Outline

Seagate R&D
Storage Intelligence
Seagate

• World’s leading provider of hard disc drives
  – Q3 FY2006*: 29.4M drives shipped; revenue of $2.3B

• Provides drives for Enterprise, Desktop, Mobile Computing and Consumer Electronics applications
  – Share leader in Desktop and Enterprise
  – 28% overall market share: highest in the industry
  – Broadest product offering in the industry – Largest customer base

• Ownership and vertical integration of critical technologies: heads, media, motors, and printed circuit boards

• Approximately 49,484** employees worldwide

• Major operations and sales offices in 15 countries

• * Forbes Magazine 2006 “Company of the Year”
Digital Lifestyle Fuels Storage Opportunity

- Convergence of digital content
- Broadband penetration across markets and devices
- Mainstream adoption of storage reliant consumer devices
- Improved content sharing among consumer products
Seagate’s Product Line - 2006

<table>
<thead>
<tr>
<th>Handheld</th>
<th>Gaming</th>
<th>Auto</th>
<th>DVR</th>
<th>Notebook</th>
<th>Desktop</th>
<th>External</th>
<th>Enterprise</th>
</tr>
</thead>
</table>

8 Markets  
31 Products  
97% Revenue Access
R&D Investment

Seagate 12/04 - 12/05: 714

Competitors 9/04 - 9/05:
- KMAG: 46
- WDC: 255
- MXO: 298
- STX: 0

Intelligent Storage 2006
Seagate Research Mission

To create, develop and evaluate advanced recording systems, components, materials, processes and technologies for future storage products that will address market and customer needs 4-10 years in the future.
Areal Density Growth

- Late 1990s – superparamagnetic limit demonstrated through modeling
- Longitudinal recording reaching areal density limits
- Perpendicular expected to extend to 0.5-1 Tb/in²
- Additional innovations required at that point
  - heat-assisted recording
  - bit patterned media recording
- Areal Density CAGR 40%
- Transfer Rate CAGR 20%
Magnetic domains oriented in the direction of travel of the head.

Soft underlayer “mirrors” write head and makes it possible to write domains much closer together.
State-of-the-Art Longitudinal vs. Perpendicular Recording

2.5 inch Momentus Notebook Drive

Longitudinal

- Drive Capacity (GB): 120
- Number of Discs: 2
- Capacity (GB/disc): 60
- KTPI (avg): 123
- KBPI (nom): 780
- Product Areal Density: 95.9
- Transfer Rate (MB/sec): 460
- RPM: 5400
- Seek Time (ms)
  - Average Read: 12.5
  - Average Write: 14

Perpendicular

- Drive Capacity (GB): 160
- Number of Discs: 2
- Capacity (GB/disc): 80
- KTPI (avg): 147
- KBPI (nom): 885
- Product Areal Density: 130.1
- Transfer Rate (MB/sec): 520
- RPM: 5400
- Seek Time (ms)
  - Average Read: 10
  - Average Write: 11
HAMR can theoretically extend areal density beyond 10 Tbps/i
Optimizing system-level reliability
- reliability mgmt through workload-specific failure & recovery models
- extends system-level performance

Data-aware processing
- understand and optimize for the *structure* of stored data via common data types – video, audio, email
- in future – actually process content

Integrated and interoperable security
- seamless data protection across the entire Seagate product line
- content protection (DRM) in CE
- privacy-enhanced drives and secure erase in desktop / notebook
- encryption, secure erase, and audit trails in archive / nearline

OSD (Object-based Storage Devices)
- space mgmt inside drives
- interface standard ratified Sept 2004
- external demo IBM/Seagate in Apr 2005

DriveTrust (on-drive security)
- disc drives as a core trusted component
- dCards – drive-enhanced smart cards
- full-disc encryption for secure delete
- drive locking – links drives to hosts
- Momentus FDE announced June 2005
OSD Technology Demonstration; April 2005

OBJECT-BASED STORAGE DEMONSTRATED AT THE SUBSYSTEM LEVEL AND AT THE DISC DRIVE LEVEL

This demo shows IBM xSeries 335 1U Application and Metadata Servers running an IBM Research shared file system with Object-Based Storage Device (OSD) support. This file system demonstrates OSD in two ways:

- It sends objects over Ethernet to an IBM OSD Array, which then stores the objects on internal block-based hard drives. This demonstrates the viability of this protocol at the iSCSI and controller level.
- It sends objects through a standard Emulex FC HBA with enhanced drivers to an array of Seagate OSDs, demonstrating the viability of the protocol at the FC fabric and disc level.

Both systems run over existing FC and Ethernet networks.

Learn more. Obtain the Object-Based Storage technology paper at: http://specials.seagate.com
Security Device Overview

ATA Interface

LBA0

User Addressable Space

Max LBA

System sectors

ATA Commands

RD/ WR

Trusted Send/Receive

SeaCos commands

dCards
Security – Initial Products with DriveTrust

Full Disc Encryption
- Laptop Loss or Theft
- Instant Disk Erase Re-Purposing

DriveLocking Feature
- Simple form of content protection
- Drive is mated to particular machines

Eventually ALL Seagate Drives
3DES or AES128 Crypto Hardware

PVR
Invention of the Disk Drive – 1956

IBM 305 RAMAC
(Random Access Method of Accounting and Control)

5 Megabyte Capacity
50 disks, each 24” in diameter
2,000 bits/in^2 storage density

This drive could store
2,000 pages of text with
2,500 characters per page
Modern 2.5” Disk Drive – 2004

Seagate Savvio 10K.1

This 10,000 RPM drive has a storage capacity of 73.4 Gbytes

Can read or write the complete works of Shakespeare, 15 times, in less than a second

Can read or write more than 200 records, spread randomly over the disc, in less than a second
## Technical Specifications – Then and Now

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>Capacity</strong></td>
<td>~ 5 MB</td>
<td>73.4 GB</td>
<td>15,000 x</td>
</tr>
<tr>
<td><strong>Areal Density</strong></td>
<td>2000 bits/in²</td>
<td>68 Gb/in²</td>
<td>34,000,000 x</td>
</tr>
<tr>
<td><strong>Disks</strong></td>
<td>50 @ 24” dia</td>
<td>2 @ 2.5” dia</td>
<td>240 x</td>
</tr>
<tr>
<td><strong>Price</strong></td>
<td>$50,000</td>
<td>&lt;$1000</td>
<td>x / 50</td>
</tr>
<tr>
<td><strong>Price/MB</strong></td>
<td>$1,000</td>
<td>&lt;$0.02</td>
<td>x / 730,000</td>
</tr>
<tr>
<td><strong>Spindle Speed</strong></td>
<td>1,200 rpm</td>
<td>10,000 rpm</td>
<td>8.3 x</td>
</tr>
<tr>
<td><strong>Seek Time</strong></td>
<td>600 ms</td>
<td>4.1 ms</td>
<td>x / 140</td>
</tr>
<tr>
<td><strong>Data Rate (burst)</strong></td>
<td>10 KB/s</td>
<td>94 MB/s</td>
<td>9,400 x</td>
</tr>
<tr>
<td><strong>Power</strong></td>
<td>5000 W</td>
<td>12 W</td>
<td>x / 740</td>
</tr>
<tr>
<td><strong>Weight</strong></td>
<td>~ 1 ton</td>
<td>1.9 lb</td>
<td>x / 1,800</td>
</tr>
</tbody>
</table>
Storage Intelligence & Scalability

OSD, Active Disc’s & Diamond @ CMU
Mercury System @ University of Washington
SQUAD @ DTC
Associative Storage
(joint project w/ Intel Labs – Pittsburgh)

Expanded interface to storage
• allow search primitives (filters) to run on the storage side of the interface
• for searching large data sets
  • find the needle in the haystack
• datatype-specific searching

- streets & buildings
- volcanoes on Venus
- galaxies
- landcover

video/audio extraction
The *Mercury* System: Exploiting Truly Fast Hardware in Data Mining

![Diagram of system architecture](image)


<table>
<thead>
<tr>
<th>Application</th>
<th>Disk-limited speedup</th>
<th>Logic-limited speedup</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exact text search</td>
<td>1.1</td>
<td>6.4</td>
</tr>
<tr>
<td>Approx. text search</td>
<td>12</td>
<td>31</td>
</tr>
<tr>
<td>Biosequence search</td>
<td>50</td>
<td>125</td>
</tr>
</tbody>
</table>

Table 1. Application speedups.
Boston Barkeep

Using a scanner that allows him to read and capture data from the magnetic stripes on the back of Massachusetts driver’s licenses, a barkeep in Boston has built a database of personal information—including driver’s license number, height, weight, date of birth, eye and hair color, address, and, in some instances, Social Security number—on his patrons.6 Without the state-issued driver’s license, collecting such data on individuals would be expensive and cumbersome and would meet with privacy objections. The introduction of machine-readable cards and the market availability of readers have increased the chances that personal information would be captured, reused, and potentially sold. The introduction of technology—without any change in policy—has led to practices that are more invasive of privacy.


Hospital Employee’s Daughter

The 13-year-old daughter of a hospital employee took a list of patients’ names and phone numbers from the hospital when visiting her mother at work. As a joke, she contacted patients and told them that they had been diagnosed with HIV. (“Hospital Clerk’s Child Allegedly Told Patients That They Had AIDS,” The Washington Post, March 1, 1995, p. A17)
Seagate: How to Secure a Drive?

Content Protection – CP – secures content for personal privacy, enterprise security, & copyrighted content.

Drive Hardening prevents an attacker from getting data from the drive through a software or physical attack.

Full Disc Encryption scrambles the contents of a drive, making them unreadable without the appropriate key.

Drive Locking ties a drive to a particular machine or group of machines.

Diagram: Technology hierarchy with layers: CP, Drive Hardening, Full Disc Encryption, Drive Locking, and Value of Secrets Protected.
TCG – Brief Tutorial

Changing computing hardware/software to protect against network attacks

Old security models broke when the Internet happened.

New Model: SIGNING

Same as you signing your name on a contract. Exactly the same. I can know Microsoft Signed, or Seagate Signed and they can know they signed.

Security Model: Intel, AMD, Seagate, HP, IBM, Sun, Apple, etc., build the hardware and software needed to guarantee that programs are protected on the same machine. Everything is signed that is used, and you know who signed it all, and you trust them.
TCG Vision – Every piece of hardware & software is validated so can’t be a Trojan
Summary

Current Research
• Selectively positioning intelligence closer to storage
• Storage that reveals only what you are allowed to use

Long Term Research
• Ten – Twenty Year Outlook…?
Twenty Year Outlook…
Academia’s & Industry’s Challenges

Private & Public Funding
Collaboration & Imagination
Willpower & Determination