Course Website

• http://www.graphics.cornell.edu/academic/nba6120/

Optional Reading

NBA 6120

DISRUPTIVE TECHNOLOGIES
Porter’s Rules

“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
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
Stack Fallacy

Anshu Sharma
Threat of new entrants

Bargaining power of customers

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

Bargaining power of suppliers

Who are your competitors?

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

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

— Gordon Moore
1965
Moore’s Law

“Chip density doubles every 18 months.”

Processing Power (P) in 15 years:

\[
P = P_{today} \cdot (2)^{15 \text{ years}} = P_t \cdot (2)^{1.5} = P_t \cdot (2)^{10} = 1000P_t
\]
Understanding Exponential Growth

Transistor Density

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

\( \frac{dy}{dt} = \text{slope} = \text{rate of change} \)
Understanding Moore’s Law
Understanding Moore’s Law

• In 2014 Semiconductor production facilities made approximately 250 billion billion (250 x 10^{18}) transistors.

• More transistors were made in 2014 than in all the years prior to 2011.

Transistors, by the Numbers – Dan Hutcheson
IEEE SPECTRUM, ISSN 0018-9235, 04/2015, Volume 52, Issue 4, p. 33
Growth In Computer Power (2x / 18months)

- 1940: Integrated Chip
- 1958: Integrated Chip
- 1980: IBM PC
- 1995: Digital Camera
- 2000: 1 Gbit Internet
- 2002: 100 Gbit Ethernet (interactive video)
- Voice Recognition

Computer power vs. time
Growth In Computer Power (2x / 18months)

(Top of Curve)

Processing is basically free.

Search Engines
Query by Content
Pictorial Query
Streaming Video
Automated Driving Controls
Genetic Engineering
HDTV

1940 1958 Integrated Chip
1980 IBM PC
1995 Digital Camera
2012 100 Gbit Ethernet
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

LOG SCALE

Processing power

1 2 3 4 5 6 YEARS
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
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>130nm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>90nm</td>
<td>97</td>
<td>193</td>
<td>386</td>
<td>1546</td>
<td>3092</td>
<td>6184</td>
</tr>
<tr>
<td>65nm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>45nm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>32nm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22nm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Functions per Chip (millions)</td>
<td>2.5Ghz</td>
<td>4.1Ghz</td>
<td>9.3Ghz</td>
<td>15Ghz</td>
<td>23Ghz</td>
<td>40Ghz</td>
</tr>
<tr>
<td>200mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>300mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>450mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clock Speed (Ghz)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wafer Size (millimeters)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>140 mm²</td>
<td>140 mm²</td>
<td>140 mm²</td>
<td>140 mm²</td>
<td>140 mm²</td>
<td>140 mm²</td>
<td>140 mm²</td>
</tr>
</tbody>
</table>

Roughly 0.5 shrink every 3 years 29% cost/reduction/function/yr.
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<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>
</tr>
<tr>
<td>Technology Node (nm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Integration Capacity (BT)</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>
</tr>
<tr>
<td>Delay Scaling</td>
<td>&gt;0.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>~1?</td>
</tr>
<tr>
<td>Energy Scaling</td>
<td>~0.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&gt;0.5</td>
</tr>
<tr>
<td>Transistors</td>
<td>Planar</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variability</td>
<td>High</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ILD</td>
<td>~3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RC Delay</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Metal Layers</td>
<td>8-9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Feb 11, 1876
Apparatus for talking through a telegraph wire.

Line

May 7th, 1880.

Edward H. Bech
Arthur Public.
Alexander Graham Bell
“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
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 /18 months
- Computer Memory: 2x /18 months
- 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 Interface

- Product Design
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
Keck’s Law
Nielsen’s Law

Internet Connectivity (Bits Per Second)


Nielsen’s Law
Processing Power Compared

- 2015: iPhone 5 > 1985 Cray-2
  (2.7x)
Pine A64
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.

Type Form was slid under raised platen.

Paper Holder folded over type form.

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
LP
CD or DVD
iPod or You Tube
Internet TV
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
S Shaped Performance Trajectories
Discrete Performance Trajectories
Typical Sustainable Technology

![Graph showing performance over time with a trend line labeled "current demand".]
Typical Sustainable Technology

Performance vs. Time

- Current technology
- Current demand
Typical Disruptive Technology

- Current technology
- Current demand
- New demand

Performance vs. Time
Rigid Disk Drive Industry

Year

Hard Disk Capacity (MB)

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.
## Disk Drives

<table>
<thead>
<tr>
<th>Year</th>
<th>Model</th>
<th>Diameter</th>
<th>Platters</th>
<th>Capacity</th>
<th>Read Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1957 IBM</td>
<td>24” diameter</td>
<td>50</td>
<td>50 platters</td>
<td>5MB capacity</td>
<td>12kbs sustained read</td>
</tr>
<tr>
<td>Fujitsu (~ 2000)</td>
<td>3.5” diameter</td>
<td>1.1 GB capacity</td>
<td>1.1 GB capacity</td>
<td>6.8 MBs sustained read</td>
<td></td>
</tr>
<tr>
<td>Today</td>
<td>1.8” drives for mobile platforms</td>
<td>1.3” drives for laptops</td>
<td>1.3” drives for laptops</td>
<td>1.0” drives for digital cameras</td>
<td>0.85” drives for digital cameras</td>
</tr>
<tr>
<td>Flash memory</td>
<td>?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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
Flash Scalability

![Graph showing design rule vs. date for different companies: IMFT, Samsung, Toshiba, Hynix. The graph indicates a decreasing trend in design rule with increasing date.](image-url)
Disruptive Technologies

• What is typical management and marketing dogma?

• Stay close to your customers!
Disruptive Technologies

Sony Walkman
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!

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