Trend of Technological Evolution by Innovation in Hard Disk Industry

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What is the Innovation?

The purpose of the enterprise is a creation of the customer. Therefore, the enterprise has only 2 and 2 basic functions. It is marketing and an innovation. Only marketing and the innovation bring forth fruit.

from “Management” . Written by P.F.Drucker

The technology is a process where manpower, the capital, the raw material, and information on the organization are changed into a high product and the service of value.

The innovation is to change the technology.

from “The Innovator’s Dilemma" . Written by C.M.Christensen
What is the Innovation?

Disruptive Innovation and Sustaining Innovation
Definition of Dr. Christensen

- **Disruptive Innovation**
  A quite different idea from a past and standard is brought in the market.
  It is supported by a new minor user who is not the main current of the industry.
  Cost competitiveness is high because it is born in the low-end market.

- **Sustaining Innovation**
  Pursuit of performance requested in high-end market
  It aims at the performance gain of an existing product by a new technology.
  Because the performance gain is continued, customers' needs might be exceeded.
History of Storage Disk Drive

1956 RAMAC
- 5 Mbytes
- Fifty 24" disks, 1200 RPM
- 2000 bits/in2

58 years ago

Total weight 2t

1986 3380
- 1.2 GB >1000W
- Nine 14" disks, 3600 RPM
- 12 Mb/in2

30 years ago

Total weight 58Kg

2014 Now

Device HDD that head flies on disk, records, reads data on disk, and plays. This structure has been succeeded without changing.
History of Storage Disk Drive

1st era:
Mainframe era
- 24" 14"

2nd era:
Minicomputer era
- 8" 5.25"

3rd era:
PC era
- 3.5" 2.5"

4th era:
Consumer era
- 3.5" 2.5"
- 1.8" 1"<1"

MP3 HDD since 2001
DVD/HDD recorder since 2002

M Units - Annual HDD Shipments

Trend of Demand Capacity and Supply Capacity

Short dashed line: Capacity practice of product
Solid line: Demand capacity of market

HDD capacity

1000

100

10

1

74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95

Year

14 inch HDD
Mainframe
8 inch HDD
Minicomputer
5.25 inch HDD
Desktop
Portable & Notebook market
3.5 inch HDD
2.5 inch HDD
1.8 inch HDD
PDA
SSD

C.M from "Dilemma of innovation". Written by Christensen.
Disruptive Innovation

Disruptive Innovation: Architecture that miniaturizes HDD size

Innovator in each HDD industry

<table>
<thead>
<tr>
<th>HDDサイズ</th>
<th>イノベーター</th>
<th>開発年度</th>
<th>初期顧客市場</th>
</tr>
</thead>
<tbody>
<tr>
<td>14 inch</td>
<td>IBM</td>
<td>1975</td>
<td>メインフレーム</td>
</tr>
<tr>
<td>8 inch</td>
<td>シュガート、マイクロポリス、プライアム</td>
<td>1978</td>
<td>ミニコンピューター</td>
</tr>
<tr>
<td>5.25 inch</td>
<td>シーゲート</td>
<td>1980</td>
<td>デスクトップパソコン</td>
</tr>
<tr>
<td>3.5 inch</td>
<td>コナー</td>
<td>1984</td>
<td>ポータブル・パソコン</td>
</tr>
<tr>
<td>2.5 inch</td>
<td>ブレーリーデック、コナー</td>
<td>1989</td>
<td>ノートブック・パソコン</td>
</tr>
<tr>
<td>1.8 inch</td>
<td>多数</td>
<td>1992</td>
<td>PDA</td>
</tr>
</tbody>
</table>

Trend of Evolution (written by D.Mann from "Systematic Technical Innovation")

Focus of Purchase of Customer

Performance -> Reliability -> Convenience -> Price

In HDD, a large-scale Disk size was always advantageous from the viewpoint of performance each other.

However, when a subordinate position model met the demand of the customer with a constant, the focus of the selection of the customer was shifted to reliability, convenience, and the price, and a small Disk model came to occupy the market.
Disruptive Innovation

- In a present HDD industry, the miniaturization more than this is impossible. That is, the low-end type disruptive innovation cannot be hoped for.

- Is it a road where the shift to the new market type disruptive Innovation to survives?

New value is produced a dimension different from the past.

From "Solution to the innovation"
Written by C.M.Christensen
Sustaining Innovation

Sustaining Innovation: Improvement technology of recording density

1. Slider technology

   Ferrite head > Thin film head > MR head > GMR head > TMR head

2. Disk technology

   Magnetic disk > Thin film magnetic disk > Vertical magnetic disk

3. Clearance between slider and disk

   Micron > Submicron > Nano > 1 nm or less

The trend of common evolution to these technologies is "Evolution from the macro to the Nano scale."

It aims at making minutely about the recording density and the FH clearance further.
Improvement of Recording Density by Slider (Mb/in²)
Improvement of Recording Density with Disk

Each technology of the disk draws S curve severally.

- **Longitudinal Magnetic Recording (LMR)**
- **Perpendicular Magnetic Recording (PMR)**
- **Discrete Track Recording (DTR)** (1-2 generations, prepare for BPM)
- **Bit Patterned Recording (BPM)**
- **Thermal Assisted Recording (TAR)** (probably on BPM)

- **130 Gbit/sq.in.**
- **1000 Gb/sq.in.?**
- **5 Tb/sq.in.?**
- **10 Tb/sq.in.?**

- **10,000 Gb/in2 = 10 Tb/in2**
- **50 TB 3.5-inch drive**
- **12 TB 2.5-inch drive**

- **50 Years**
- **>50 Million increase in areal density**
Improvement of Recording Density by Flying Height

The trend of further evolution is used for a decrease in the clearance between recent slider disks.

Because the clearance has approached at a molecular level, the control technology of more advanced of flying height (FH) has become indispensable.

To always adjust to a complex user environment, it came to be able to manage.

Trend of evolution: Control

Straight line control action

> When producing, FH is managed.

Control action that uses mediation

> The user environment is assumed and FH is set.

Introduction of feedback

> FH adjustment that uses TFC in user environment

Intellectual feedback

> The temperature, the atmospheric pressure, gravity, and potential are perceived and it feeds back.
Principle of Thermal Flying Height Control (TFC)

Structure of head and disk in HDD

Diagrammatic illustration of head and disk in HDD
Conclusion

1. The disruptive Innovation in the HDD industry was a simple miniaturization according to the downsizing of the system. However, this low-end type disruptive Innovation comes to the limit. Groping for the next, disruptive Innovation starts.

Trend of evolution: Focus of purchase of customer (performance -> convenience -> reliability -> price)

2. Maintain tracks of the performance gain always established to high-tech development. In a word, it has aimed to improve the performance, and to get to the area where the rate of profit is high. It did not destroy such a technology though there were a lot of difficult one. The development, the target that the customer suggested was pursued.

Trend of evolution: Evolution from macro to Nano scale / Control

3. The manufacturer where results existed had technology that led the innovation that continued. However, it was an upstart that it took the lead, it developed, and had adopted destroyed technology. However, the upstart did not necessarily survive in the HDD industry. As for this, a part of technology to improve the recording density is thought that it is a reason that one company (IBM) was leaving others far behind until about 2000.
Aiming at the future

- **Approach 1 in HGST Japan**

**Innovation Harvest**

- The fence in the development field is exceeded and the idea in-house is recruited.
- Regular review of specialist and executives
- An excellent idea is an object of the commendation.
- Securing of budget frame for idea achievement
Aiming at the future

Approach 2 in HGST Japan

Aiming at further high reliability

- Trend of Evolution: Design Methodology

1. Trial and error
   (mainframe market in the 1950's)

2. Design that thinks about stationary state
   (mainframe minicomputer market in the 1960-1980's)

3. Design to which transitional effect is taken
   (desktop portable market in the 1980-2000's)

4. Design to which slow effect of deterioration is taken
   (desktop portable market after 2000)

5. Design to which cross coupling is taken
   (future tasks)

6. Design to which Murphy's law is taken
   (future tasks)
Aiming at the future

Trend of Evolution : Design Methodology

Design by Murphy's law

Consideration "When something can be foolish the customer, they will surely do so about this product" is included in the design process.

=> It aims at the improvement of the design margin by a guard band examination thorough of HALT(Highly Accelerated Life Test) etc.

Written by D.Mann from "Systematic technical innovation"
Thank you for listening.

HGST Japan

http://www.hgst.com/