Methuselah Remembers
What to Keep, How to Keep it

Thomas Coughlin
Coughlin Associates
www.tomcoughlin.com
Methuselah Remembers

Days slip by like space-time between the greasy fingers of history

Young ones condemned to partial memories, recent events

Children’s images, favorite stories—lost like ancient mystery

Retaining more perhaps the victors won’t determine controversial arguments

Methuselah remembers, he has the record, preserved and maintained in formats that won’t die!
Outline

• Drivers for Storage in the Home
• The Future of User Generated Content
• Organizing Digital Libraries
• Conclusions
Drivers for Storage in the Home
Demand for Storage is Extremely Elastic

- Based upon HDD market trends over the last 5 years

<table>
<thead>
<tr>
<th>Capacity Increase (2003-2008)</th>
<th>189 EB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revenue Increase (2003-2008)</td>
<td>$13.6 B</td>
</tr>
<tr>
<td>ASP Decline (2003-2008)</td>
<td>17.6%</td>
</tr>
<tr>
<td>$/GB Decline (2003-2008)</td>
<td>$1.72</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ratio Capacity Increase/ASP Decline</th>
<th>10.77</th>
<th>Exabytes/$ price decline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ratio Drive Shipments to ASP Decline</td>
<td>16.75</td>
<td>M units per $ decline in ASP</td>
</tr>
<tr>
<td>Ratio Capacity Increase per $/GB Decline</td>
<td>110.07</td>
<td>Exabytes per $/GB decline</td>
</tr>
<tr>
<td>Exabytes per % $/GB Decline</td>
<td>2.08</td>
<td></td>
</tr>
<tr>
<td>% Capacity Increase to % $/GB Decline</td>
<td>1,890%</td>
<td></td>
</tr>
<tr>
<td>Ratio Drive Shipments per $/GB Decline</td>
<td>171.22</td>
<td>M units per $/GB Decline</td>
</tr>
<tr>
<td>M Units per % $/GB Decline</td>
<td>3.23</td>
<td></td>
</tr>
<tr>
<td>% M Unit Increase per % $/GB Decline</td>
<td>123.4%</td>
<td></td>
</tr>
</tbody>
</table>
Annual HDD Shipment and Shipped Storage Capacity

HDDs Shipped Annually (M)

Storage Capacity Shipped Annually (EB)

© 2008 Coughlin Associates
Cost for Storing 1 PB for 20 Years

- As a guess say in 2008 1 PB of storage using 1 TB HDDs with proper environment, racks, HVAC, etc. cost about $166,000 up front and $16,000 per year to maintain.
- When you update this say in 5 years you would have another $28,000 in capital and $8,000 in annual operating expenses.
- It might be that this trend could continue with ever lower costs with time.
- Of course the costs can vary a lot depending upon many factors and sources.
- Over 50% of the total cost of preserving the 1 PB of content is in the first year.
Storage and streaming bandwidth for music and video formats

<table>
<thead>
<tr>
<th>Format</th>
<th>Bandwidth (Mbps)</th>
<th>Storage Capacity/Hour (GB)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MUSIC FORMATS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MP3</td>
<td>~0.128</td>
<td>~0.576</td>
</tr>
<tr>
<td>Loss-less Compressed CD</td>
<td>~0.700 min.</td>
<td>~0.315</td>
</tr>
<tr>
<td>CD Quality</td>
<td>1.400</td>
<td>0.630</td>
</tr>
<tr>
<td>DVD Audio</td>
<td>9.600 max.</td>
<td>4.320</td>
</tr>
<tr>
<td><strong>VIDEO FORMATS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Format for iPOD (MPEG-4)</td>
<td>~0.750</td>
<td>~0.337</td>
</tr>
<tr>
<td>DVD MPEG 2</td>
<td>11.080</td>
<td>2.700</td>
</tr>
<tr>
<td>MPEG 4</td>
<td>~1.400</td>
<td>~0.630</td>
</tr>
<tr>
<td>SDTV</td>
<td>~8.000</td>
<td>~2.000</td>
</tr>
<tr>
<td>Blu Ray/HD DVD</td>
<td>36.550</td>
<td>3.750</td>
</tr>
<tr>
<td>HDTV</td>
<td>~19.300</td>
<td>~8.890</td>
</tr>
<tr>
<td>Ultra-HDTV</td>
<td>~295.000</td>
<td>~133.000</td>
</tr>
</tbody>
</table>
Home Entertainment Accumulated Digital Content per Average Household

- Even an average household will have Terabytes of commercial data in the next decade.
- As content resolution increases the required storage capacity must increase as well.

**Consumer Survey on Digital Storage in Consumer Electronics** (Coughlin Associates, January 2008)

<table>
<thead>
<tr>
<th>Year</th>
<th>HD Television</th>
<th>SD Television</th>
<th>HD Video Download</th>
<th>SD Video Download</th>
<th>Music</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>106.36</td>
<td>78.07</td>
<td>-</td>
<td>6.71</td>
<td>0.58</td>
</tr>
<tr>
<td>2007</td>
<td>234.00</td>
<td>164.66</td>
<td>2.28</td>
<td>32.74</td>
<td>0.88</td>
</tr>
<tr>
<td>2008</td>
<td>433.75</td>
<td>257.80</td>
<td>8.80</td>
<td>58.37</td>
<td>1.19</td>
</tr>
<tr>
<td>2009</td>
<td>779.00</td>
<td>353.80</td>
<td>22.89</td>
<td>83.19</td>
<td>1.50</td>
</tr>
<tr>
<td>2010</td>
<td>1,336.00</td>
<td>447.65</td>
<td>49.08</td>
<td>106.62</td>
<td>1.82</td>
</tr>
<tr>
<td>2011</td>
<td>2,008.00</td>
<td>524.29</td>
<td>96.15</td>
<td>127.60</td>
<td>2.13</td>
</tr>
<tr>
<td>2012</td>
<td>2,806.00</td>
<td>582.30</td>
<td>186.22</td>
<td>143.34</td>
<td>2.45</td>
</tr>
<tr>
<td>2013</td>
<td>3,728.00</td>
<td>621.69</td>
<td>330.32</td>
<td>152.49</td>
<td>2.76</td>
</tr>
</tbody>
</table>
Accumulated Digital Content in 2013
Per Average Household

- HD Television: 77%
- SD Television: 13%
- HD Video Download: 7%
- SD Video Download: 3%

Accumulated Digital Content Per Average Household

<table>
<thead>
<tr>
<th></th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal Data</td>
<td>22</td>
<td>34</td>
<td>51</td>
<td>72</td>
<td>99</td>
<td>132</td>
<td>171</td>
<td>214</td>
</tr>
<tr>
<td>Retail Home Video</td>
<td>321</td>
<td>417</td>
<td>522</td>
<td>637</td>
<td>770</td>
<td>945</td>
<td>1183</td>
<td>1502</td>
</tr>
<tr>
<td>Gaming</td>
<td>12</td>
<td>29</td>
<td>52</td>
<td>83</td>
<td>127</td>
<td>187</td>
<td>270</td>
<td>384</td>
</tr>
<tr>
<td>Home Backup</td>
<td>32</td>
<td>98</td>
<td>195</td>
<td>333</td>
<td>523</td>
<td>781</td>
<td>1254</td>
<td>1920</td>
</tr>
<tr>
<td>Home Entertainment</td>
<td>192</td>
<td>435</td>
<td>760</td>
<td>1240</td>
<td>1941</td>
<td>2759</td>
<td>3720</td>
<td>4835</td>
</tr>
</tbody>
</table>

•Consumer Survey on Digital Storage in Consumer Electronics (Coughlin Associates, January 2008)
Total Storage in American Homes in 2013

- Assume 100 M American Households, each with an average of 9 TB of storage
- This is 900 M TB of storage or 900 Exabytes of storage in US households by 2013
- Of this amount ~21 Exabytes are user generated content
- Some households will have much more than 9 TB, by the next decade there will be PB households (at least 1,000 TB)
- Total user generated content capacity will exceed commercial content by the end of this decade
By 2013 over 600 Exabytes of storage shipped annually for CE applications

Digital Storage in Consumer Electronics
2008 (Coughlin Associates, release January 2008)
The Future of User Generated Content
Block diagram of personal memory assistant showing major component functions

Digital Storage (>10 TB)

Experience Capture
HW and SW
(capture metadata includes location and time)

Life Log Device

Personal Map of Experiences, Places and Times

Life Search Function

User Interface and privacy protection

Off-line processing in home storage utility

Wireless background search and compilation

Such a device could require 10 TB of storage capacity on-board!
Life Log 2008

- This device only has 4 GB of flash memory at present
- This device “wants” a high capacity hard drive so it can capture higher resolution content
- Plenty of room for evolution of these types of products
Affect of Personal Recording on Home Storage Demand

Accumulated Personal Digital Content in 2015
Per Top 10% Household with 1 life-log

- Photos 92%
- SD Home Video 2%
- Email 1%
- HD Home Video 1%
- Life Log 4%

Digital Storage in Consumer Electronics 2008
(Coughlin Associates, release January 2008)
Organizing Digital Libraries
Digital Library Challenges

- Preservation from Disaster (Library of Alexandria Protection)
- Include UGC as well as commercial or state content preservation (Biggest source of content in future)
- Must be available for a long time in the future even by a civilization much reduced from ours (Dark Age Protection)
Preservation from Disaster

- The library of Alexander contained much of the knowledge of the ancient world
- Many of the writings at the Alexandrian library were destroyed in a series of fires
- A digital library must protect the content from catastrophic disaster
Drivers of Consumer Digital Storage

• Ease of content creation: Being built into many modern consumer devices e.g. cameras, digital recorders—Growth of User Generated Content (UGC)

• Content Sharing: Easy to multiple digital content 1,000 or more through on-line sharing.

• New methods of creating metadata automatically so content can be used easier.

• New ways to share and coordinate data around the home.
Civilization Reboot

• The remains of libraries have been the basis of the rebirth of civilization
• A digital civilization may leave little physical or analog content that can be read without special equipment and/or software
• How can we create a civilization reboot capability with digital content?
• Need special reboot material (digital Rosetta stone)
  – Visual instructions on how to build a microscope
  – Microscopic visual language instructions and instructions on building the hardware and software to read digital content
  – Digital content, including guide to where to find more digital content
  – Many copies of this digital Rosetta stone to ensure survival
Rosetta Disk

- The Rosetta disk is the physical companion of the Rosetta Digital Language Archive, and a prototype of the Long Now Foundation’s 10,000 year library concept.

- The disk surface is etched with a message written in 8 major world languages which if magnified 1,000 times contains over 15,000 pages of language documentation.

- http://www.rosettaproject.org
LOCKSS

• LOCKSS (Lots of Copies Keep Stuff Safe), based at Stanford University Libraries, is an international community initiative that provides libraries with digital preservation tools and support so that they can easily and inexpensively collect and preserve their own copies of authorized e-content.

• http://www.lockss.org/lockss/Home
Metadata

• Metadata--information about a file or data object that allows easier search and use of the content
• Currently most metadata is entered manually
• Automated generation of metadata using content robots and sensors
  – such as automated GPS location recording on pictures and video
  – speech recognition and translation to text
  – image and video recognition and recording of the indexing information
  – Metadata into everyday life
• With inexpensive storage, metadata could become unlimited,
  – making the original content easier to find and use
  – enabling enormous capability to create single frame content analysis
  – also cross-correlation information between frames or even between many types of content and across multiple files
  – Enables analyzing the use of content by an individual to create unique tailored metadata
Natural Information Preservation
(70 M Year Old T. Rex Soft Tissue)

Dinosaurs Had White Meat!
What Can We Know?

• Magnetic recording technology may allow up to 50 Tb/in² (50 × 10^{18} b/in²)

Source: Information in the Holographic Universe, August 2003 Scientific American
Conclusions

• The demand for storage for CE applications is very elastic—if they have more storage they will use it!
• User generated content will be greater than commercial content by the end of the decade.
• Future digital libraries must include some user generated content.
• Future digital libraries must protect against disasters and allow for civilization reboots.
• Automated metadata generation will be key to organizing, protecting and using digital libraries.
Sources

- Consumer Survey on Digital Storage in Consumer Electronics 2008, Coughlin Associates
- Presentations at 2006, 2007 and 2008 Storage Visions Conferences (www.storagevisions.com) and CES

For more information go to the tech papers section of www.tomcoughlin.com
Thanks