Required Reading

Optional Reading


Return on Investment (ROI)

Assumptions:

Payback period (time)

Net Present Value
  Value of future benefits in today’s money

Internal Rate of Return
Return on Investment (ROI) Model does not work well

Difficulties:

• How long does the product last?
• What is the price (revenue)/unit?
• Exponential change
• Non-linear pricing behavior
• Competition (monopoly pricing)
• Prediction of demand
• Technical obstacles
Profitability vs. Investment in the Computer Industry
Profitability vs. Investment in the Computer Industry

Rising Profitability
Measured by ratio = \( \frac{\text{cash generated during year}}{\text{investments made in new technology previous year}} \)

where new technology = new equipment + R & D

cash = gross profit (including R & D)

Rising Investment
Measured by ratio = \( \frac{\text{plant & equipment investment}}{R & D} \)
Profitability vs. Investment
Profitability vs. Investment in the Computer Industry

• It is obvious that with the shrinking technology, it is getting more expensive to move to the next generation process technology.

• It is also obvious that the manufacturing cost as well as the sales price of processing chips is decreasing rapidly.
Diminishing Profitability

![Graph showing diminishing profitability](image)

- Current Price
- Price
- Performance
- $\frac{P^1}{C^1} > \frac{P^2}{C^2}$
With these observations, what should the dominant chip manufacturers (Intel, IBM, TI, TSMC, Samsung, AMD, etc.) do?
Andrew S. Grove, Chief Executive and Chairman of Intel Corporation

From the New York Times, caption: “Mr. Grove in 1991 with a silicon wafer, part of the process to make Intel’s 386 microprocessor.”

9/2/1936 - 3/21/2016
The growth in mobile microprocessors outpaced the growth in desktop microprocessors.

Systems price points have migrated to lower levels and average selling prices indicate continued erosion.
• Mobile microprocessors ASP’s are less than desktop microprocessor ASP’s.

• In 2007 gross margins were negatively impacted by declining ASP’s and higher start-up costs for the new 45nm process technology.

• At the end of 2007, Intel had roughly $20B cash.
In 2008 the average selling price for all products continued to decline.
The revenues for the mobility group as contrasted to the digital enterprise group continued to increase.
Intel Research and Development 2011

Bar chart showing research and development spending from 2007 to 2011. The spending increased from 5.8% in 2007 to 8.4% in 2011.
Intel Capital Additions to Property, Plant and Equipment 2011
A new fab costs approximately $3-4B or more

Should Intel Continue to Invest In Creating New Fabrication Facilities?
• Having invested in its 32nm fab, Intel achieved higher than expected efficiencies and introduced new chips faster than expected.

• Sandy Bridge, their latest microprocessors was introduced in 2011.

• AMD, even if it designed better chips, was stuck with its 45nm production and couldn’t compete. Their chips were more expensive to produce.

• Intel’s new chips possibly eroded the graphics market for competitors (nVidia & AMD) as PC makers no longer needed stand-alone graphics processors.
Intel Geographic Breakdown of Revenue 2011

- Americas: 2001 - 35%, 2006 - 21%, 2011 - 21%
- Europe: 2001 - 25%, 2006 - 19%, 2011 - 13%
- Japan: 2001 - 9%, 2006 - 11%, 2011 - 9%
Intel’s Hillsboro
• Intel announced that it would spend $9B to upgrade four fabrication plants to move to 22nm technology (one in Israel).
• ARM and IBM announced a joint agreement to move to 14nm technology.
The high price servers are representing a much smaller percentage of revenue stream.

The prices of laptops and netbook computers are continuing to decrease.

Competition and price wars in the mobile computing segments (mobile phones, smart devices, tablets) are fierce.
In 2011 Intel had announced it would build a $5B high-tech manufacturing plant, Fab 42, in Arizona.

2012 President Obama visited the plant and mentioned Fab 42 in his State of the Union Address.

January 14, 2014, Intel puts the new Arizona chip factory on back burner.

Why did Intel PAUSE?
Intel cancels 14nm Fab 42 in AZ, due to increasing competition from ARM
• Intel again delays 10nm technology. It will depend on revenue increase from Windows 10 and its new Skylake processor.

• The second generation of 14nm production technology had significant yield improvements.

• At the same time, Intel moved to purchase Altera so it could shift from PC’s to mobile devices.
Intel’s $7B Investment

Wall Street Journal, Feb. 8th, 2017
Potential Plans

- 7 nanometer chip technology
- 5 G Networks
- Drones
Fewer companies can deliver smaller and more powerful chips (July 20, 2009)

Microprocessor
The ‘brain’ of a computer. Contains hundreds of millions of transistors interconnected by fine wires made of copper. Each transistor acts as an on/off switch, controlling the flow of electricity through the chip to send, receive, and process information up to 300bn times a second.

Layers of copper wires bring electrical currents to the transistors at the bottom.

2,000 45 nanometer (nm) transistors can fit across the width of a human hair.
Fewer companies can deliver smaller and more powerful chips

July 20, 2009

Fabrication capabilities

<table>
<thead>
<tr>
<th>Transistor size (nanometer)</th>
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<tbody>
<tr>
<td>Intel</td>
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<tr>
<td>Samsung</td>
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<tr>
<td>STMicro.</td>
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<tr>
<td>IBM</td>
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<td>Toshiba</td>
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<td>AMD</td>
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<td>Texas Ins.</td>
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<td>Fujitsu</td>
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<td>NEC</td>
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<td>Panasonic</td>
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<td>Freescale</td>
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<td>Renesas</td>
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<td>Infineon</td>
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<td>NXP</td>
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<tr>
<td>Sony</td>
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<td>Motorola</td>
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<td>Hitachi</td>
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<td>Philips</td>
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<tr>
<td>Mitsubishi</td>
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<tr>
<td>Siemens</td>
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</tbody>
</table>

Semiconductor maker revenues

<table>
<thead>
<tr>
<th>Shipments, estimated 2008 ($bn)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intel</td>
</tr>
<tr>
<td>Samsung</td>
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<tr>
<td>Toshiba</td>
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<td>Texas Ins.</td>
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<tr>
<td>TSMC</td>
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<td>STMicro.</td>
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<td>Renesas</td>
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<td>Sony</td>
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<td>Qualcomm</td>
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<td>Hynix</td>
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<td>Infineon</td>
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<td>NEC</td>
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<tr>
<td>AMD</td>
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<tr>
<td>Freescale</td>
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<tr>
<td>Broadcom</td>
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<tr>
<td>Panasonic</td>
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<tr>
<td>Micron</td>
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<tr>
<td>NXP</td>
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<tr>
<td>Sharp</td>
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<tr>
<td>Elpida</td>
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</table>

$9bn estimated annual revenue needed to support new fabrication facilities

Source: Intel

FT Graphic: Mario Lendva
Many companies (Integrated Device Manufacturers, IDMs) design and manufacture integrated circuits (efficiency through vertical integration).

Today, there are many companies that:
- only design devices (fabless semiconductor companies),
- as well as merchant foundries that only manufacture devices.

The foundry model is a business vision that seeks to optimize productivity.

In 1987, the world’s first dedicated merchant foundry opened its doors: Taiwan Semiconductor Manufacturing Company (TSMC).
TSMC’s Customers

- Manufacture’s chips for
  - Qualcomm
  - Nvidia
  - Advanced Micro Devices (AMD)
  - Broadcom, Altera
    > (even some for Intel & Texas Instruments)
  - Apple’s A5, A6 for iPad & iPhone
  - Apple’s new A8

source: https://en.wikipedia.org/wiki/TSMC
In 2014 TSMC’s Revenue reached 25 Billion USD.

They are particularly good at producing low power mobile devices at 28nm.

They capital spending was between 10.5 – 11 Billion USD.
TSMC’s Fabrication Plants 2014

- TSMC had four 300mm wafer plants in Taiwan
- TSMC had four 200mm wafer plants in Taiwan
- TSMC had one 200mm wafer plant in Shanghai, Washington State, Singapore, and other smaller plants.
ARM Holdings

• Original name was Acorn Computers
• In 1990 a new customer arrived, Apple: and company was renamed Advanced RISC Machines (ARM)
“Watts are more important than MIPS of FLOPS”
- George Gilder
By 2014, ARM dominated the smartphone market and had the following market share:

- 95% smartphone market
- 10% mobile market
- 35% digital TV’s
- 23% PC’s

In 2014 ARM cores were licensed for 12 Billion chips
ARM’s Customers

• Apple (iPhone 5, iPad, iPhone 5s, iPhone 6, etc.)
• Samsung (Galaxy S4, S5, etc.)
• Qualcomm (Snapdragon)
Japan’s Softbank Purchased ARM For $32B 2016

- Influenced by the growing “Internet of Things” (IOT)
- Price was greater than 40% over the closing stock price
Predicting Demand

How do you predict what the technology, manufacturing cost, market demand, market supply, and competition will be five years in the future?
CASE STUDY 1:
The Great Chip Glut: Economist August 11, 2001

- East Asia did not understand the industry’s woes
  - Oversupply
  - Taiwan’s “foundries”
  - TSMC
  - UMC
  - Singapore – Charted Semiconductor
  - Korea’s Hynix (Hyundai) - $1B loss in 2Q01
  - Malaysia – new fab, 1st Silicon + 2 more
  - China – Shanghai alone, 2 fabs under construction
    - 2 more on drawing board
    - 12 more planned

- Operating at 30% of capacity (from 70%)
Case Study #2

Intel’s MMX Introduction

Microprocessor Report, July 1997
In a fast moving technology, how do you market your product?

How do you get brand name recognition?

When do you start advertising?
What is MMX?

- First major extension to x86 instruction set since 1985
- 57 new instructions to accelerate:
  - 2D & 3D graphics
  - Video
  - Speech synthesis and recognition
Lessons Learned?

• Need to completely integrate new product development, production capacity, advertising and marketing

• New products need to be introduced frequently to keep ASP constant or at high levels

• Case explains the drive for continually shrinking technology
Case Study #3  

Product Shelf Life

• In a rapidly changing technology, the product shelf life can exacerbate the problem.
Product Shelf Life Time Is Decreasing

Source: Hewlett-Packard

Note: Each line on the graph represents the sales history over time of all those products launched the year at which the line originates.
Product Selling Price Is Also Decreasing Faster

Source: Hewlett-Packard

Note: Each point on the graph indicates the number of years between (1) the year that sales of a particular cohort of products first reached one-half their subsequent sales peak and (2) the year when sales again fell to that one-half peak level.

Case Study # 4

• Intel’s Weak Celeron Offerings
In late 1998 Intel’s weak Celeron offering were being hammered by low-end chips from AMD and Cyrix.

AMD was suffering at the time with an operating loss of $173M in the second quarter and a 26% decline CPU revenues.

Intel was also feeling the pain, second quarter revenues and ASP were also down.

What could Intel have done?
Case Study #5  2005

- One Laptop Per Child (OLPC)
- (The predecessor to Notebooks and Netbooks)
OLPC

Manufacturer: Quanta Computers
Connectivity: Wireless LAN
Media: 1 GB flash memory
Operating system: Linux
Input: Keyboard, Touchpad, Microphone, Camera
Camera: Built-in video camera (640x480; 30 FPS)
Power: Battery removable pack
CPU: AMD
Memory: 256 MB DRAM
Display: Dual-mode 19.1 cm/7.5” diagonal TFT LCD 1200x900
Cost: $188
Displays

- Traditional barrier to building cheap laptops
- Need to be readable in bright sunlight and low lighting conditions
- Need power efficiency
$100 Laptop Display

- Can be mass produced
- Resolution: 95% of the laptops at that time
- Uses 1/7 the power consumption
- Costs 1/3 price
- Can be read in bright sunlight or room light w/o backlighting
Starting November 12, 2007 OLPC will offer a Give 1 Get 1 program.

For $399 – purchase 2x10 laptops

One for a child in a developing nation
One for a child at home
• Flash memory vs. spinning hard drive
  It uses little power and doesn’t break when dropped.
  Consumer price is 2MB for 1 penny.

• Ingenious LCD panel that detects when onscreen images are static and tells the CPU to shut down
A rugged laptop based on Intel’s 900Mhz Celeron with 256MB RAM and 2GB of flash memory, WiFi, Ethernet, and Linux O/S
A Via processor with a 1280 x 768 screen resolution, Windows XP or Vista or either a hard drive or a 64GB solid state device.
A Linux operating system with 4GB solid state drive, a built in DVD, and a suite of software to replace Microsoft Office.
When Asustek launched its Eee PC in Fall 2007, they expected their customers to be from poor countries. Instead, their inventory was bought out by middle class consumers.
Budget Laptops of 2015


- **Microsoft Surface 3**
  - $499.00
  - 10.8” 1,920 x 1,080 touchscreen
  - 1.6 GHz Quad-Core Intel Processor
  - 2 GB RAM
  - 64 GB SSD

- **Hisense Chromebook**
  - $149.00
  - 11” 1,366x768 touchscreen
  - 1.8 GHz Rockchip Processor
  - 2 GB RAM
  - 16 GB SSD

- **Toshiba Chromebook 2**
  - $299.00 - $320.09
  - 13.3” 1,920 x 1,080 LED display
  - 2.16 GHz Dual-Core Intel Processor
  - 4 GB RAM
  - 16 GB SSD

- **Acer Chromebook 15**
  - $305.11 - $327.93
  - 15.6” 1,920 x 1080 LED display
  - 1.5 GHz Dual-Core Intel Processor
  - 4 GB RAM
  - 16 GB SSD

- **HP Stream 11.6**
  - $199.00
  - 11.6” 1,366 x 768 WLED display
  - 2.16 GHz Processor
  - 2 GB RAM
  - 32 GB SSD
Budget Tablets of 2015


**Amazon Kindle Fire HDX 7**
Price: $235.49
- 7" 1,920 x 1,080 Multi-Touch Display
- 2.2 GHz Quad-Core ARM Processor
- 2 GB RAM
- 16 GB Integrated Storage

**Samsung Galaxy Tab A (8-inch)**
Price: $179.00 - $229.99
- 8" 1,024 x 768 Multi-Touch Display
- 1.2 GHz Quad-Core Qualcomm Processor
- 2 GB RAM
- 16 GB SSD

**Dell Venue 7**
Price: $129.96
- 7" 1,280 x 800 Multi-Touch Display
- 1.6 GHz Dual-Core Intel Atom Processor
- LPDDR3 SDRAM
- 16 GB Integrated Memory Storage

**Amazon Fire HD 6**
Price: $99.00
- 6" 1,280 x 800 Multi-Touch Display
- 1.5 GHz Quad-Core ARM Processor
- 2 GB RAM
- 16 GB SSD

**Apple iPad Mini 3**
Price: $399.00
- 7.9" 2,048 x 1,536 Retina Multi-Touch Display
- 1.3 GHz Dual-Core (ARM) Apple A7
- 1 GB RAM – A7
- 16 GB Integrated Storage

DATATECTURE
Flickr. MySpace. iTunes. Gmail.

In our hyperconnected, superfast age, how can the Internet data centers we’ve built keep up?

→

Quincy, Wash., home to rows of servers in a 500,000-square-foot data center that Microsoft built in 2006.

Water-Powered Computers
“Every economic era is based on a key abundance and a key scarcity.”

George Gilder,
Forbes ASAP, 1992
Four Commandments

1. Moore’s Law
2. Rock’s Law
3. Metcalfe’s Law
4. Wirth’s Law
Moore’s Law

“Chip density doubles every 18 months.”

Processing Power (P) in 15 years:

\[
P = P_{today}(2)^{15 \text{ years}}_{18 \text{ months}} = P_t(2)^{1.5} = P_t(2)^{10} = 1000P_t
\]
Moore’s Law

1965 “Cramming More Components onto Integrated Circuits”

(anniversary issue of Electronics, April 1965)

- Predicted an annual doubling of components which could be fabricated on a semiconductor chip.
- Also included a cartoon with a sales booth for “home computers” – another prescient insight

Actually, by 1975, doubling period was 17 months
1985, doubling period was 22 months
1995, doubling period was 32 months
today, doubling period is 23 months
Moore’s Law (continued)

• Original paper noted that the cost per electronic component was inversely proportional to the number of components/chip

• In 1988 Erich Bloch (then head of IBM’s research division), later Chairman of NSF Board, & sponsor for Cornell’s Theory Center

  “Moore’s law won’t work at feature sizes less than a quarter of a micron (250 nanometers)”

• Moore, underestimated the staying power of photolithography, “No exponential trend lasts forever, but forever can be postponed”
Moore’s Original Prediction

1965

[Graph showing the relationship between the number of components per integrated circuit and the relative manufacturing cost per component for 1962, 1965, and 1970.]
Rock’s* Law

“The cost of semiconductor tools will double every four years”

Actually this was not true and current cost is $3 – 4B (slightly more than in the 1990’s)

What actually happened was:

1980’s. . .increase in yield
1990’s. . .increase in throughput

(from 20 wafers/hr. → 50 wafers/hr.)

Now, reduced size with 193μm stepper and larger wafers (300mm)

* Rock was an initial investor in Intel
“The value of a network grows as the square of the number of users”

≈ 1980 - later in “There Oughta be a Law,” NY Times 1996

• Unlike the previous laws, this can’t be quantified because value (what economists call utility) can’t be measured.

• However, note the impact of search engines, and the business model of Google, Yahoo, etc.

* Inventor of the Internet standard
Wirth’s* Law

“Software is slowing faster than hardware is accelerating”

*IEEE Computer 1995*

“Were it not for a thousand times faster hardware, modern software would be utterly unusable”

• Most of the features that bloated the programs were superfluous for most of the users most of the time

* Niklaus Wirth, Professor of ETH, Zurich and inventor of Pascal*
| Case Study #6 | Cloud Computing |
Mobile Internet Outpaces Desktop Internet Adoption

iPhone + iTouch Users = 8x AOL Users 9 Quarters After Launch

Mobile Internet

iPhone + iTouch
Launched 6/07

Desktop Internet

NTT docomo i-mode
Launched 6/99

AOL
v 2.0 Launched 9/94

Netscape
Launched 12/94

Subscribers (MM)

Q1 Q3 Q5 Q7 Q9 Q11 Q13 Q15 Q17 Q19

Q1 Q3 Q5 Q7 Q9 Q11 Q13 Q15 Q17 Q19

Note: *AOL subscribers data not available before COPPP: Netscape users limited to US only. Morgan Stanley Research estimated ~36MM netbooks shipped in first eight quarters since launch (10/07). Source: Company Reports, Morgan Stanley Research.

Philip Elmer-Dewitt. “Morgan Stanley drinks the Apple Kool-Aid,” CNNMoney.com, 12/16/09
VIRTUALIZATION LAYER
Each physical server can host a number of virtual servers

HARDWARE LAYER
Physical servers, disk arrays & network hardware

MANAGEMENT LAYER
Customer can choose required resources as needed

IaaS
VIRTUAL INFRASTRUCTURE
(Infrastructure as a service)

PaaS
(Platform as a service)
Allows developers to run applications
Mobile Internet growth

• International Data Corporation (IDC) predicts 16.6% growth rate for mobile Internet devices between 2010 and 2015

• There will be more mobile users than wireline users with the booming market for smartphones and tablet PCs
Cloud Computing - Pros

- No development program – the infrastructure is already in-place
- Existing data centers (e.g. Amazon, Google, etc.) can rent spare capacity
- Enables start-ups to offer on-line applications immediately without major capital investments
Cloud Computing - Cons

• Integrity and security of user’s data is not guaranteed
• Lack of standards to allow companies to move from one provider to another
• The entire system depends on available bandwidth
Conjuring Clouds

BIG SEVEN
A survey of 1,771 firms showed they plan on using these public cloud vendors by mid-2009

Google 20%
Microsoft 15%
IBM 15%
Amazon 13%
Salesforce.com* 12%
Sun Microsystems 8%
VMware 8%

Source: The 451 Group
Virtual Computers, Real Money

**TOP USES FOR CLOUD COMPUTING**
Based on an October 2008 survey of 1,771 companies

- Internet application hosting: 50%
- Databases: 32%
- Disaster recovery: 26%
- Remote storage: 26%
- Application testing & development: 22%
- Batch computing jobs: 9%
- Billing: 4%
- Log processing: 1%
- Don't know: 4%
- Other: 13%

*Source: The 451 Group*
Conjuring Clouds

BLASTOFF
Demand for Amazon's new cloud soared

Bandwidth consumed by Amazon Web Services

Bandwidth consumed by Amazon's global retail websites

Source: Amazon.com
Recent Bandwidth Usage

• Netflix Bandwidth Usage Climbs to Nearly 37% of Internet Traffic at Peak Hours (2015)

• Fascinating Number: Google Is Now 40% Of The Internet (2013)

• Streaming services now account for over 70% of peak traffic in North America (Facebook accounts for 15.96%) (2015)
END...