Porter’s Laws and Disruptive Technologies

NBAY 1620
March 1, 2017
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Lecture 1
• http://www.graphics.cornell.edu/academic/nbay6120/
Required Reading


Optional Reading

NBA
6120
DISRUPTIVE
TECHNOLOGIES
Natural Interfaces

Cornell Sketchpad, 2002

Digital Drafting Board 2017

Microsoft Surface, 2016

iPhone, 2017
“The essence of strategy formulation is coping with competition”

Professor Michael Porter
Harvard Business Review
March/April 1979
The Industry jockeying for position among current competitors

- Threat of new entrants
- Bargaining power of suppliers
- Bargaining power of customers
- Threat of substitute products or services
Who are your competitors?

- Threat of new entrants
- Bargaining power of customers
- Threat of substitute products or services
- Bargaining power of suppliers

Internet - increases threat, reduces barriers to entry, easy distribution channels, low cost

If only a few companies dominate - increases supplier power, easier to integrate forward

Technology changes - increases substitution threat with rapidly changing price/performance

- Internet - increases customer power
  - comparison shopping, search engines, auctions
Technology Threats (Opportunities?)

- New substitutes with different attributes
- New substitutes based on technology changes:
  - Exponentially increasing price/performance ratio
  - Relative rates of change
  - Knowledge of where the system bottlenecks exist
Malls Reel as Web Roars With Holiday Shopping
Uber Expands Self-Driving Car Service to San Francisco

Amazon, in Threat to UPS, Tries Its Own Deliveries

An Alternative to Shippers Like FedEx and UPS, New Service Could Deliver Goods the Same Day as Purchased
Threat of new entrants

Bargaining power of customers

Internet - increases threat reduces barriers to entry easy distribution channels low cost

Bargaining power of suppliers

If only a few companies dominate - increases supplier power easier to integrate forward

Technology changes - increases substitution threat with rapidly changing price/performance

Who are your competitors?

Threat of substitute products or services

Internet - increases customer power comparison shopping, search engines, auctions
Porter’s Suggestions:

1. Position company to provide best defense
2. Influence balance of forces through strategic moves
3. Anticipating shifts in the underlying forces and responding
Examples

• Oracle buying Sun
• Intel buying McAfee (security) and SySDSoft (wireless software firm)
• Qualcomm buying chip manufacturer, Atheros
• Google adding fiber around selected cities
Examples

- Facebook buying Instagram and Oculus
- Dish trying to acquire Sprint Networks
- Google buying Motorola Mobility
- Amazon buying The Washington Post
- Comcast buying NBC
What Do You Do With The Unexpected?

• Unionization of Uber Drivers?
• Legislation Barring Uber
• Instantaneous Price Changes Based on Demand Which Create Unethical Cancellations
Exponential Growth

Moore’s Law
The number of transistors that the industry would be able to place on a computer chip would double every year.

— Gordon Moore
1965
“Chip density doubles every 18 months.”

Processing Power ($P$) in 15 years:

\[
P = P_{\text{today}} (2)^{\frac{15 \text{ years}}{18 \text{ months}}} = P_t (2)^{1.5}
\]

\[
= P_t (2)^{10} = 1000 P_t
\]
Understanding Exponential Growth

Transistor Density vs. Year

\[ y = 2^t \]

slope = rate of change
Understanding Exponential Growth

\[ y = 2^t \]

\[ \frac{dy}{dt} = \frac{d}{dt}(2^t) = 2^t \log 2 \]

\( y = \) Performance (transistor density, bandwidth, etc.)

\( t = \) in measured doubling time periods

\( \frac{dy}{dt} = \) slope = rate of change
Understanding Exponential Growth

The magnitude of the incremental change is approximately equal to all of the available processing power that preceded it!
Understanding Moore’s Law

A: January 1975 - January 1999
B: January 1999 - July 2000

A/B = 1

Year
Growth In Computer Power (2x / 18months)

- 1940: Integrated Chip
- 1958: IBM PC
- 1980: Digital Camera
- 1995: 1 Gbit Internet
- 2000: Voice Recognition
- 2002: 100 Gbit Ethernet (interactive video)
Growth In Computer Power (2x / 18months)

(Top of Curve)

Processing is basically free.
Impact of Abundant Computer Power

- Needles in a “Haystack” (security monitoring, focused advertising, etc)
- The internet of things (omnipresent sensors)
- Digital health care (remote medical diagnosis)
- MOOCs (Massive open online courses)
- Autonomous driving vehicles
- 3D data acquisition
- 3D printing
Understanding Moore’s Law – Log Scale
How many instructions are completed in a 3.6 Ghz PC in the time it takes for the bullet to pierce the apple?

Apple diameter = 3.36”
Bullet velocity = 2800ft/sec

photograph by Harold Edgerton
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<td>130nm</td>
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<td>90nm</td>
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<td>32nm</td>
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<td>22nm</td>
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<tr>
<td>Functions per Chip (millions)</td>
<td>97</td>
<td>193</td>
<td>386</td>
<td>1546</td>
<td>3092</td>
<td>6184</td>
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<tr>
<td>Clock Speed (Ghz)</td>
<td>2.5Ghz</td>
<td>4.1Ghz</td>
<td>9.3Ghz</td>
<td>15Ghz</td>
<td>23Ghz</td>
<td>40Ghz</td>
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<tr>
<td>Wafer Size (millimeters)</td>
<td>200mm</td>
<td>300mm</td>
<td>300mm</td>
<td>300mm</td>
<td>450mm</td>
<td>450mm</td>
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<tr>
<td>Chip Size (mm²)</td>
<td>140 mm²</td>
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Roughly 0.5 shrink every 3 years 29% cost/reduction/function/yr.
## Technology Outlook

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<td>High Volume Manufacturing</td>
<td>45</td>
<td>32</td>
<td>22</td>
<td>16</td>
<td>11</td>
<td>8</td>
<td>6</td>
<td>4</td>
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<tr>
<td>Technology Node (nm)</td>
<td>8</td>
<td>16</td>
<td>32</td>
<td>64</td>
<td>128</td>
<td>256</td>
<td>512</td>
<td>1024</td>
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<td>Integration Capacity (BT)</td>
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<td>Delay Scaling</td>
<td>&gt;0.7</td>
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<td>~1?</td>
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<td>Energy Scaling</td>
<td>~0.5</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>&gt;0.5</td>
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<tr>
<td>Transistors</td>
<td>Planar</td>
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<td>Variability</td>
<td>High</td>
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<td>ILD</td>
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<td>RC Delay</td>
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<td>1</td>
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<td>1</td>
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<tr>
<td>Metal Layers</td>
<td>8-9</td>
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Predicting the Future

Mistakes of the Past
Feb 11 1876
Apparatus for talking through a telegraph wire

Exhibit A
Speaking Telephone
Carrel Vivian Church
Edward H. Bello

May 7th 1876
no Public
“This ‘telephone’ has too many shortcomings to be seriously considered as a means of communication. The device is inherently of no value to us.”

~ Western Union Internal Memo, 1876
My achievements occurred, not because of my skating skill, but my innate ability to skate to where “the puck will be”!

~ Wayne Gretzky
Everything is a System

Large Scale:
Google → Internet → Mobile device

Desktop:
CPU → Memory/Hard drive → Display

Chip Level:
Memory → Data Movement → Cache → Instruction Execution
Digital Photography

For digital photography to succeed, it needed:

- Camera
- Storage
- Battery Power
- Printers
- Transmission
Growth Rates of System Components of the Electronic Age

- Processing Power: 2x /18months
- Computer Memory: 2x /18months
- Mass Storage: 3x /18 months
- Bandwidth: 10x /3 years
Growth Rates of System Components of the Electronic Age

• 3D Graphics
  – Image Capture ................. 2x / 18 months
  – Image Display ................. 2x / year
    (Hardware, Software)
• Display Resolution ............... 2x/50 years
• User Interfaces
Relative Rates of Growth of Computer System Components

1. Bandwidth
2. Mass storage
3. 3D Graphics
4. Processing power
5. Computer memory
6. Display resolution
Transistor Density (Processing Power)

Vacuum tubes and core memory
Processing Power

100 Million X

Vacuum tubes and core memory
Processing Power

One Trillion X

Vacuum tubes and core memory
Processing Power Compared

• 2015: iPhone 5 > 1985 Cray-2
  (2.7x)
Pine A64
Keck’s Law

Bandwidth of Optical Fiber

IEEE Spectrum
Nielsen’s Law

Internet Bandwidth
Decrease in Chip Feature Size

Figure 4. Logarithm of actual versus predicted feature size since 1970 matches a straight line with regression coefficient $R^2 = 0.97$. Future sizes are predicted by dividing the previous size by $\sqrt{2}$; see the open triangles and dotted line. Future sizes two generations into the future are close to half the current sizes; see the square dots.

Powers of 10
Dykstra
Leather Balls stuffed with hair or wool were used to ink type.

Vertical Wood Screw lowered or raised platen when turned.

Horizontal Lever turned screw.

Wood Platen pressed paper against type.

Paper Holder folded over type form.

Type Form was slid under raised platen.

Paper to be printed was put in paper holder.
iPad

- **Introduced**: 2010 (February)
- **Price**: starting at $499
The Impact of the iPad

- PC Manufacturers
- Microsoft
- Intel & AMD
- Disk Drive Manufacturers
- Bookstores
Disruptive Technologies

Disruptive Technologies Salient characteristics

• Different package of performance attributes not valued by existing customers

• Performance attributes that are valued can improve at very rapid rates - and invade those established markets
Concept of Performance Trajectories

• Rate at which performance is expected to improve (demand)
• Rate at which performance improves (supply)
Performance Trajectories: *Log Scale vs. Arithmetic Scale*

![Diagram showing performance trajectories on log scale vs. arithmetic scale. The log scale shows a linear increase in Mbs (megabytes per second) with time, while the arithmetic scale shows an exponential growth leading to a much higher Mbs at the same time.]
S Shaped Performance Trajectories
Discrete Performance Trajectories
Typical Sustainable Technology

Performance vs. Time

current demand
Typical Sustainable Technology

- Performance vs Time
- Current technology and demand trajectories
Typical Disruptive Technology

- Current Technology
- Current Demand
- New Demand

Performance

Time
Typical Disruptive Technology

- Current technology
- Current demand
- Disruptive technology
- New demand

Performance vs. Time
Rigid Disk Drive Industry

- Hard Disk Capacity (MB): 1, 10, 100, 1000

14-inch drive technology

Demand in mainframe market
Alan F. Shugart
Developer of Disk Drive Industry

John Markoff. “Alan F. Shugart, 76, A Developer of Disk Drive Industry,” NYT, 12/15/06.
Rigid Disk Drive Industry

Hard Disk Capacity (MB)

Year


14-inch drive technology

8-inch drive technology

demand in mainframe market

demand in minicomputer market
<table>
<thead>
<tr>
<th>Disk Drives</th>
<th>1957 IBM</th>
<th>Fujitsu (~ 2000)</th>
<th>Today</th>
<th>Flash memory ?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24” diameter</td>
<td>3.5” diameter</td>
<td>1.8” drives for mobile platforms</td>
<td>1.0” drives for digital cameras</td>
</tr>
<tr>
<td></td>
<td>50 platters</td>
<td>1.1 GB capacity</td>
<td>1.3” drives for laptops</td>
<td>0.85” drives for digital cameras</td>
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<tr>
<td></td>
<td>5MB capacity</td>
<td>6.8 MBs sustained read</td>
<td></td>
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<td></td>
<td>12kbs sustained read</td>
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Hard disk drive volumetric density trend
Cost of storage for disk drive, paper, film, and semiconductor memory

Will Flash Memory replace Disk Storage?
Is this a Disruptive Technology?

Already with 34nm technology Intel and Micron have broken the $1/GB barrier
Solid State Storage

2017

1 TB Hard drive ~ $40-50

1 TB SSD ~ $200 - $300
IBM researchers have stored and retrieved digital data from an array of just 12 atoms

New York Times, 1/12/12
DNA Storage

- Researchers write book using DNA
- (50,000 words, 11 images, 1 computer program, 0.7 MB)
Disruptive Technologies

• What is typical management and marketing dogma?

• Stay close to your customers!
Disruptive Technologies

• What happens when your best customers reject a new technology?

• Xerox’s large photocopy centers had no use for small photocopiers

• IBM’s large customers had no use for minicomputers
Disruptive Technologies

• What happens when your best customers reject a new technology?

• DEC’s minicomputer customers (PDP 11/40-11/70 and VAX 11/780-11/730) had no use for PC’s

• SGI’s graphics customers had no use for PC graphic boards
THE SAD SAGA OF SILICON GRAPHICS

Its gee-whiz computer graphics brought fame and fortune. But now, dogged by troubles, its market value has dropped by half. Here's the untold tale of what went wrong. Can CEO Ed McCracken fix things?
Disruptive Technologies

• Research shows most well managed companies are ahead of their industries (both with incremental improvements or new approaches PROVIDED THESE TECHNOLOGIES ADDRESS THE NEXT GENERATION NEEDS OF THEIR CUSTOMERS

• These same companies make bad decisions when the technologies do not meet the needs of their main stream customers and appeal only to SMALL OR EMERGING MARKETS
Disruptive Technologies: What choices?

With established companies managers have 2 choices:

• **Go downmarket** -- accept lower profit margins, initially these emerging markets may be lower cost

• **Go upmarket** -- alluringly high profit margins, e.g., margins of IBM mainframes are higher than PCs
CAN GEORGE FISHER FIX KODAK?
SHOOTOUT!

LEW PLATT, CEO, HEWLETT-PACKARD

HOW HP PLANS TO TAKE ON KODAK—AND REVOLUTIONIZE THE WAY YOU CAPTURE AND PRINT IMAGES

PAGE 100

Internet: www.businessweek.com  America Online: Keyword: BW
Disruptive Technologies

• How does a company allocate resources?

• Existing processes are designed to “weed out” proposed products/technologies that DO NOT ADDRESS CUSTOMERS NEEDS
Netflix

- First CDs, then DVDs
- Then envelope shapes
- Then partnership with Blockbuster refused
- Then streaming video
- Now Comcast
Blockbuster and Redbox

Netflix 5-year stock chart
Convergence

• Computer Processing
• Photographic Imaging
• Geometry Acquisition
• Display Technology
• Tracking Technology
• 3D Printing
Convergence

• Virtual Reality

• Cloud Computing
  – Artificial Intelligence
  – Machine Learning
  – Neural Networks

• Human Computer Interfaces
  – Graphical input
  – Voice input
End...