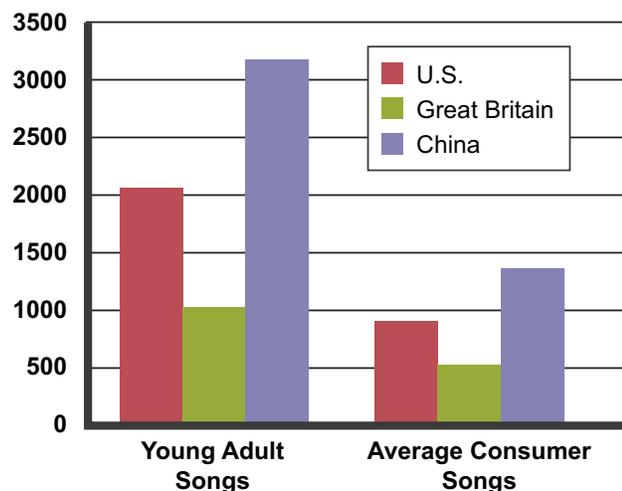
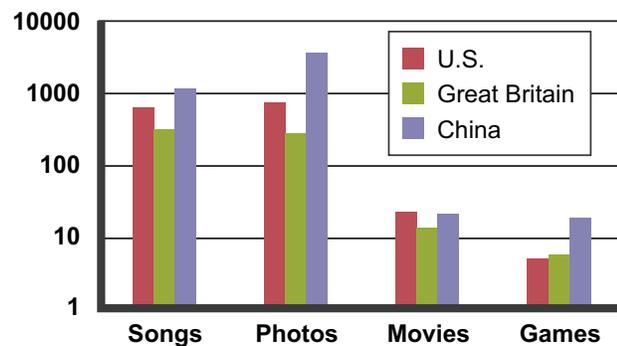
A study conducted in May 2008 by KRC Research and HGST⁸ evaluated consumer behavior in Great Britain, China and the U.S. with regard to usage of digital devices, the type and amount of digital content being acquired and stored and the actual dollar values and “emotional” connections consumers attach to their burgeoning digital content collections. The findings revealed some interesting insights.

Across the globe, the study validated, the number of digital devices being used by consumers is proliferating apace. In particular, mobile phone cameras and MP3 players are hugely on the rise, but more laptops, digital cameras, digital video recorders, portable movie players and PDAs continue to penetrate every home around the world. As the number of devices grows, the volume of stored material is also steadily increasing, as these figures from the KRC Research and HGST study show:

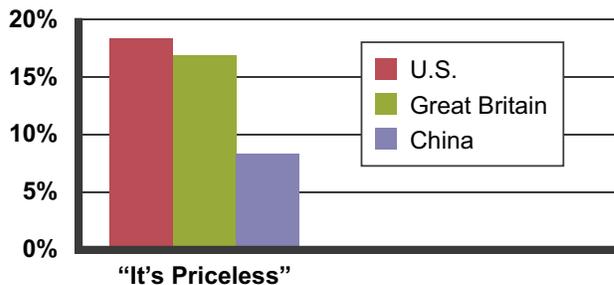
- The typical British consumer now stores 502 songs, 466 photos, 14 films and eight games
- In the U.S., consumers store, on average, 907 songs, 924 photos, 25 movies and seven games
- The averages for consumers in China: 1,311 songs, 3,083 photos, 24 movies and 22 games

Young adults (aged 18-24) around the world possess voracious appetites when it comes to digital media, particularly music. Young adults in China have, on average 3,195 songs, while their peers in the U.S. store about 2,065 songs and their contemporaries in Great Britain store 1,056 songs.

Not only has the volume of data stored by consumers steadily increased over time, the value of this content is prized more highly than ever. For example, the May 2008 KRC-HGST study revealed that U.S. consumers have an average of \$1,660 worth of digital content per person, up 46% from the average just three years



ago when HGST and KRC Research completed the same study. Chinese consumers each own stored content worth about ¥4,772 (US\$691). Consumers in Great Britain have around £600 (US\$1,185) worth of stored collections.



Consumers also display a strong emotional connection to their data. The KRC-HGST study found that half of the U.S. women who own digital devices (46%) said their data is either *priceless* or *valuable*. And, when asked, consumers frequently replied that they wanted “*so much storage that it was never an issue*” (25% in U.S., 28% in China and 20% in Great Britain), which would seem to reflect the sentiment that, similar to closet space, one can never have enough hard drive storage space.

The surveys and statistics all provide evidence that the “connected generation”—in fact, some even now call this the “hyper-connected generation” due to the amount of time we spend in the wired world, but also the broad array of devices we now use to remain connected—is quite real and quite prevalent. The reality is that for most of us, the notion of life without computers and handhelds is, quite simply, unthinkable.

TDG, a research firm, has estimated⁹ that personal content generated by consumer electronics will grow to almost 2TB by 2010. That number is consistent with IDC’s prediction of a tenfold increase over the next five years. Today, a consumer will buy a new computer with an internal hard drive ranging in size from 250-750GB and today that might seem like it will be enough. Yet the predictions of these two research firms suggest that in just a couple of years, those newly purchased computers will have drives ranging from 1-3TB. And the consumer will likely fill it with uncompressed digital audio, high-definition movies, camcorder footage, and digital photographs.

Summary

At its heart, the Tera Era is a technology phenomenon. The storage capacities of hard drives continue to set new records due to major advancements and innovations like Perpendicular Magnetic Recording, a daunting technological process the storage industry pursued steadily for decades and ultimately achieved.

These impressive accomplishments by the storage industry have enabled other technology sectors to advance as well, and today hard drive storage capacity is itself at the heart of many applications that are now so ingrained in our daily lives it’s easy to take them for granted. For example, Google is often cited as one of the world’s largest hard drive consumers. Yet Google would simply not be Google without the high capacity, high speed, highly reliable hard drives that power its many services.

But it’s not just capacity for capacity’s sake. The amazing array of content we now expect to have at our fingertips at a moment’s notice is staggering. And the speed with which we demand that content is also amazing. Still images, moving images, digital video and voice, as well as our favorite websites, TV shows and films—all in high definition—have become part of our collective lives. We expect them all and we want them now. And whether these items reside on a handheld, on a laptop or in the “cloud” of digital data stored somewhere else, at some point along the journey they are being created, accessed, archived, backed up and possibly even “mirrored” on a hard drive.

The Tera Era is also a cultural event. It is happening in our homes, at the office and at school. And it's happening everywhere else we go in our communities. In this new culture, we place a priority on information access that is unlike anything prior generations could have imagined. And we want to share that information. In this new culture, we share photos, home videos, music, research, advice, opinions, information and commerce. What's more, we're not just sharing this information with friends and family, we're connected 24x7 and we're sharing it with the world—with virtually anyone who shares our interests.

Not only do we want the computing power and flexibility to share our digital work and personal lives with everyone and anyone we choose, but we want to be able to access our digital "stuff" from anywhere in the world at any time. In an Internet café in Italy booking a hotel for the next city on the journey? Absolutely. On a business trip to Dubai accessing the team's report through a VPN? You bet. And no matter where we are in the world or what time it is or who we want to share our data with, that data ultimately still resides on a hard drive...somewhere.

The other cultural element in the Tera Era, of course, is language. Just as in the past when it was time for kilobyte to be replaced by megabyte and then for gigabyte to replace megabyte, the time for change has come again.

It's now time to say goodbye to the gigabyte and hello to the terabyte.

It's happening now. This is the Tera Era.

For more information about the Tera Era, visit

www.hgst.com/TeraEra.

Endnotes

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One GB is equal to one billion bytes and one TB equals 1,000 GB (one trillion bytes) when referring to hard drive capacity. Accessible capacity will vary from the stated capacity due to formatting and partitioning of the hard drive, the computer's operating system, and other factors.

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