Porter's Laws and Disruptive Technologies

NBAY 1620
March 1, 2017
Donald P. Greenberg
Lecture 1

NBAY 6120 Course Website Spring 2017

- http://www.graphics.cornell.edu/academic/nbay6120/

Required Reading

- Michael E. Porter. How Competitive Forces Shape Strategy, Harvard Business Review, March-April 1979, pp. 137-145.(Search http://erms.library.cornell.edu/
- Joseph L. Bower and Clayton M. Christensen. Disruptive Technologies: Catching the Wave, Harvard Business Review, January-February 1995, pp. 43-53. (Search http://erms.library.cornell.edu/)

Optional Reading

- Jill Lepore. "The Disruption Machine," The New Yorker, June 23, 2014. http://www.newyorker.com/reporting/2014/06/23/140623fa_fact_lepore?currentPage=all

NBA 6120

DISRUPTIVE TECHNOLOGIES

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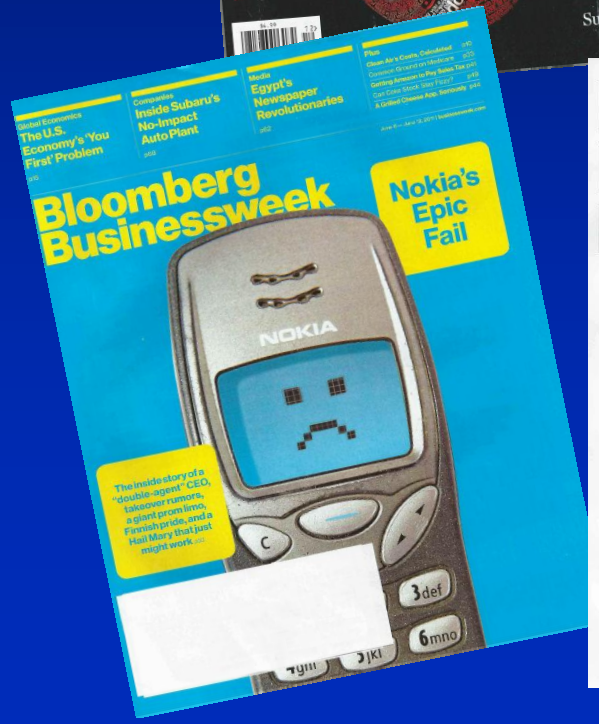
DISRUPTIVE TECHNOLOGIES



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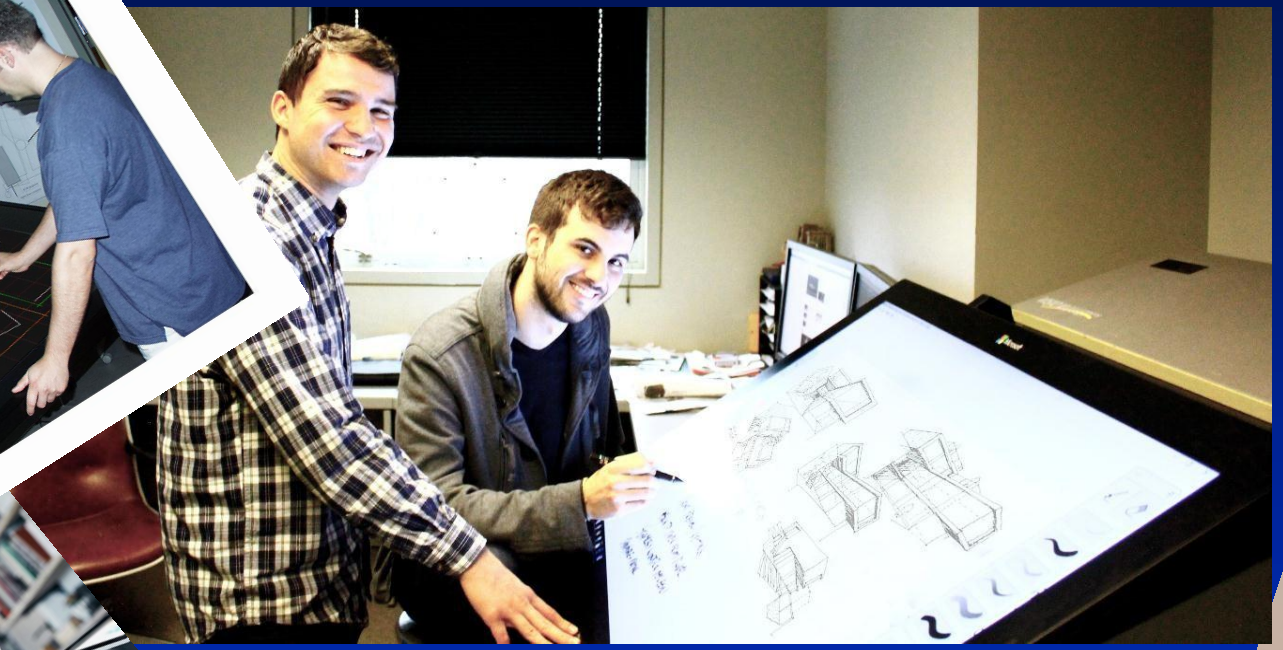
DISRUPTIVE TECHNOLOGIES

Natural Interfaces

Cornell Sketchpad, 2002



Digital Drafting Board 2017

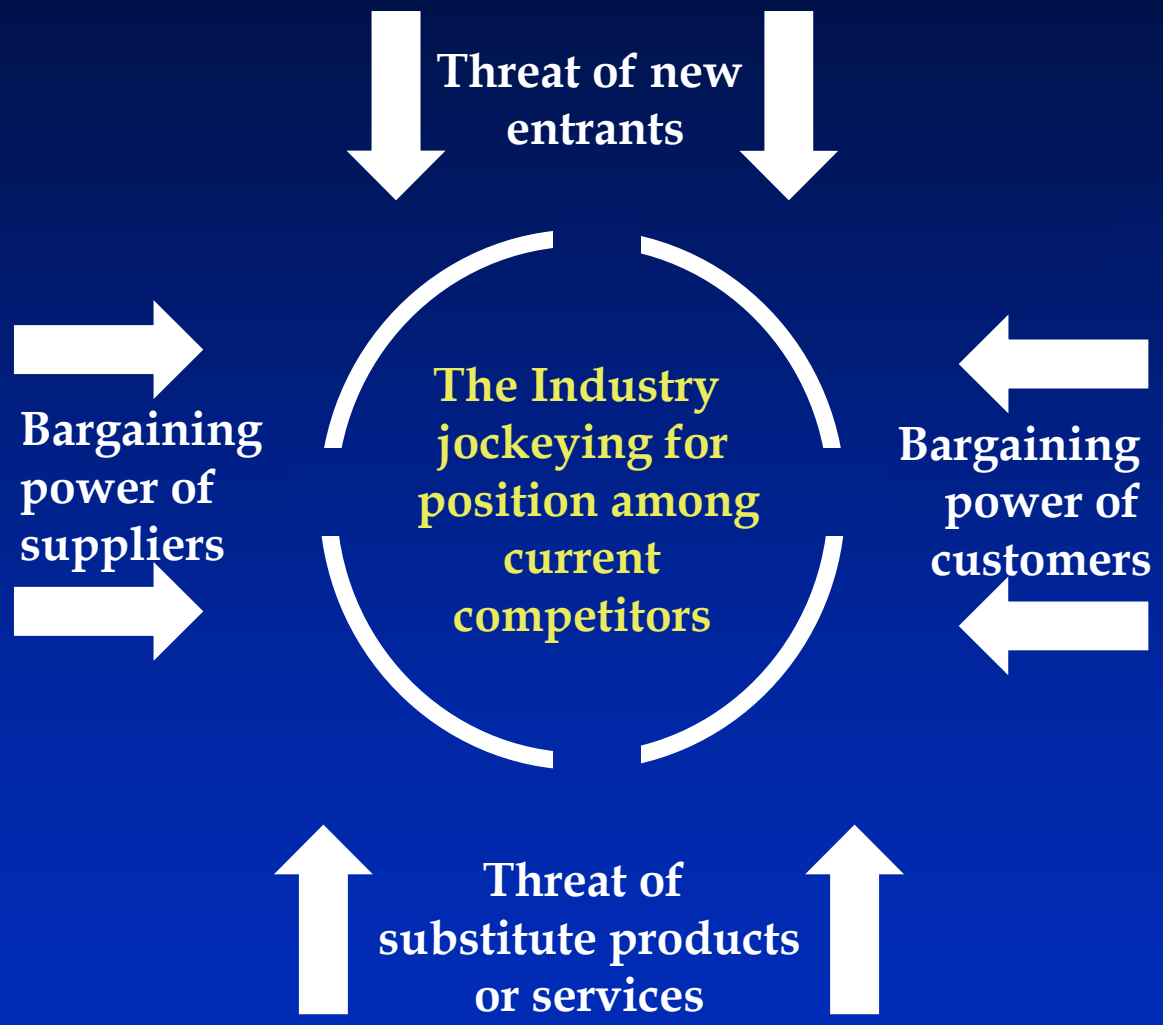
Microsoft Surface, 2016

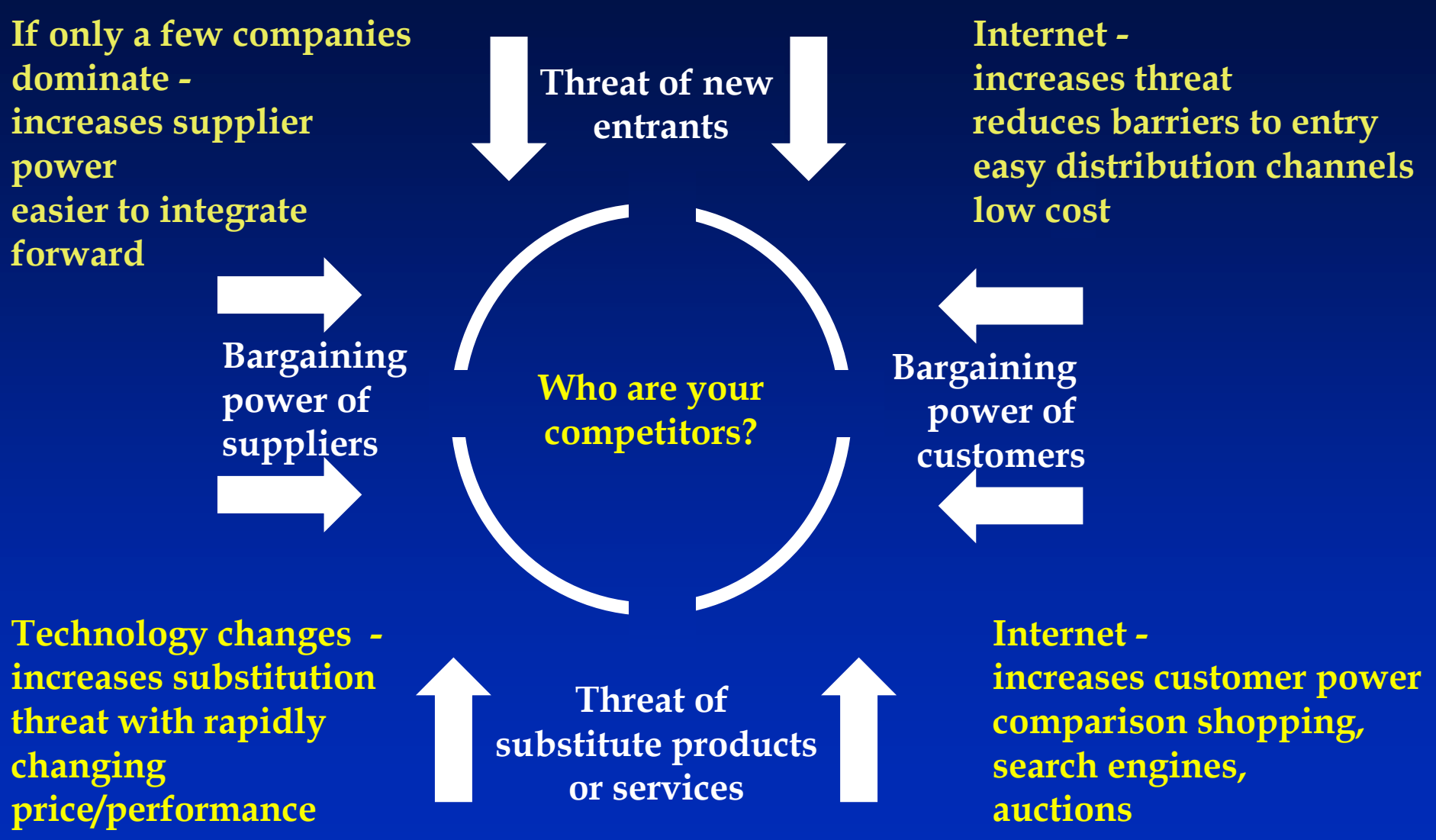
iPhone, 2017

Porter's Rules

"The essence of strategy formulation is coping with competition"

Professor Michael Porter
Harvard Business Review
March/April 1979


Threat of new entrants
Bargaining power of suppliers
The Industry jockeying for position among current competitors
Bargaining power of customers
Threat of substitute products or services

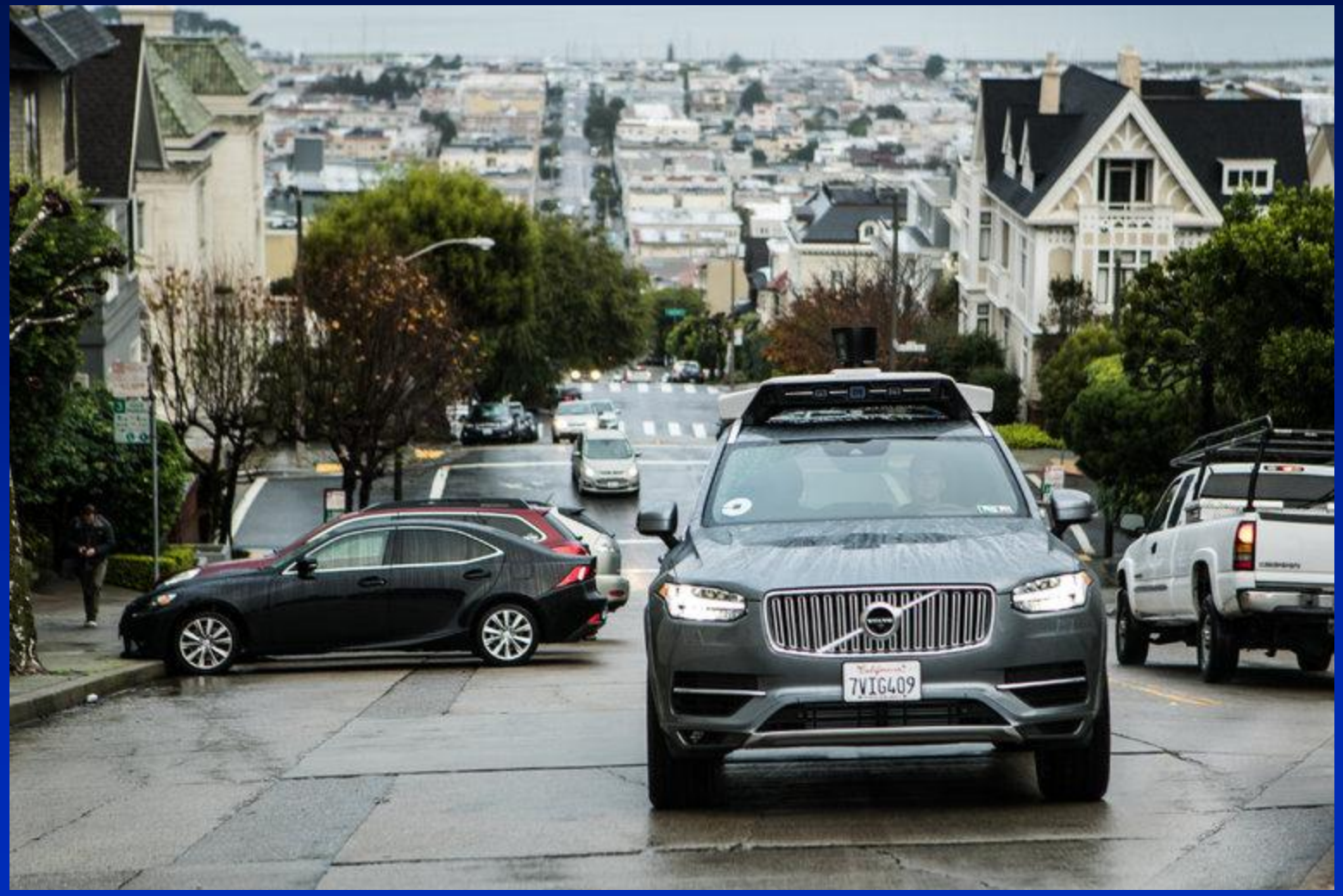

If only a few companies dominate -
increases supplier power
easier to integrate forward
Threat of new entrants
Internet -
increases threat
reduces barriers to entry
easy distribution channels
low cost
Bargaining power of suppliers
Who are your competitors?
Bargaining power of customers
Technology changes -
increases substitution threat with rapidly changing price/performance
Threat of substitute products or services
Internet -
increases customer power
comparison shopping, search engines, auctions

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

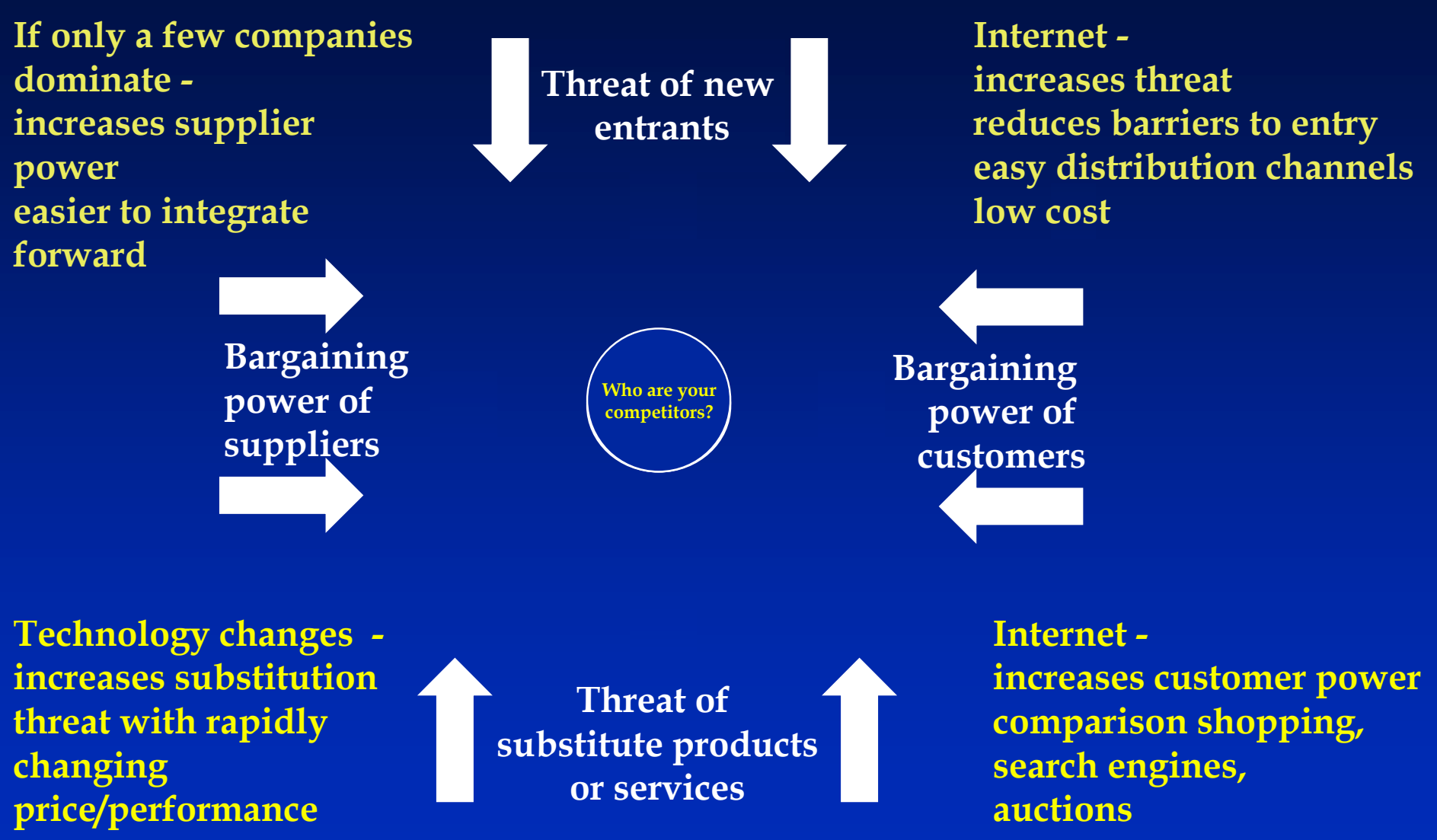
Uber Expands Self-Driving Car Service to San Francisco



New York Times, Dec. 14, 2016

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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Porter's Suggestions:

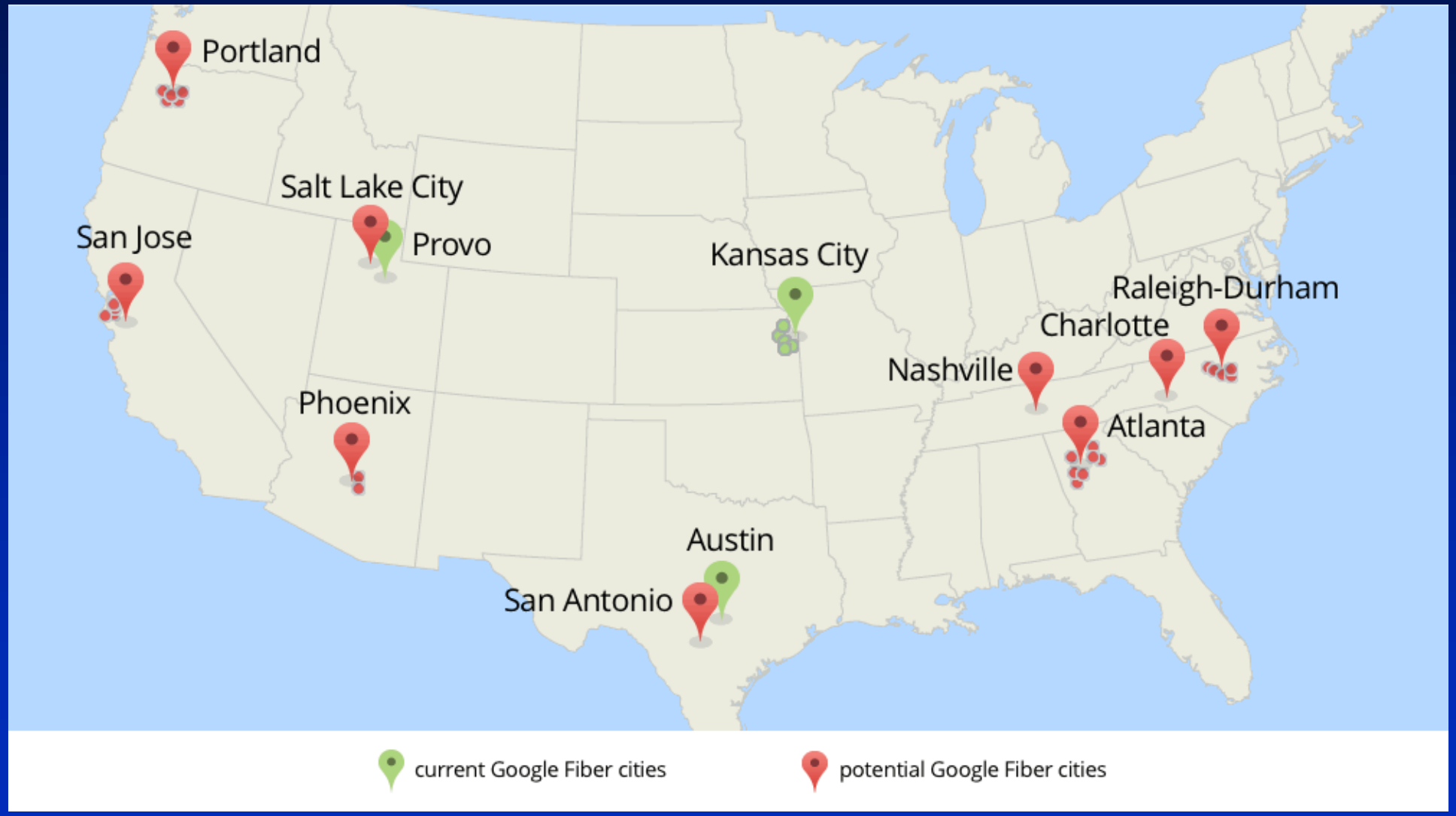
1. Position company to provide best defense
2. Influence balance of forces through strategic moves
3. Anticipating shifts in the underlying forces and responding

Examples

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

Google Fiber Plans

Smart 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

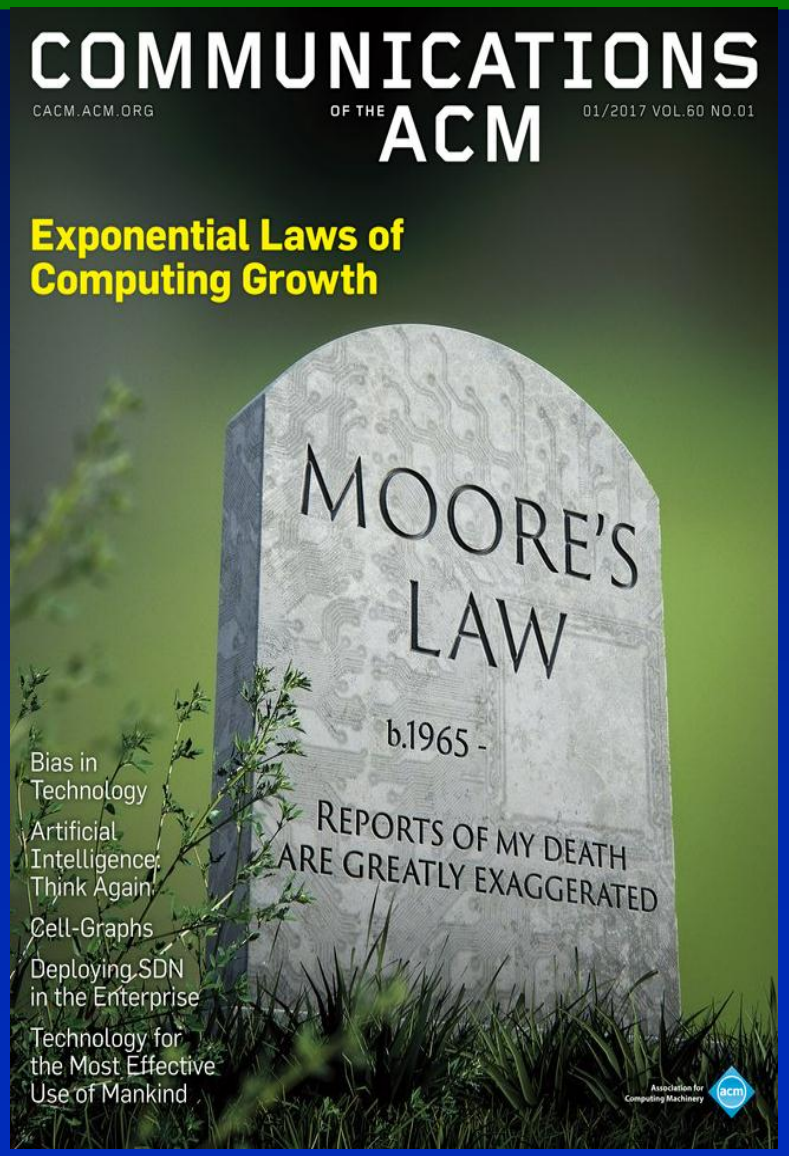
What Do You Do With The Unexpected?

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

Exponential Growth

Moore’s Law

Exponential Laws of Computing Growth



Dennings and Lewis, Jan. 2016

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

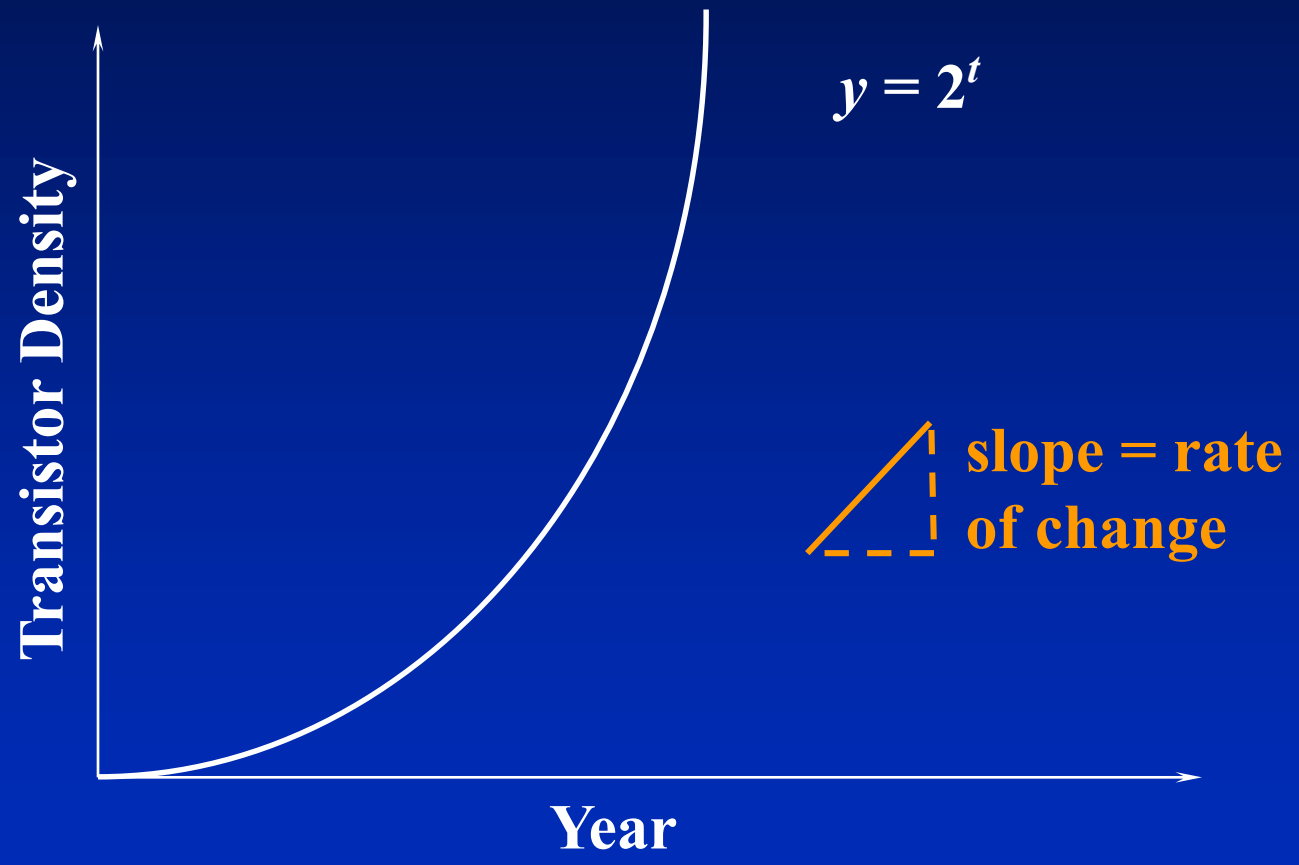
Moore's Law

"Chip density doubles every 18 months."

Processing Power (P) in 15 years:

$$P = P_{today}(2)^{\frac{15\ years}{18\ months}} = P_t(2)^{\frac{15}{1.5}}$$
$$= P_t(2)^{10} = 1000P_t$$

Understanding Exponential Growth



Understanding Exponential Growth

$$y = 2^t$$

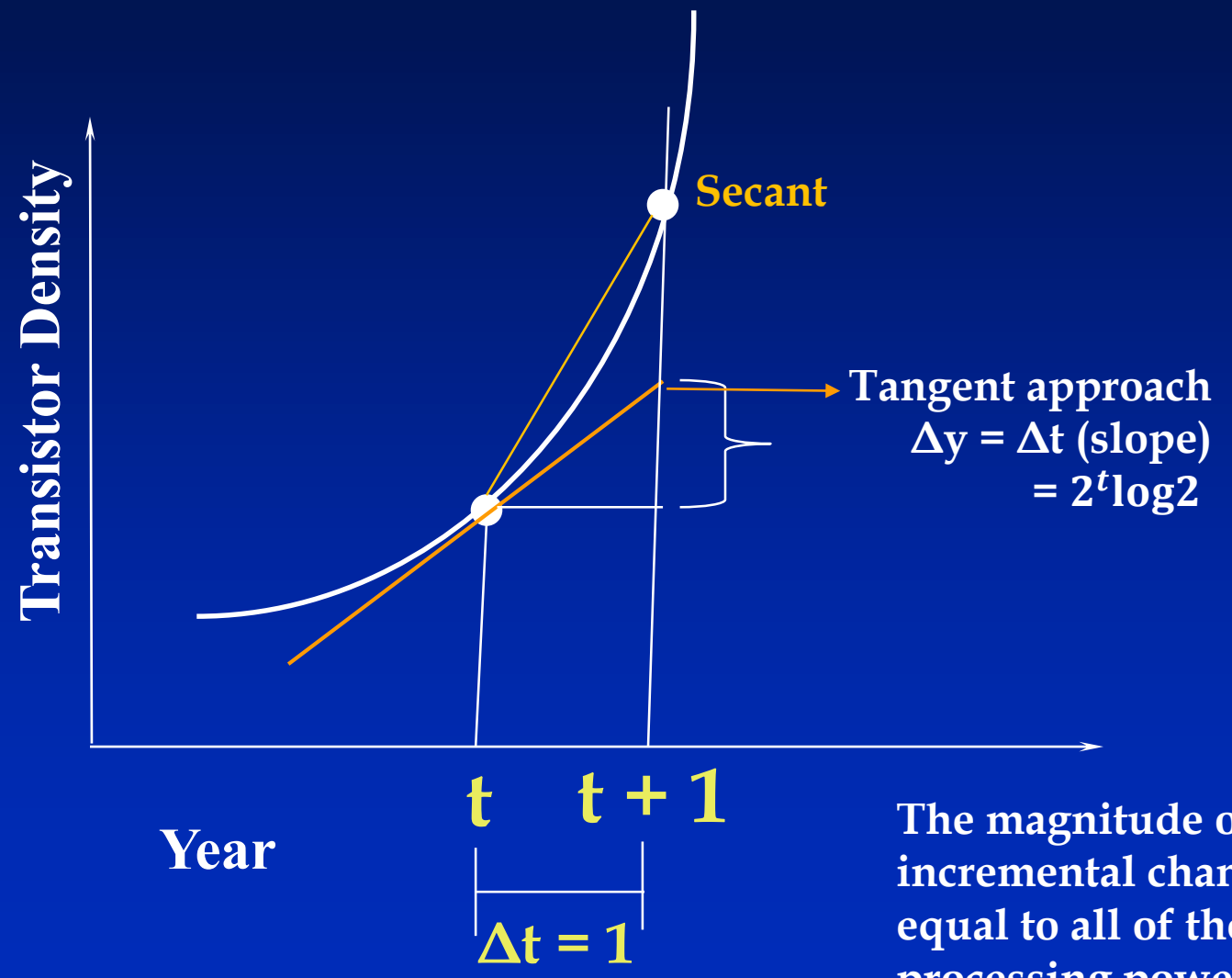
$$\frac{dy}{dt} = \frac{d}{dt}(2^t) = 2^t \log 2$$

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

t = in measured doubling time periods

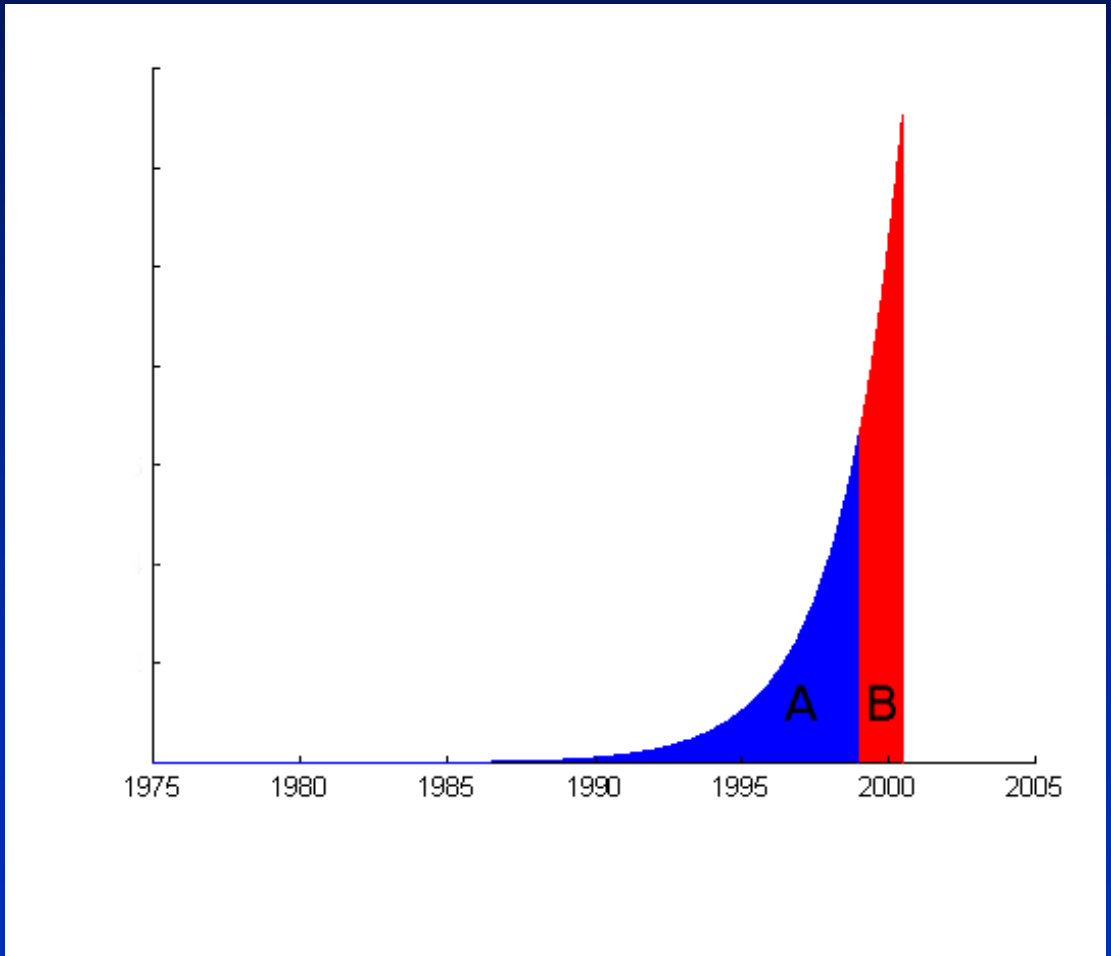
dy/dt = slope = rate of change

Understanding Exponential Growth

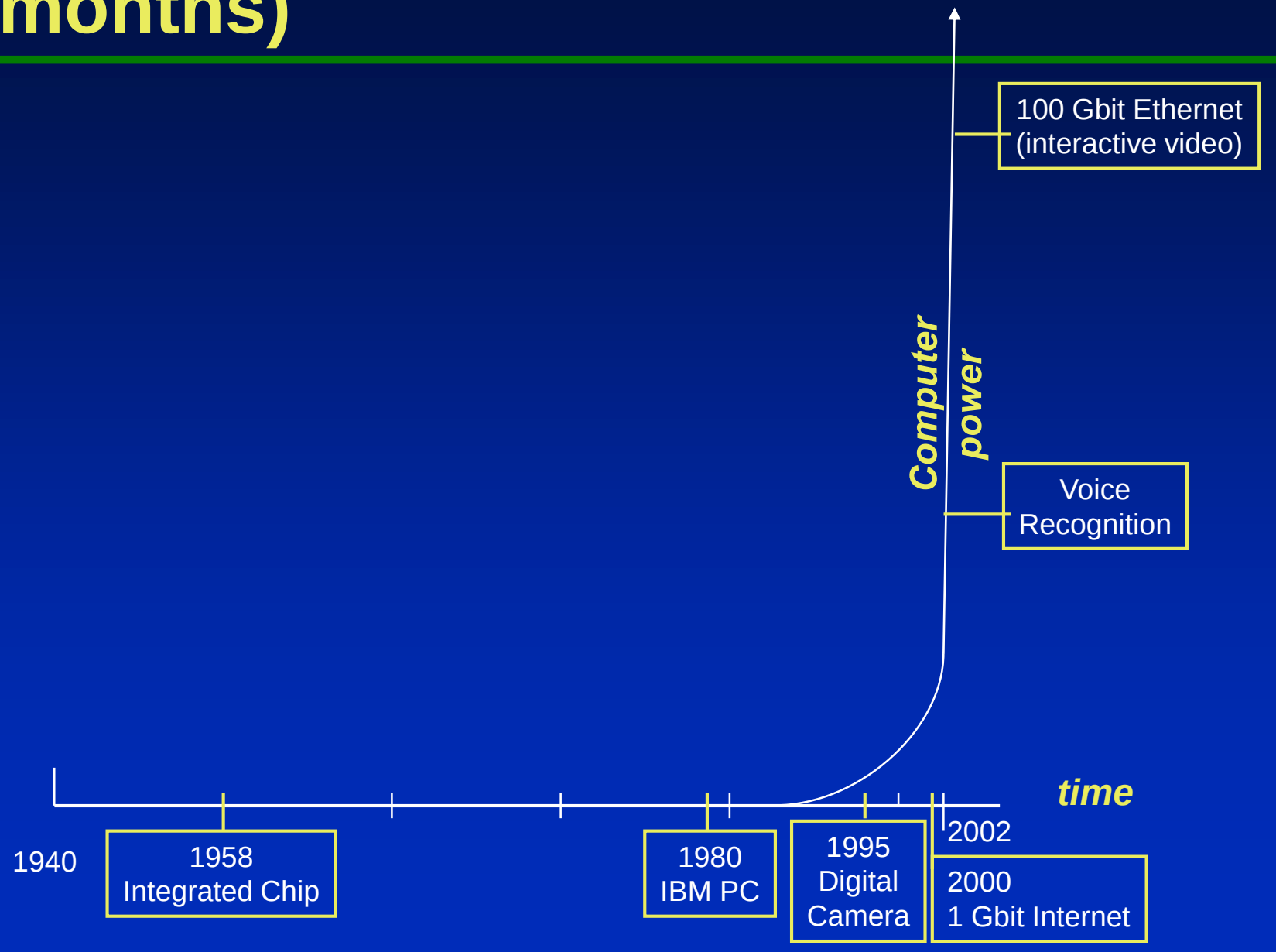


The magnitude of the incremental change is approximately equal to all of the available processing power that preceded it!

Understanding Moore's Law



Growth In Computer Power (2x / 18months)



Growth In Computer Power (2x / 18months)

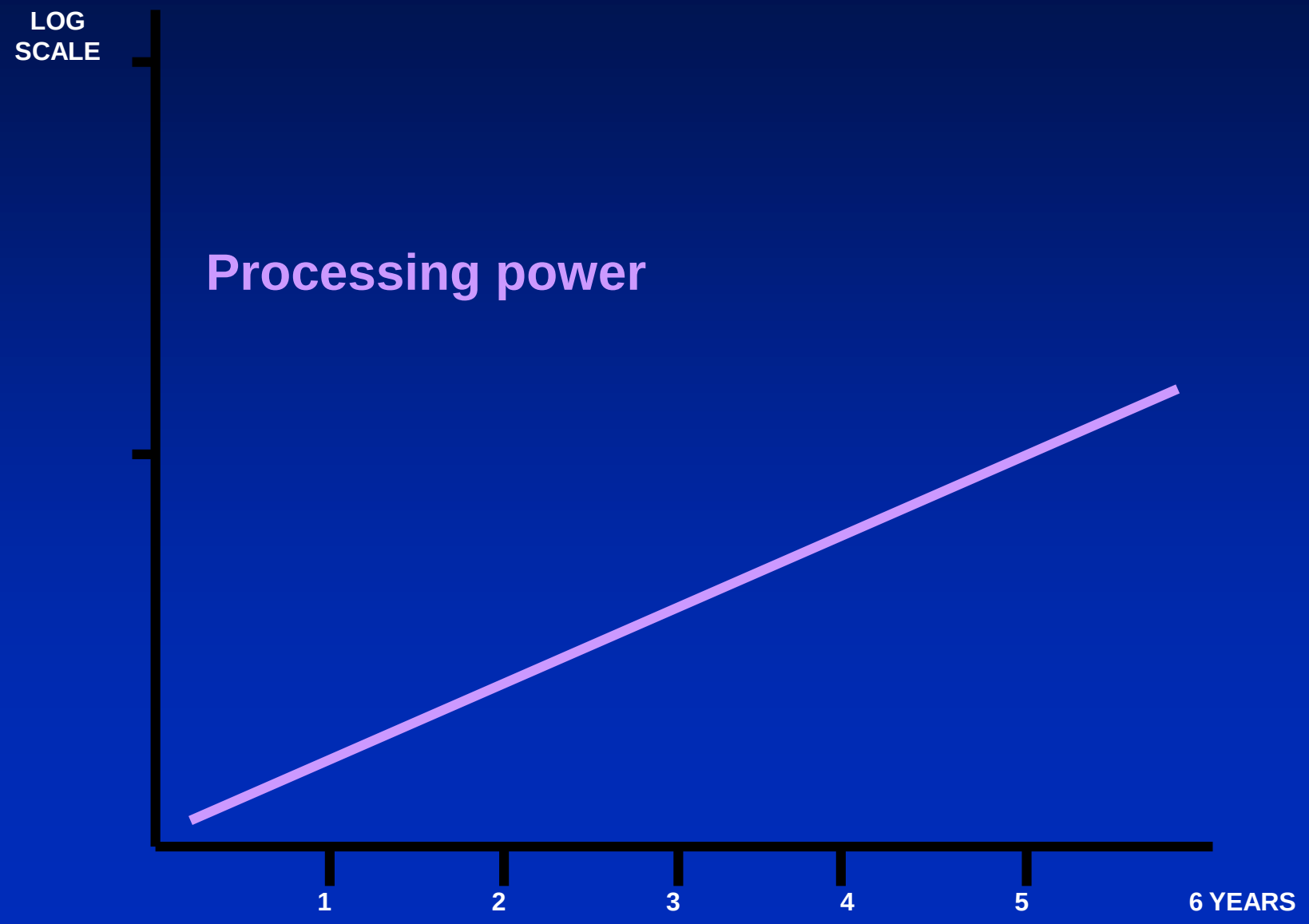
(Top of Curve)

Processing is basically free.

Impact of Abundant Computer Power

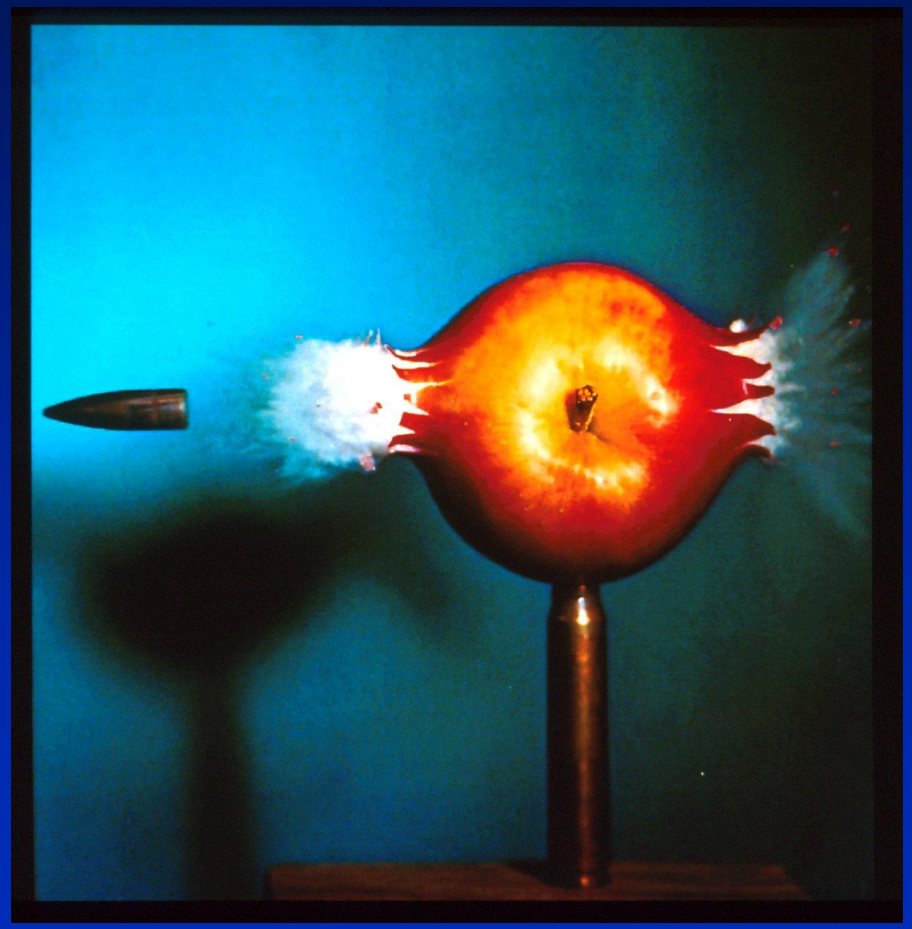
- Needles in a “Haystack” (security monitoring, focused advertising, etc)
- The internet of things (omnipresent sensors)
- Digital health care (remote medical diagnosis)
- MOOCs (Massive open online courses)
- Autonomous driving vehicles
- 3D data acquisition
- 3D printing

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



International Technology Roadmap for Semiconductors

	2001	2004	2007	2010	2013	2016
Technology (nanometers)	**130nm**	**90nm**	**65nm**	**45nm**	**32nm**	**22nm**
Functions per Chip (millions)	97	193	386	1546	3092	6184
Clock Speed (Ghz)	2.5Ghz	4.1Ghz	9.3Ghz	15Ghz	23Ghz	40Ghz
Wafer Size (millimeters)	200mm	300mm	300mm	300mm	450mm	450mm
Chip Size (mm^2)	140 mm^2	14 0 mm^2	140 mm^2	140 mm^2	140 mm^2	140 mm^2

Roughly 0.5 shrink every 3 years 29% cost/reduction/function/yr.

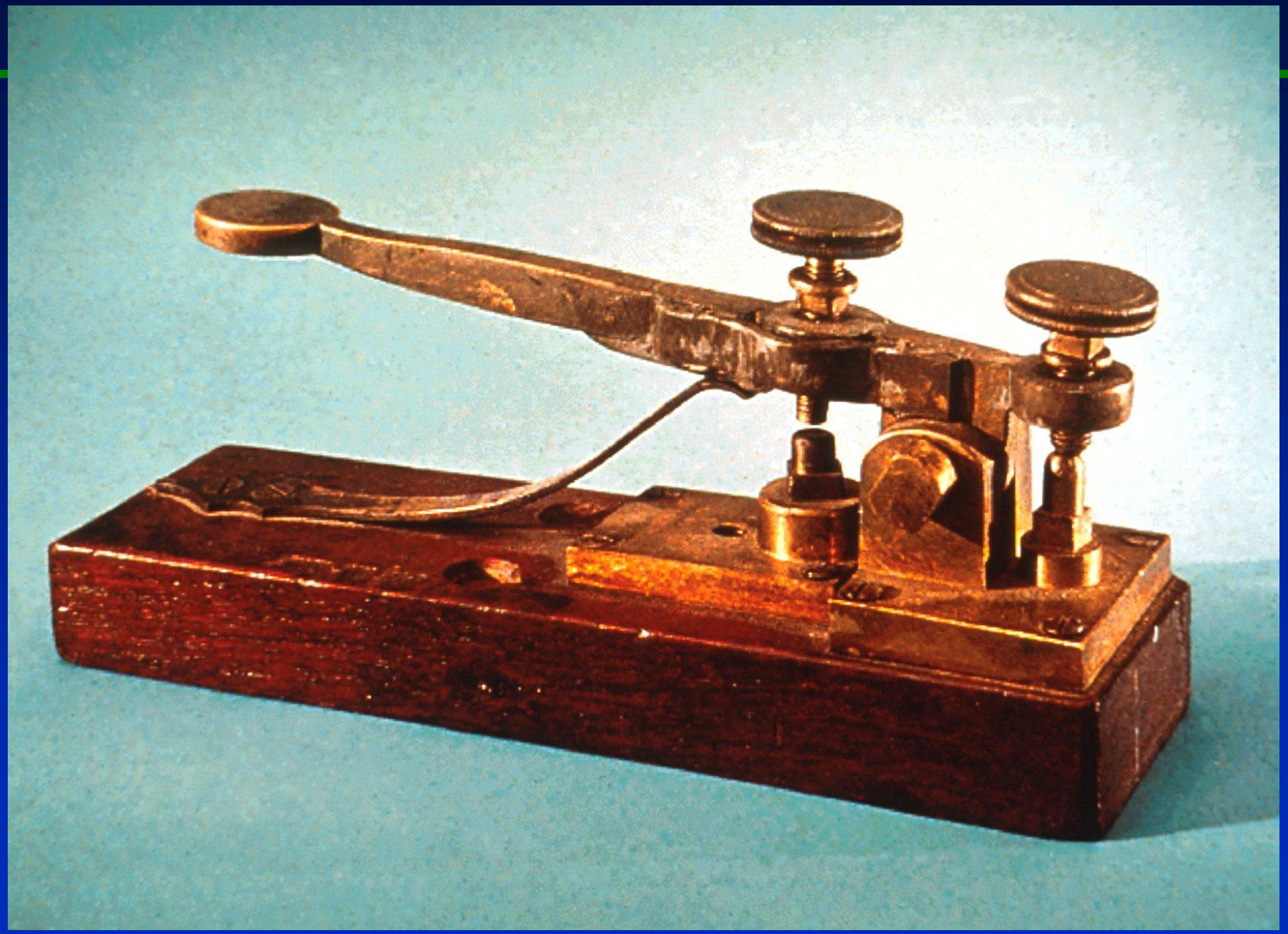
Technology Outlook

High Volume Manufacturing	2008	2010	2012	2014	2016	2018	2020	2022
Technology Node (nm)	45	32	22	16	11	8	6	4
Integration Capacity (BT)	8	16	32	64	128	256	512	1024
Delay Scaling	>0.7	~1?						
Energy Scaling	~0.5	>0.5						
Transistors	Planar	3G, FinFET						
Variability	High	Extreme						
ILD	~3	towards 2						
RC Delay	1	1	1	1	1	1	1	1
Metal Layers	8-9	0.5 to 1 Layer per generation						

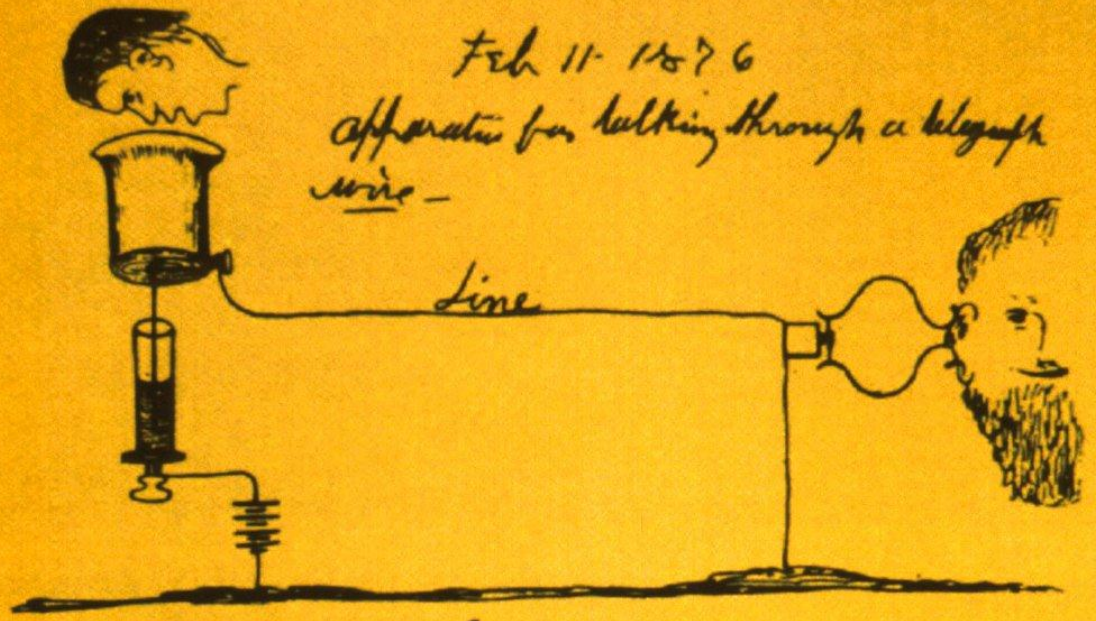
http://www.xbitlabs.com/news/cpu/display/20090822094141_Intel_Outlines_Process_Technology_Roadmap.html

Predicting the Future

Mistakes of the Past



Telegraph Key (Smithsonian)



Feb 11 1876
Apparatus for talking through a telegraph wire –

Gray vs Bell et al
Speaking Telephone Interference
a & L
Exhibit Gray Speaking Telephone
Caveat original sketch.

Edward H Beebe
Notary Public

May 7th 1880.

"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

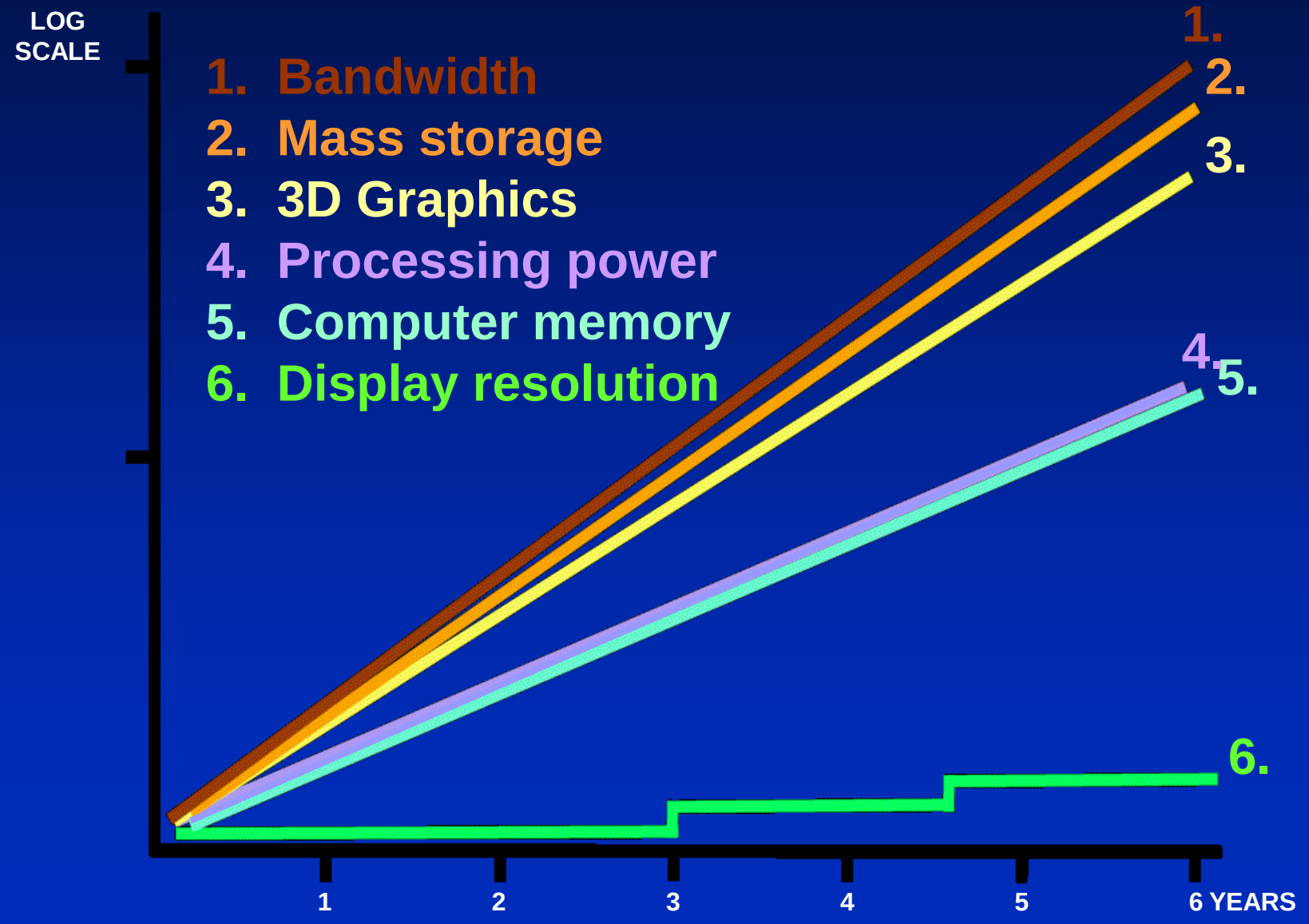
- Processing Power. . . . . 2x /18months
- Computer Memory. . . . . 2x /18months
- Mass Storage. . . . . 3x /18 months
- Bandwidth. . . . . 10x /3 years

Growth Rates of System Components of the Electronic Age

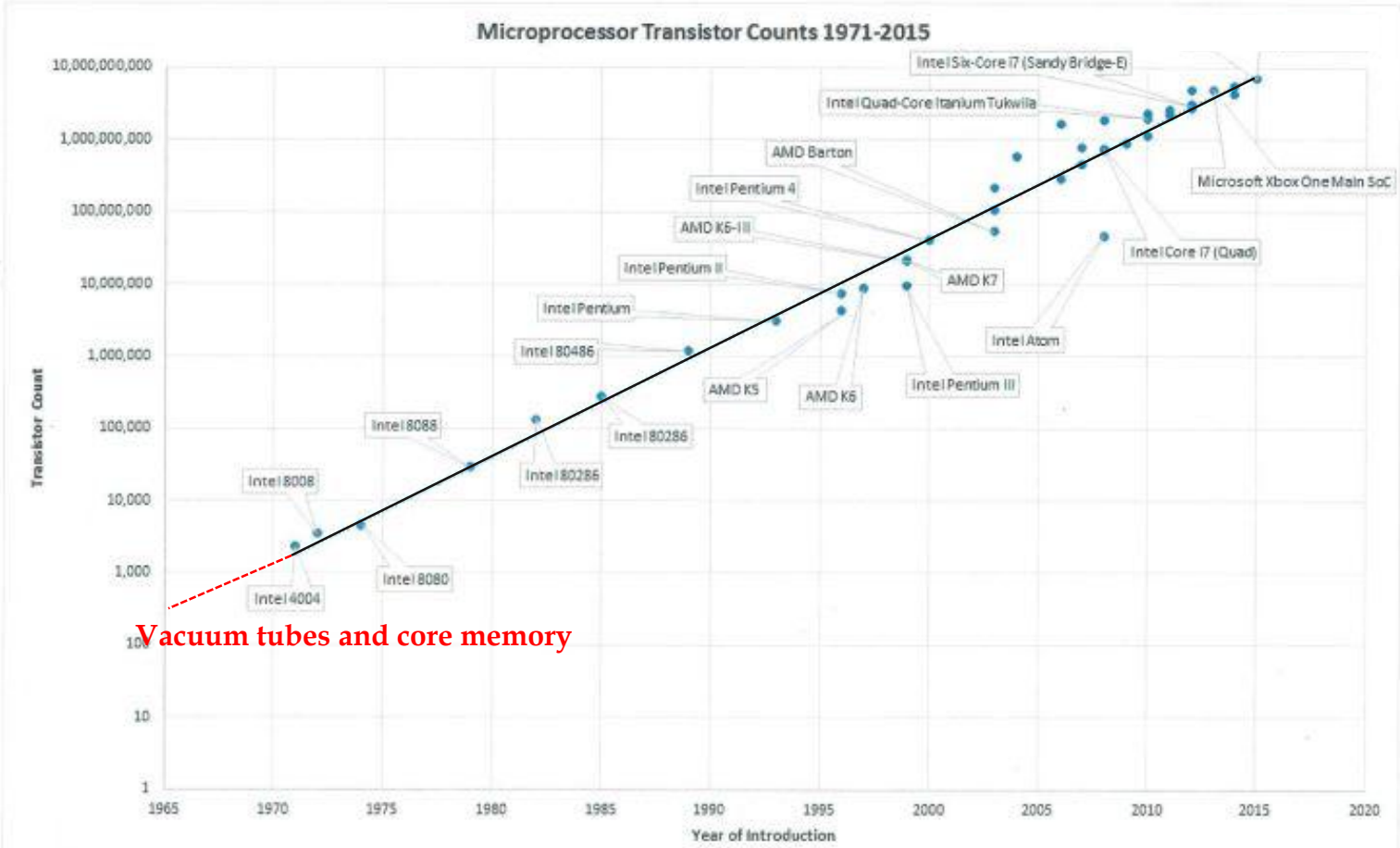
- 3D Graphics
  - Image Capture. . . . . 2x / 18 months
  - Image Display. . . . . 2x / year

  (Hardware, Software)
- Display Resolution. . . . . 2x/50 years
- User Interfaces

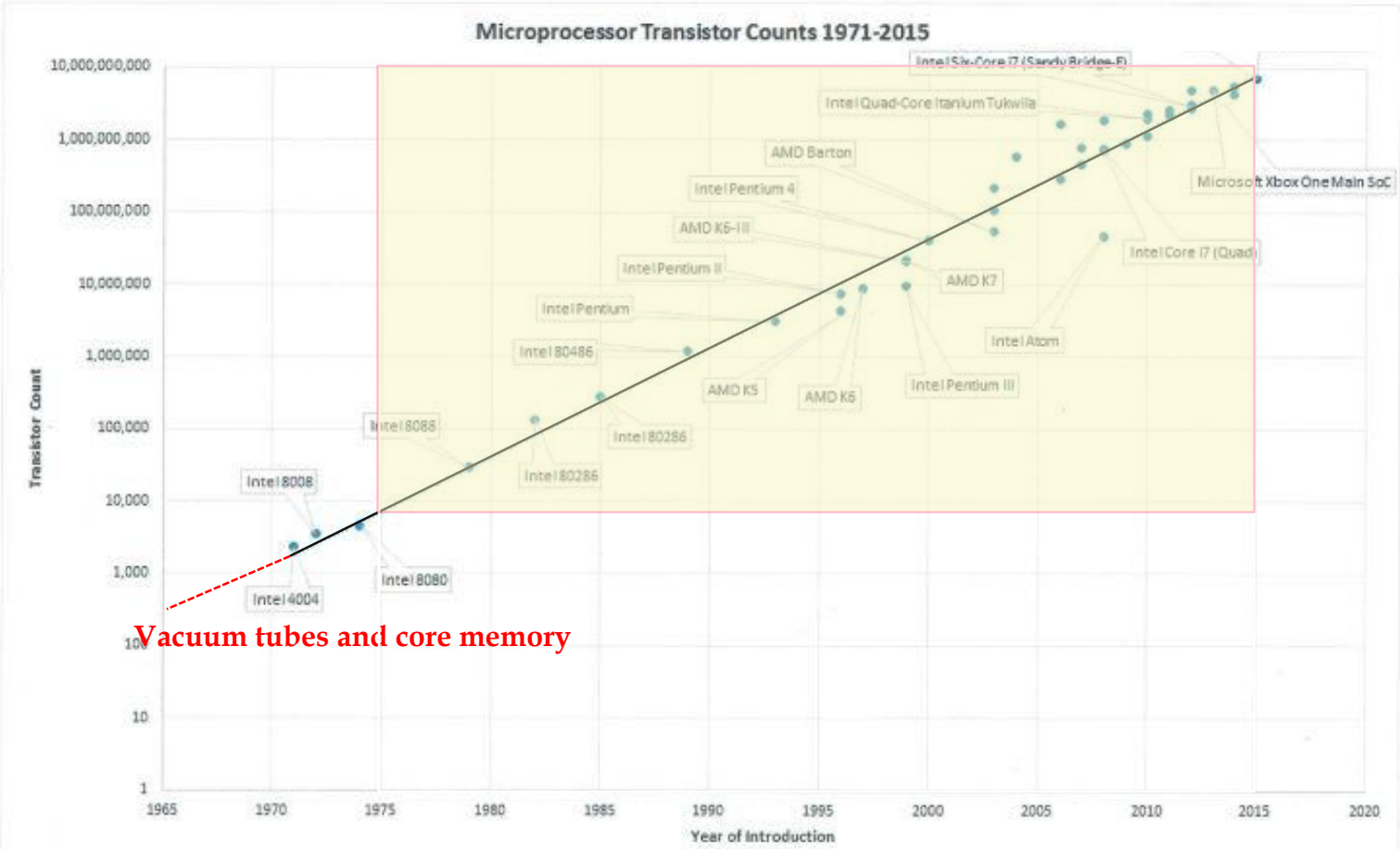
Relative Rates of Growth of Computer System Components



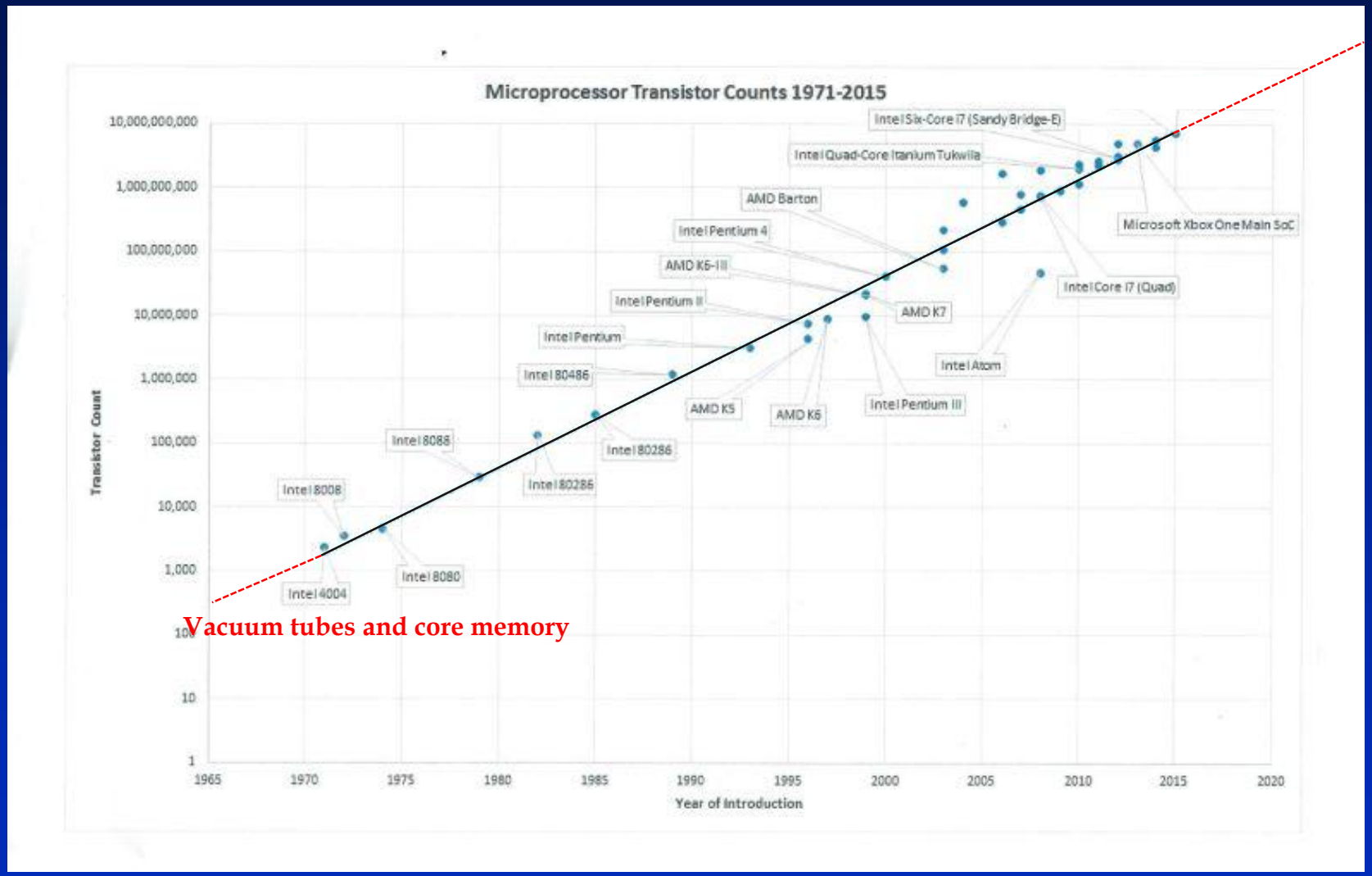
Transistor Density (Processing Power)



Processing Power 100 Million X



Processing Power One Trillion X



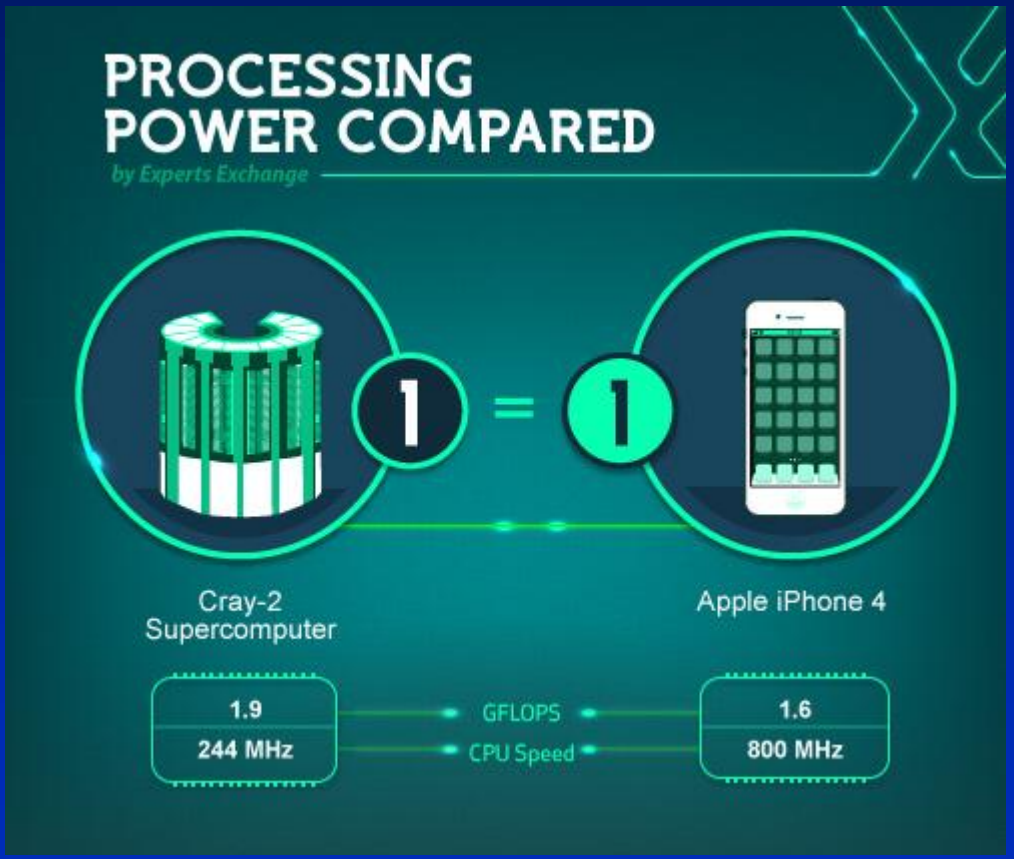
1,000,000,000,000

2025

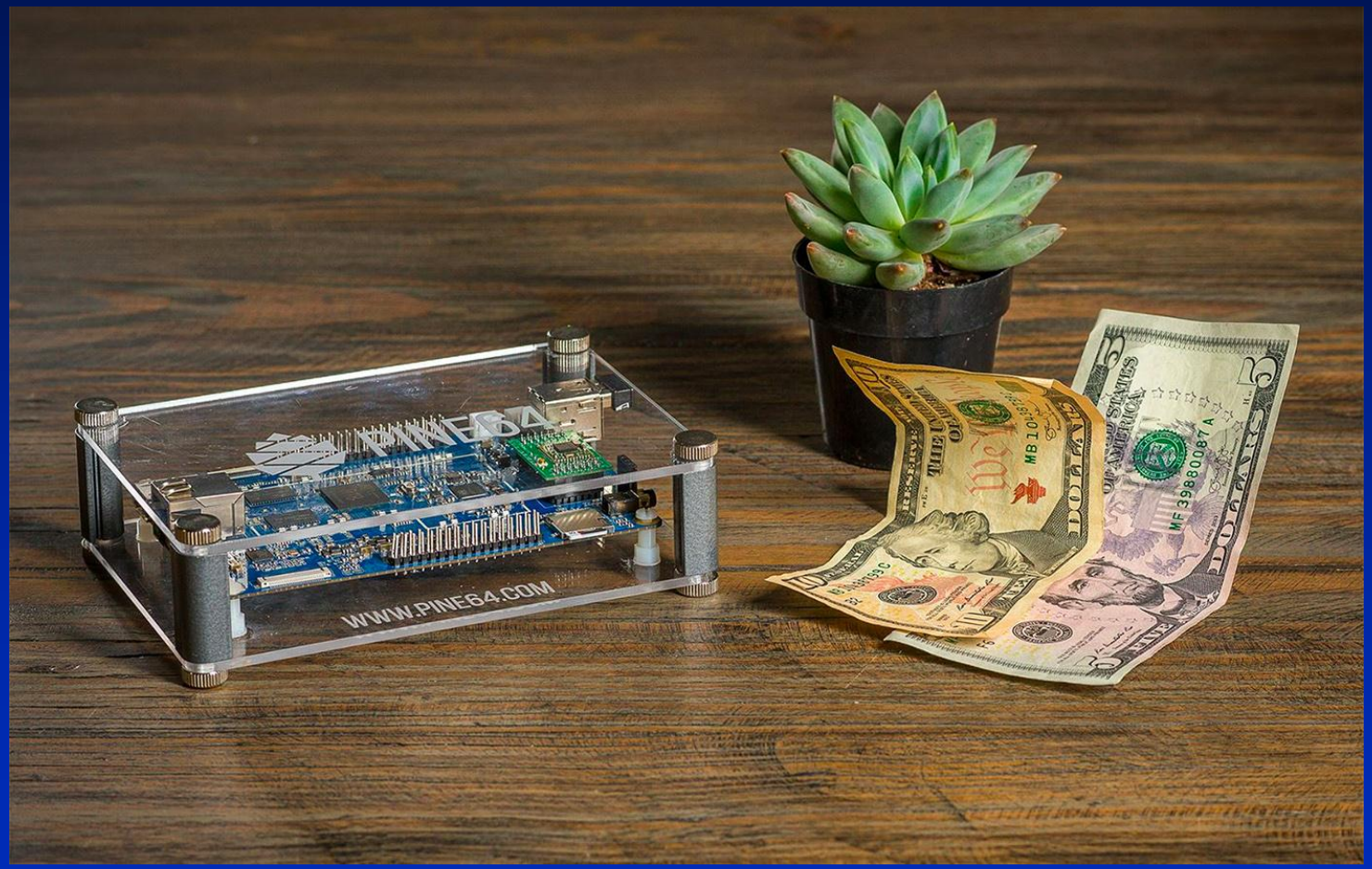
Processing Power Compared

- 2015: iPhone 5 > 1985 Cray-2

(2.7x)

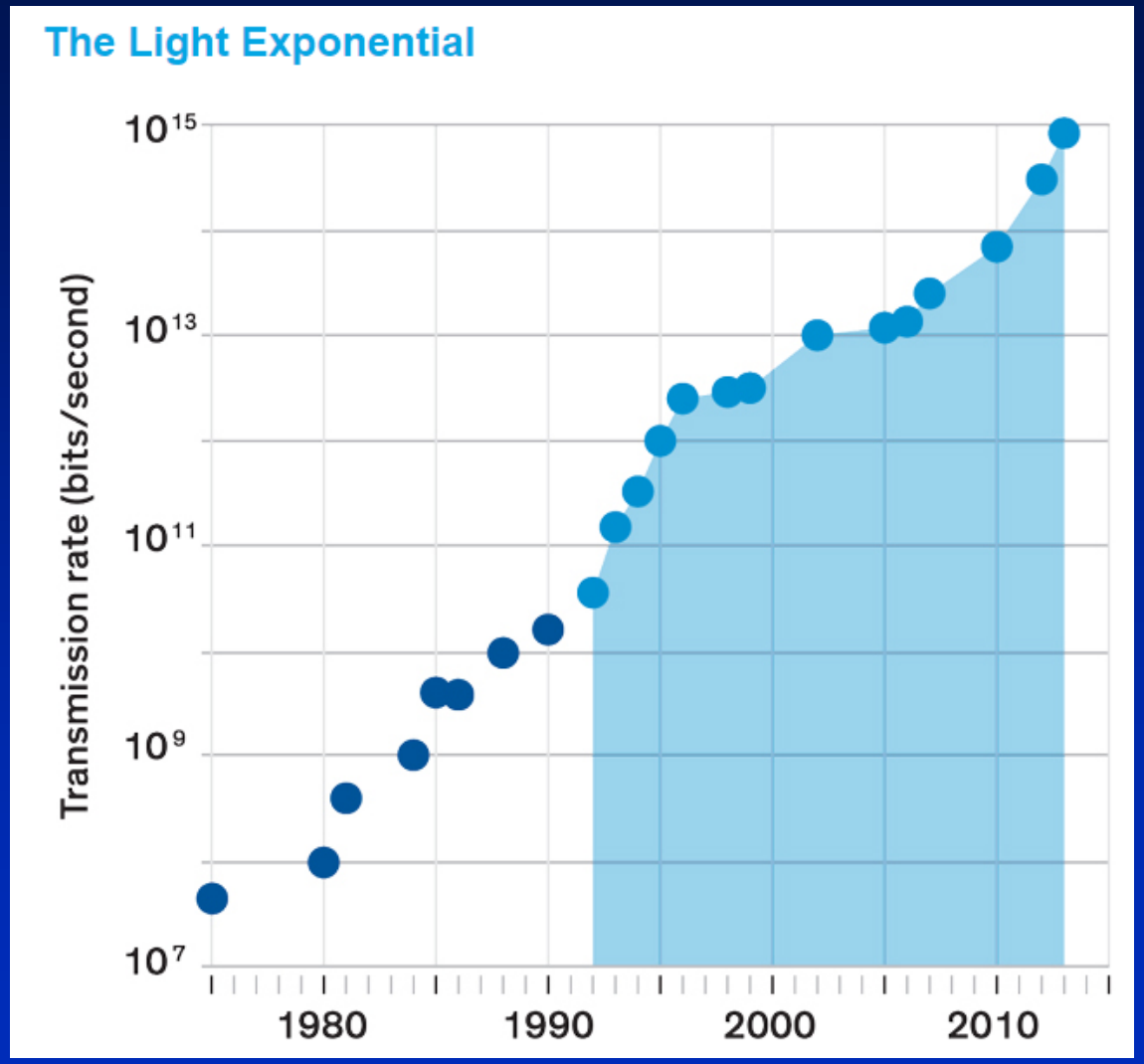


Pine A64



Engadget.com

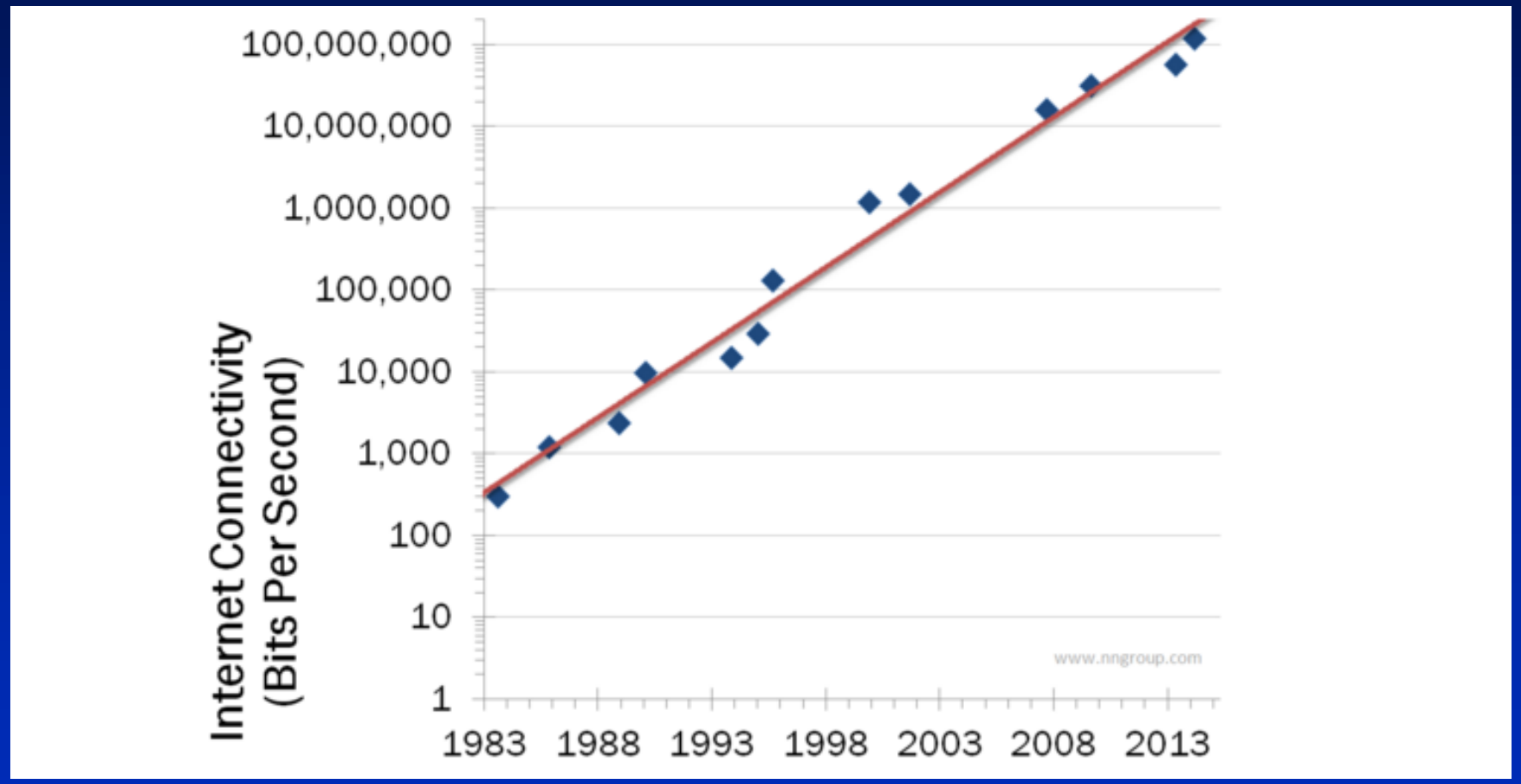
Keck's Law



Bandwidth of Optical Fiber

IEEE Spectrum

Nielsen's Law

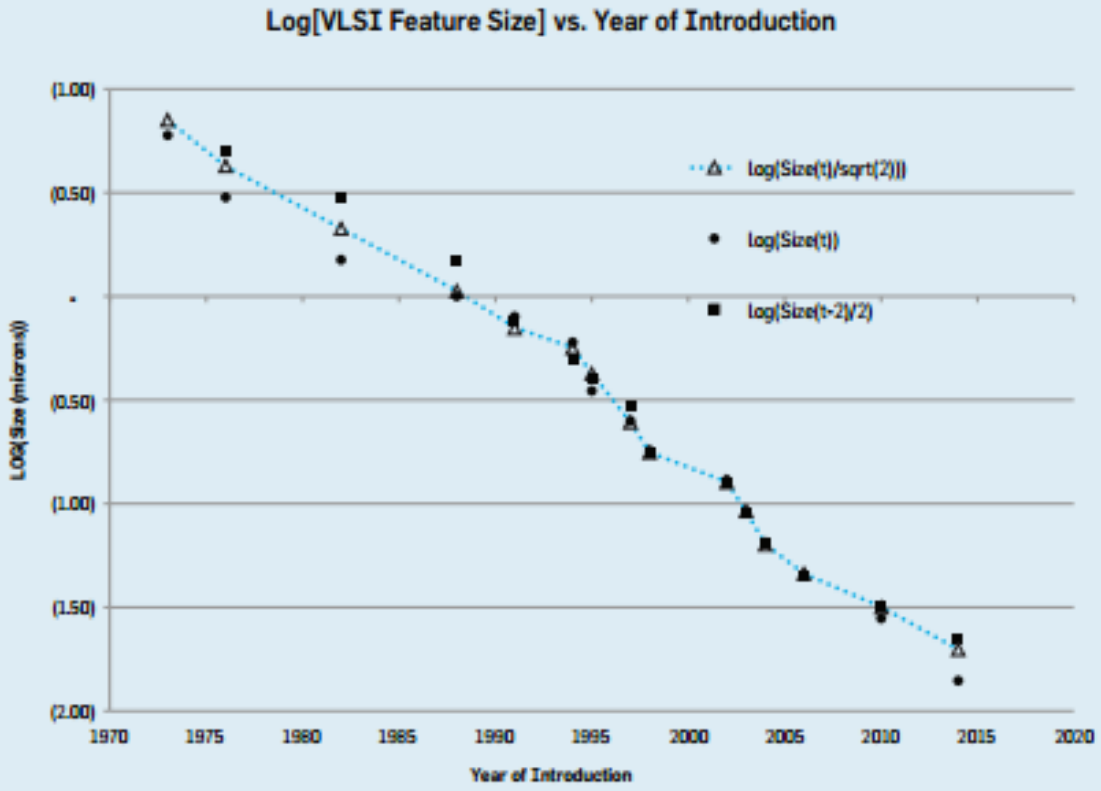


Internet Bandwidth

Decrease in Chip Feature Size

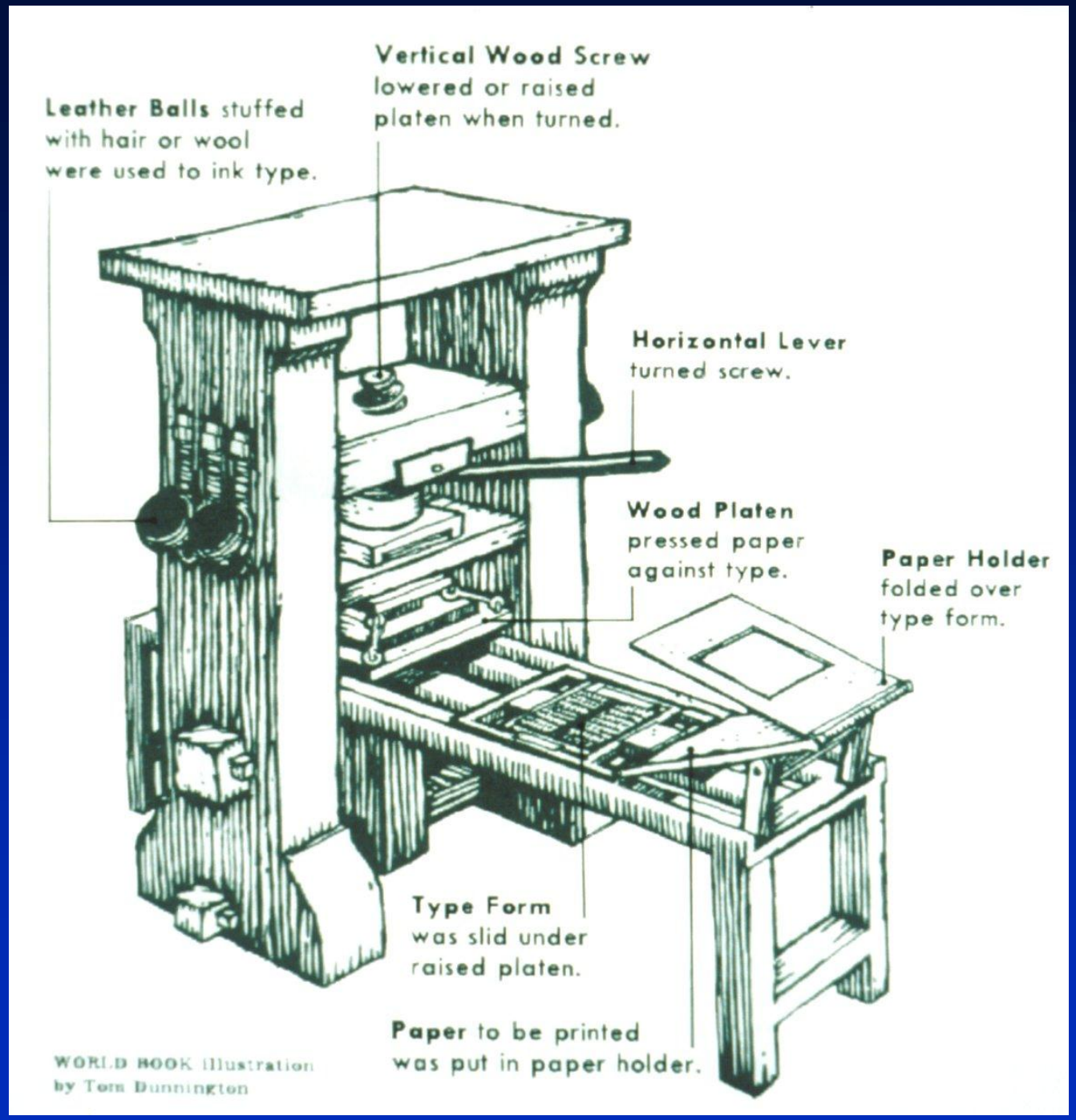
Figure 4. Logarithm of actual versus predicted feature size since 1970 matches a straight line with regression coefficient $R^2 = 0.97$. Future sizes are predicted by dividing the previous size by sqrt(2); see the open triangles and dotted line. Future sizes two generations into the future are close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

Data from David Harris, Lecture 21: "Scaling and Economics," Harvey Mudd College, Claremont, CA, 2004 (http://pages.hmc.edu/harris/class/e158/04/lect21.pdf) and Zvi Or-Bach, "Is the Cost Reduction Associated with Scaling Over?" MonolithIC3D, San Jose, CA, 2004 (http://www.monolithic3d.com/blog/is-the-cost-reduction-associated-with-scaling-over).



Dennings and Lewis, Jan. 2016

Powers of 10
Dykstra


Vertical Wood Screw lowered or raised platen when turned.
Leather Balls stuffed with hair or wool were used to ink type.
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.
WORLD BOOK illustration by Tom Dunnington

iPad

- Introduced: 2010 (February)
- Price: starting at $499

The Impact of the iPad

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

Disruptive Technologies

Required Reading

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- Jill Lepore. "The Disruption Machine," The New Yorker, June 23, 2014. http://www.newyorker.com/reporting/2014/06/23/140623fa_fact_lepore?currentPage=all

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


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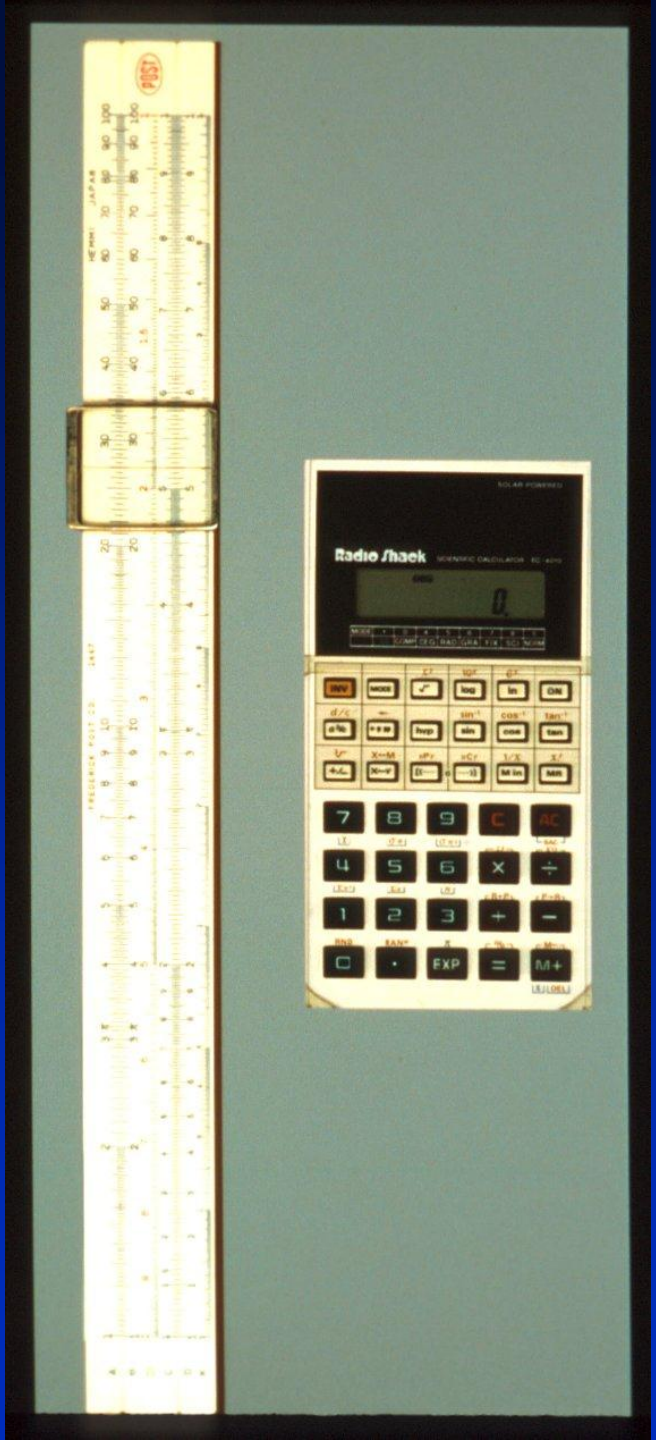
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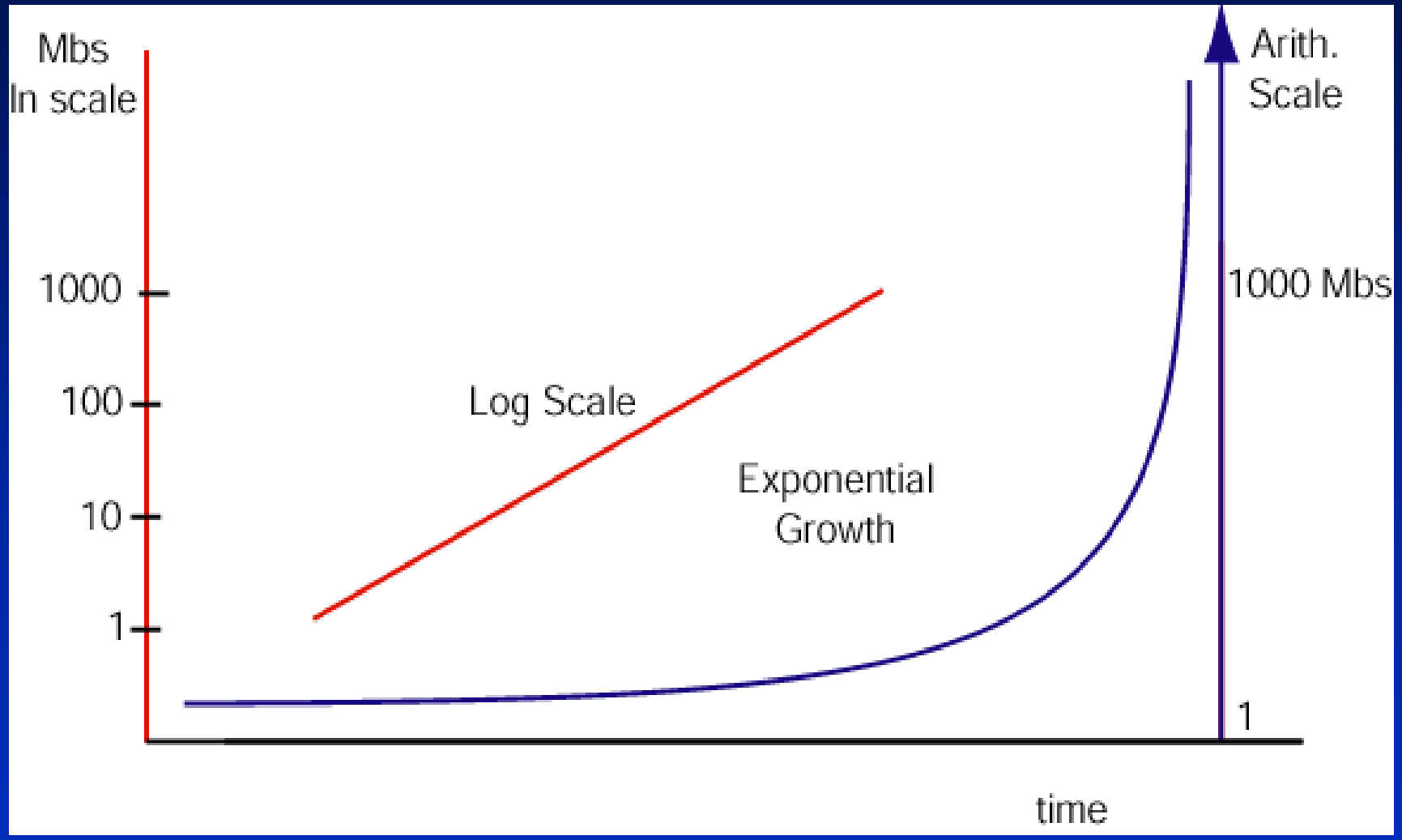
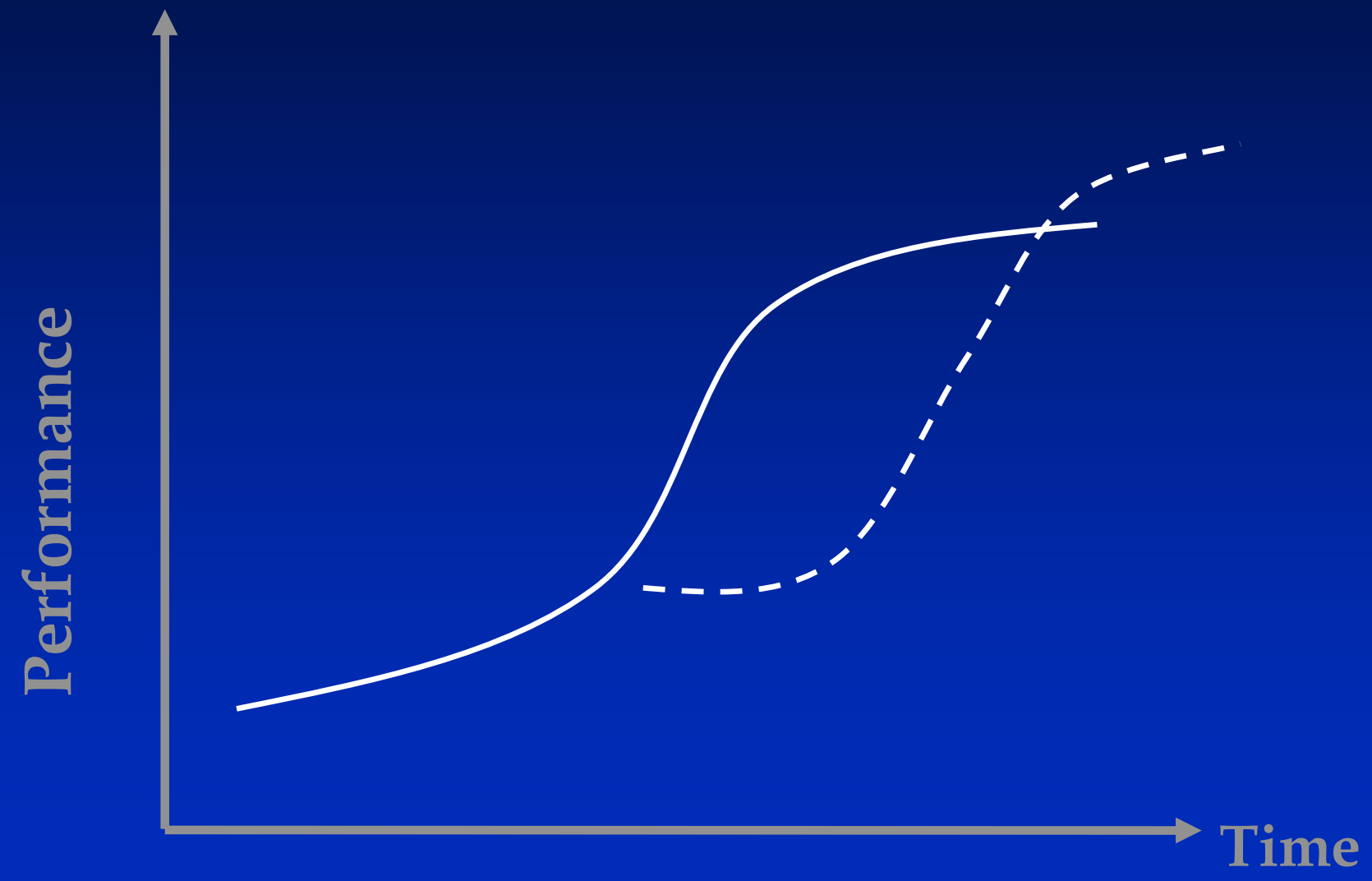
Concept of Performance Trajectories

- Rate at which performance is expected to improve (demand)
- Rate at which performance improves (supply)

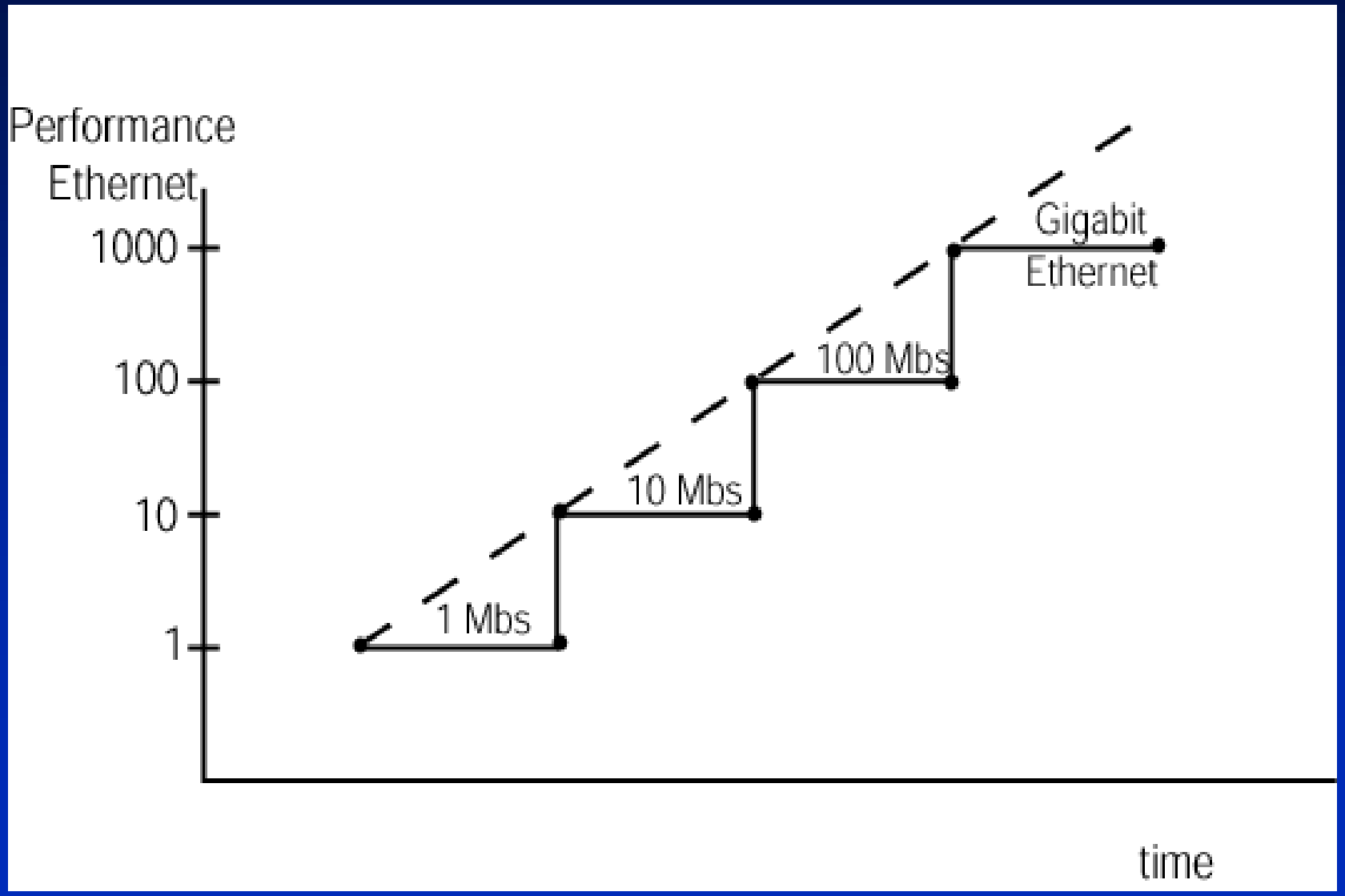
Performance Trajectories: *Log Scale vs. Arithmetic Scale*



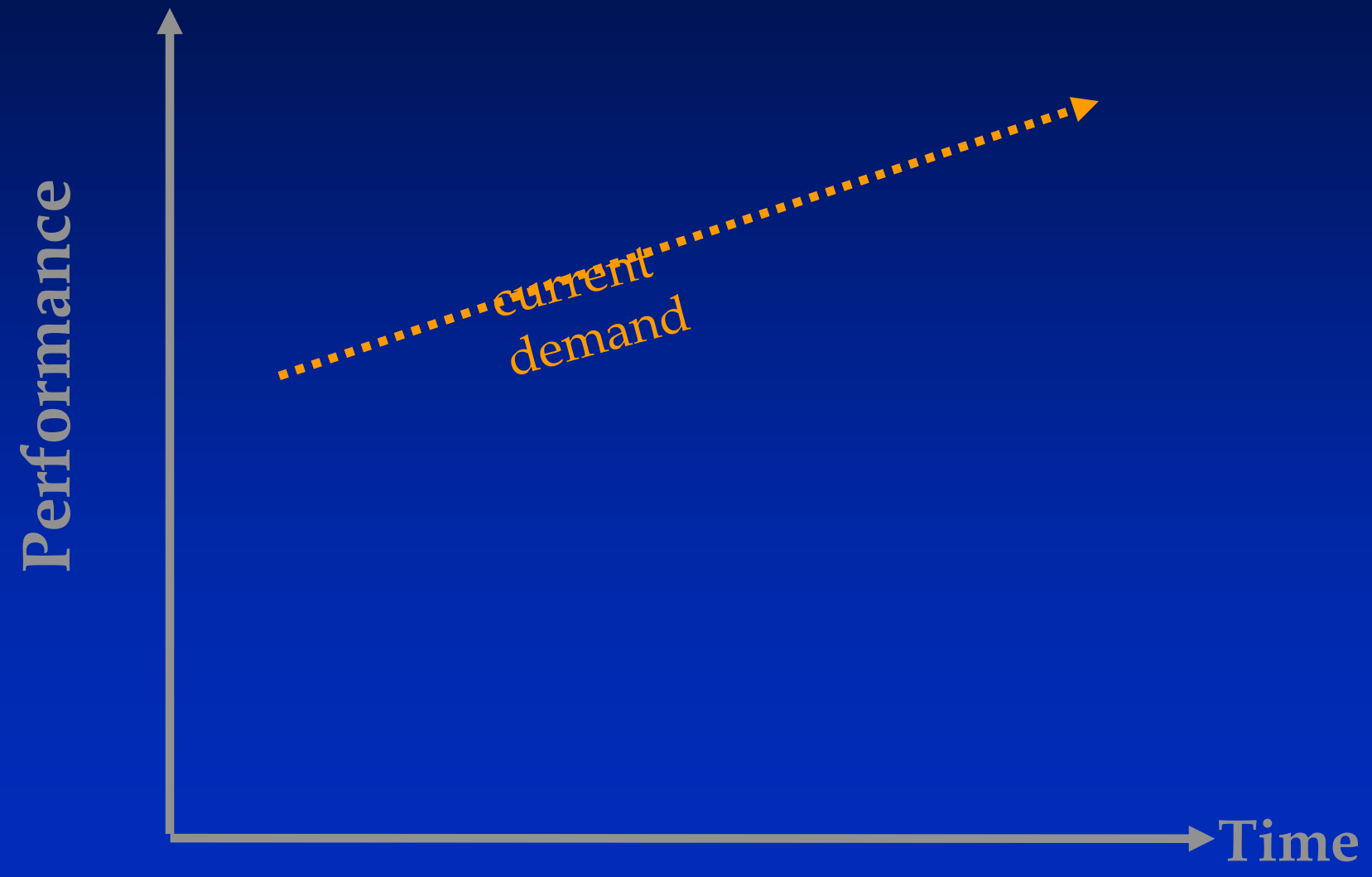
S Shaped Performance Trajectories



Discrete Performance Trajectories



Typical Sustainable Technology



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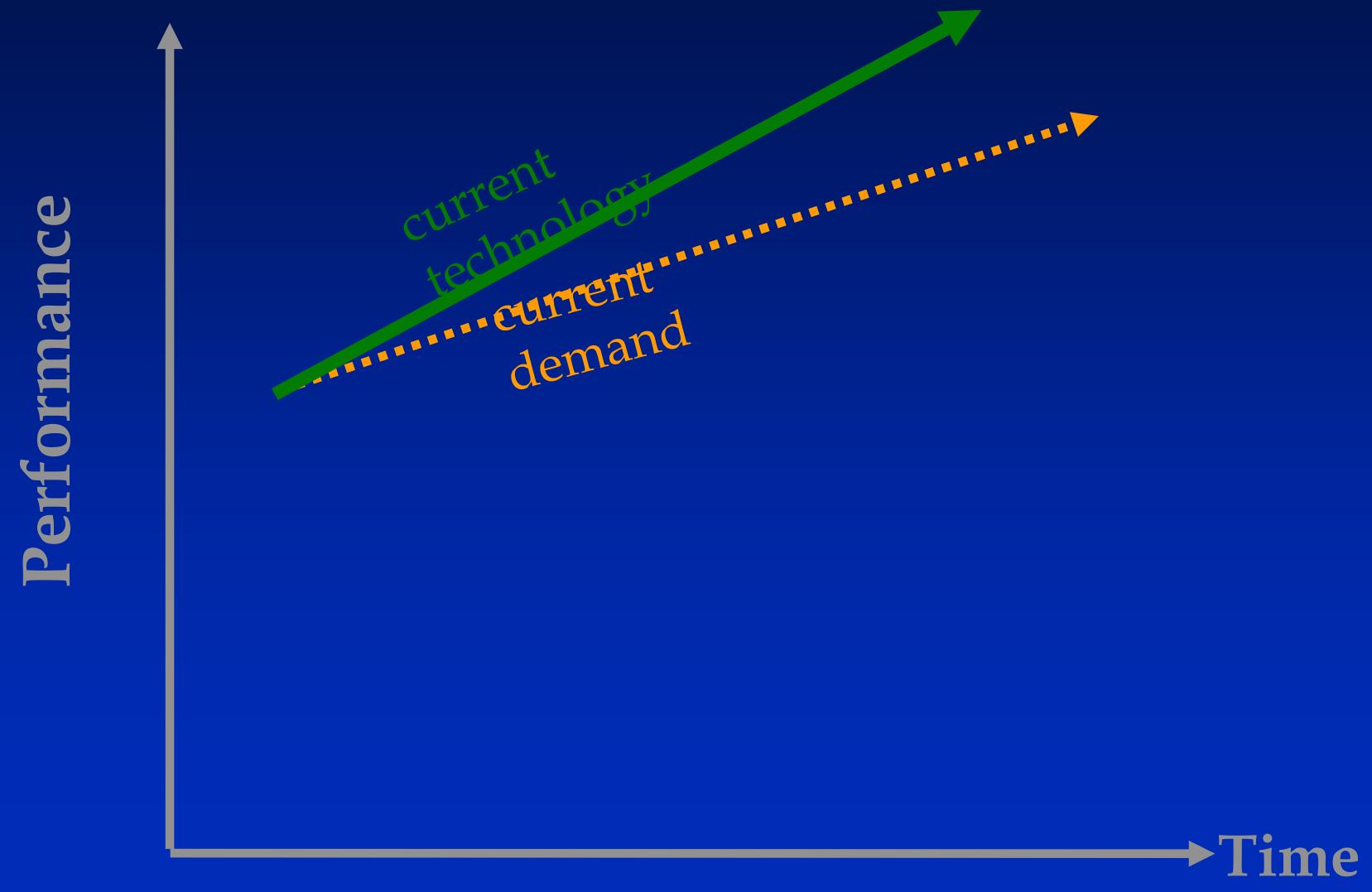
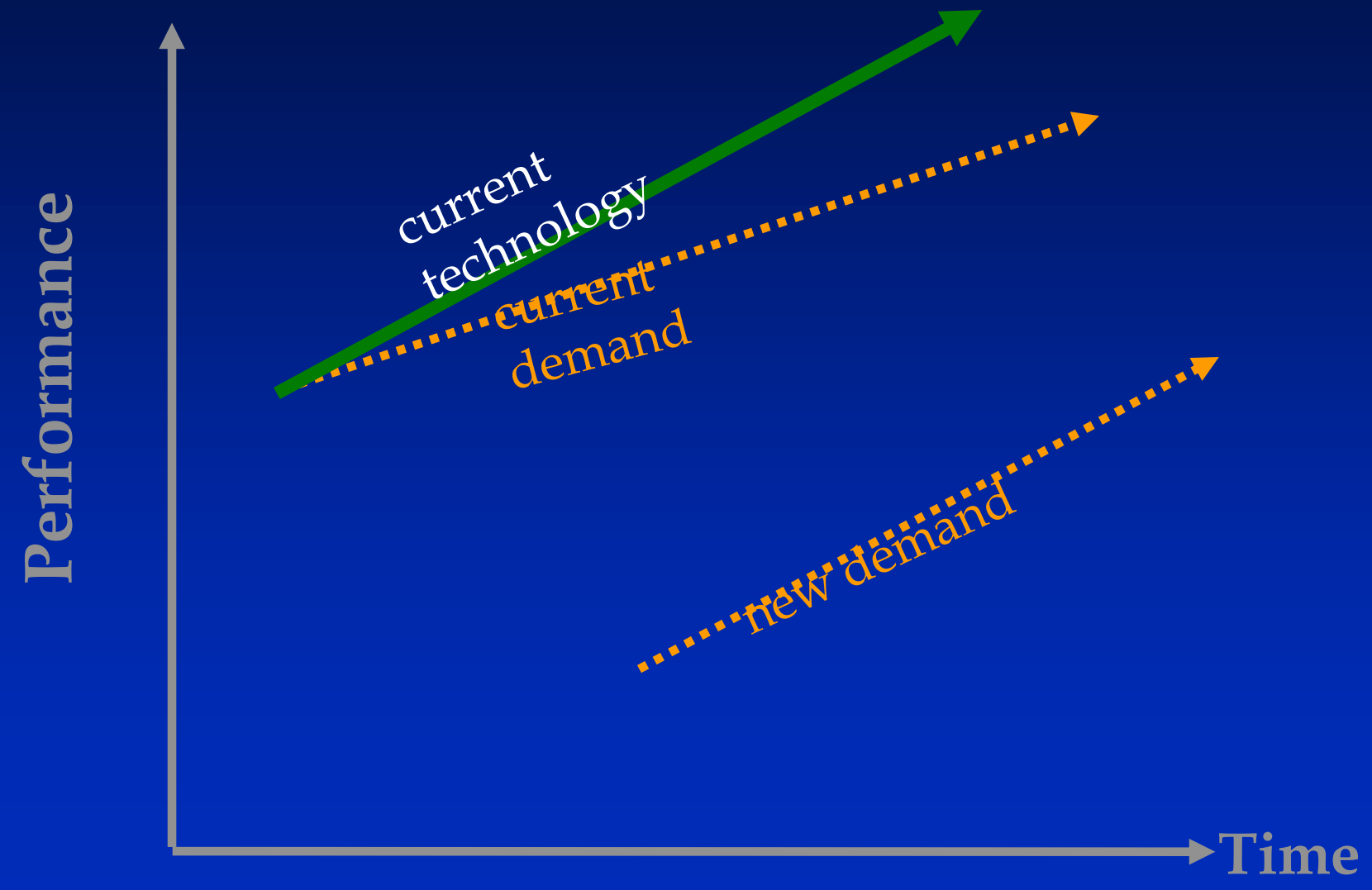
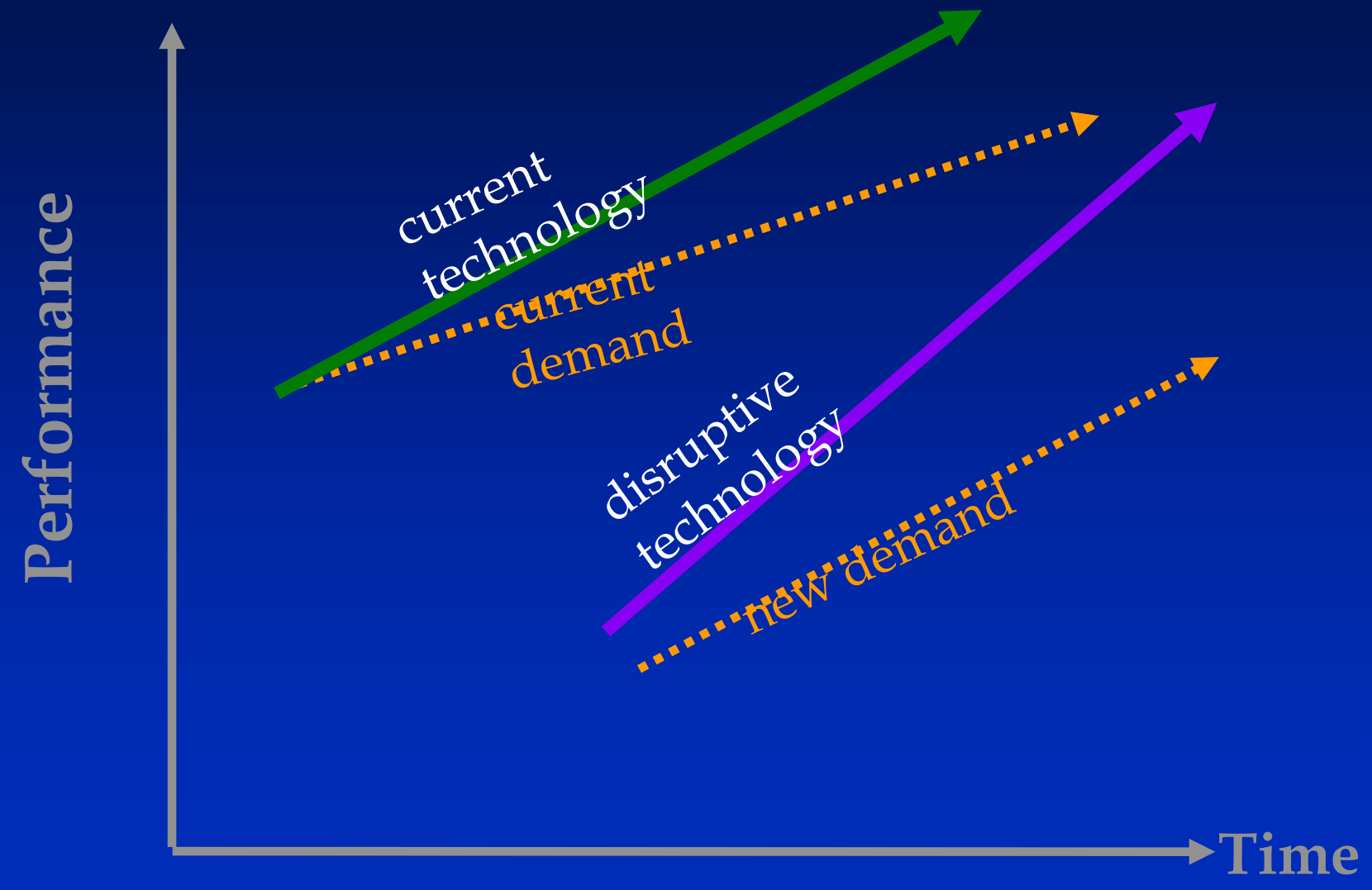


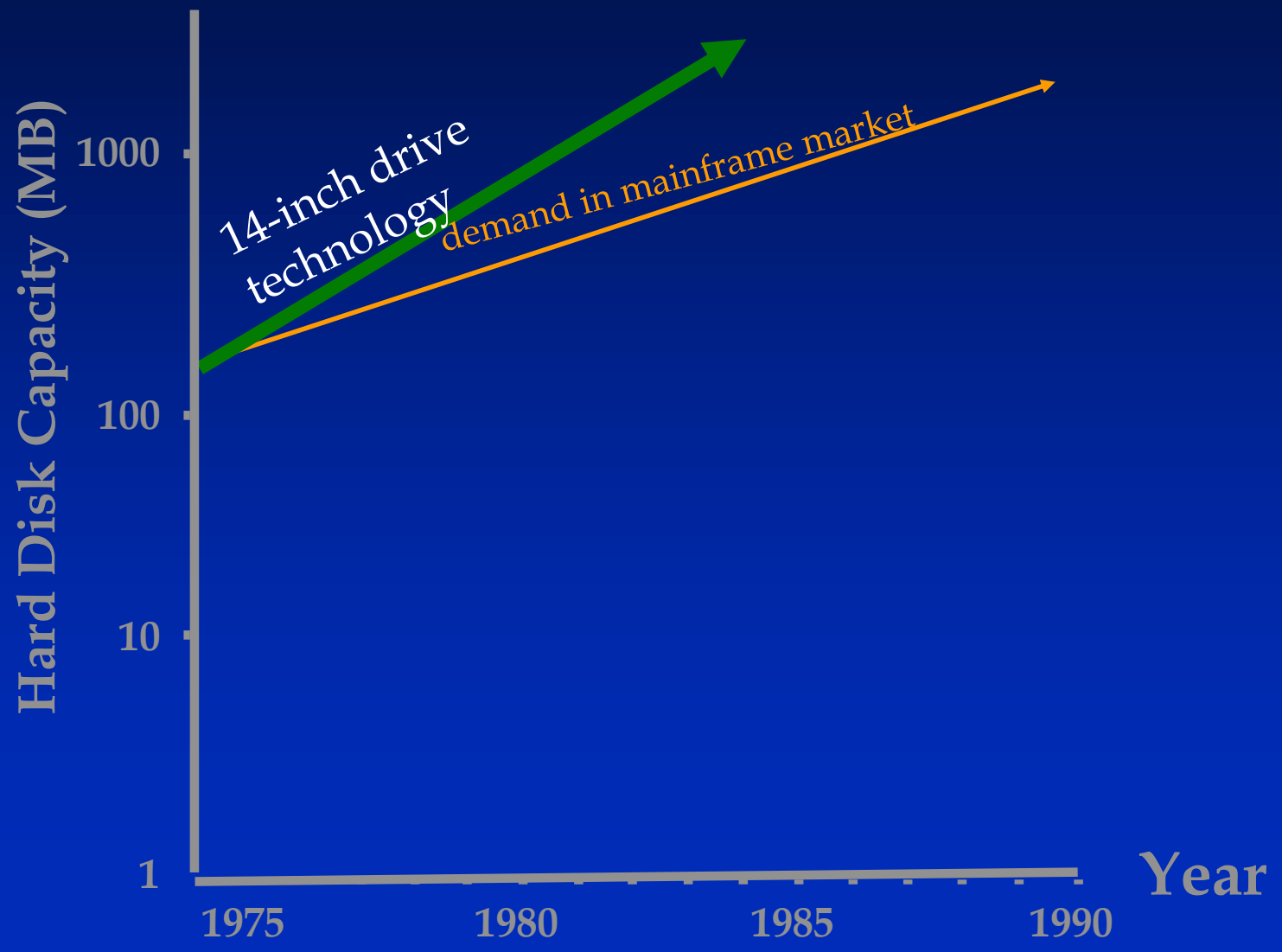
Typical Disruptive Technology



Typical Disruptive Technology



Rigid Disk Drive Industry

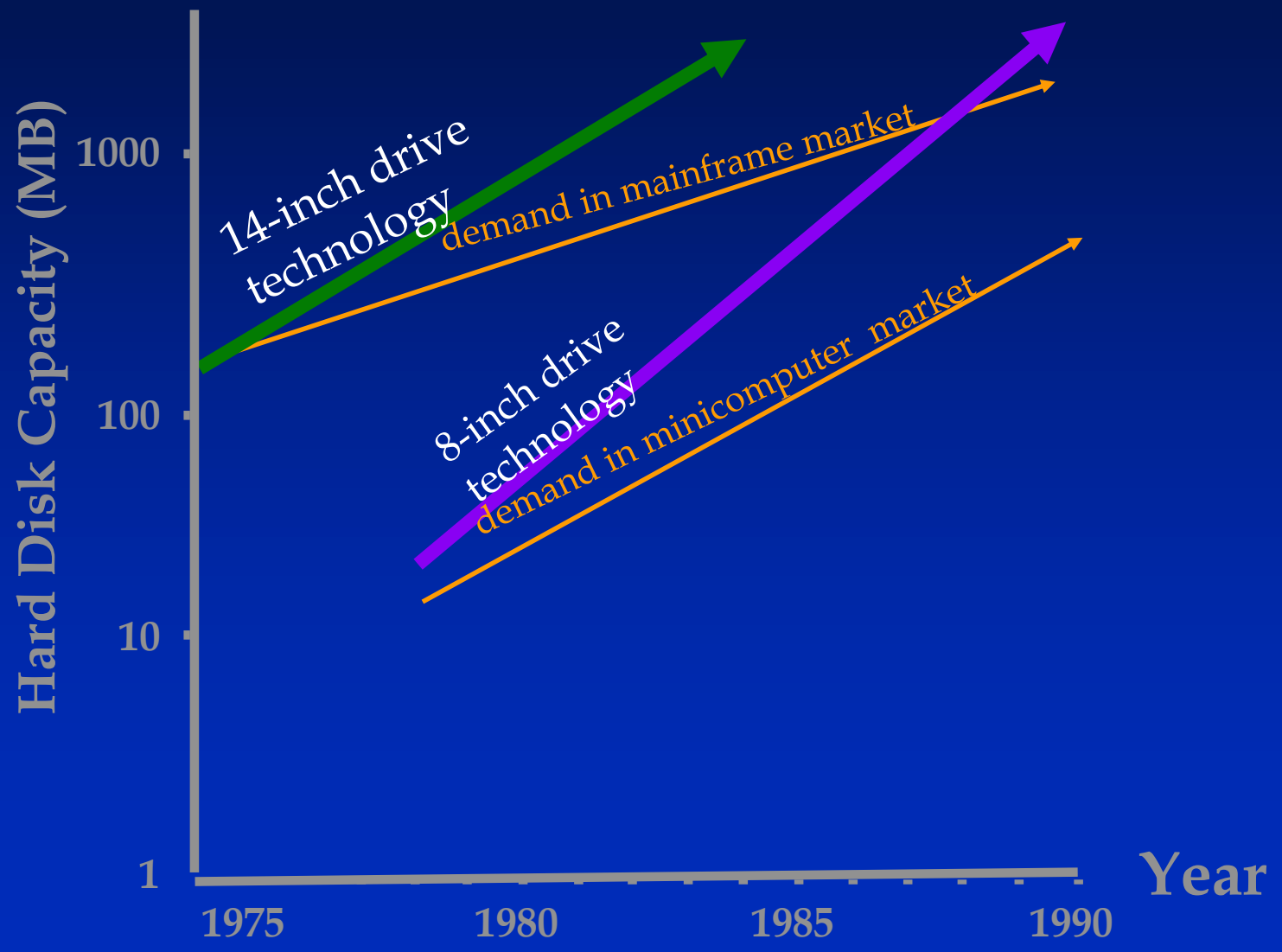


Alan F. Shugart

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



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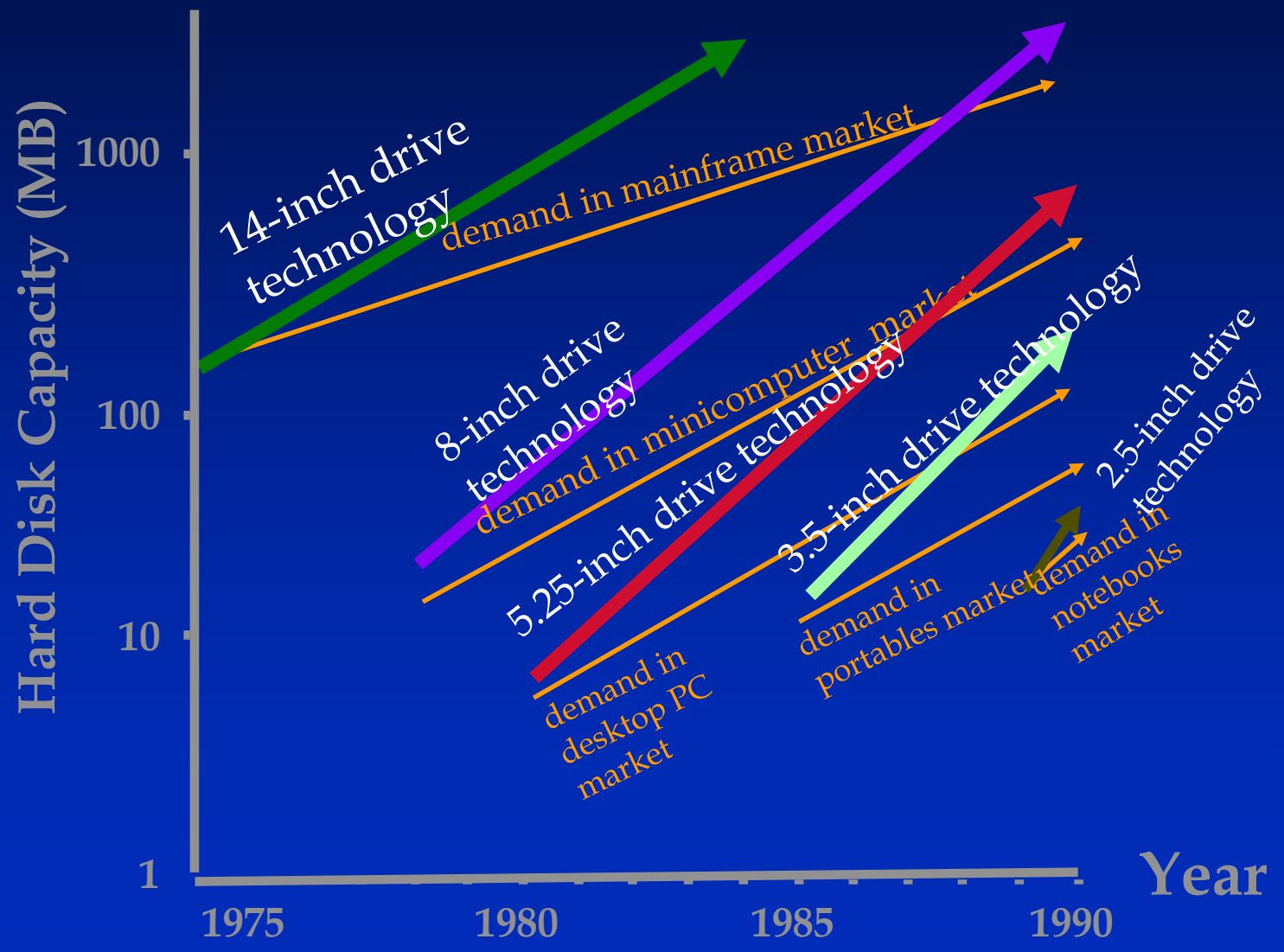
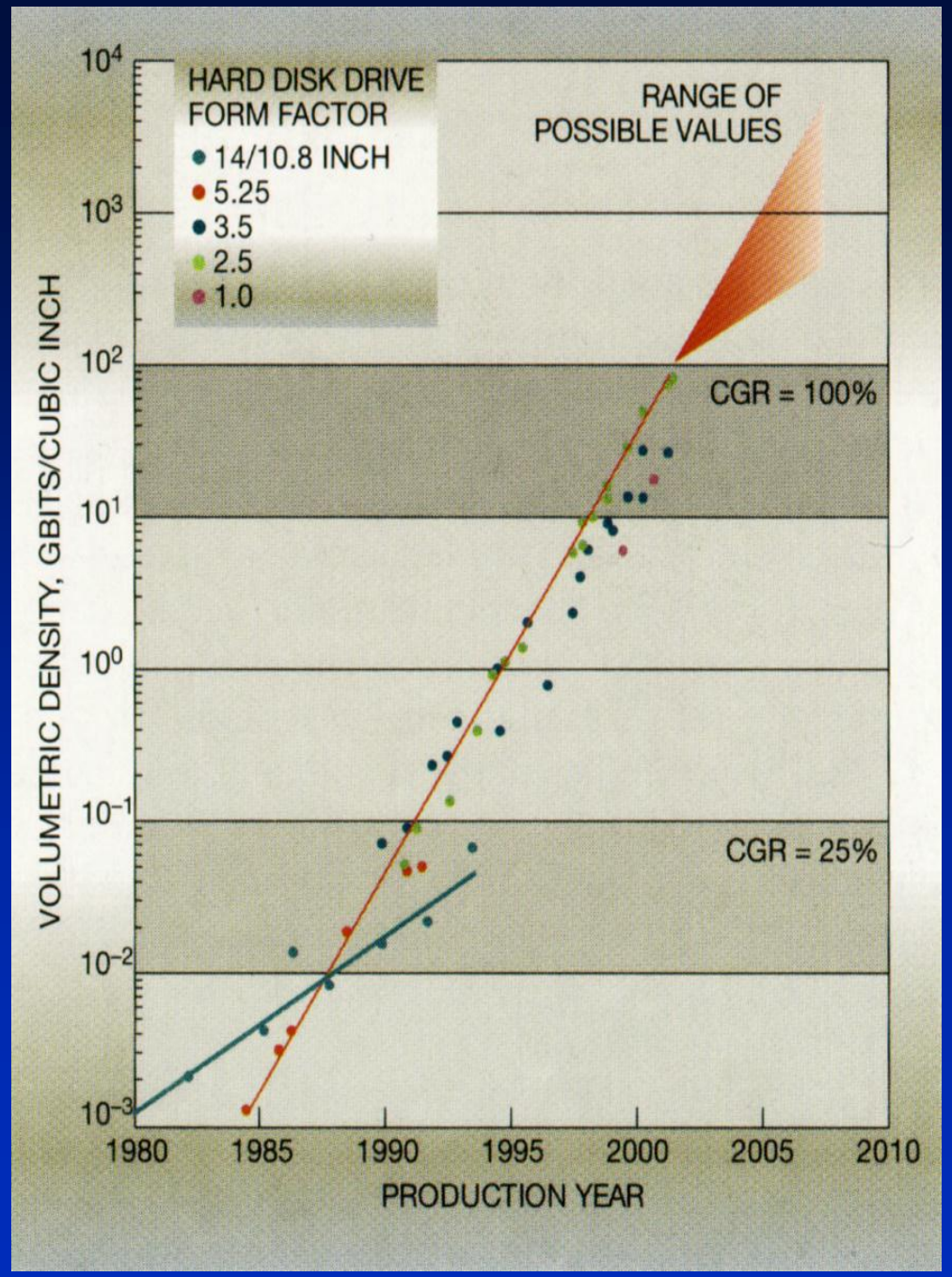


Disk Drives

1957 IBM	24” diameter
	50 platters
	5MB capacity
	12kbs sustained read
Fujitsu (~ 2000)	3.5” diameter
	1.1 GB capacity
	6.8 MBs sustained read
Today	1.8” drives for mobile platforms
	1.3” drives for laptops
Flash memory ?	1.0” drives for digital cameras
	0.85” drives for digital cameras

Hard disk drive volumetric density trend



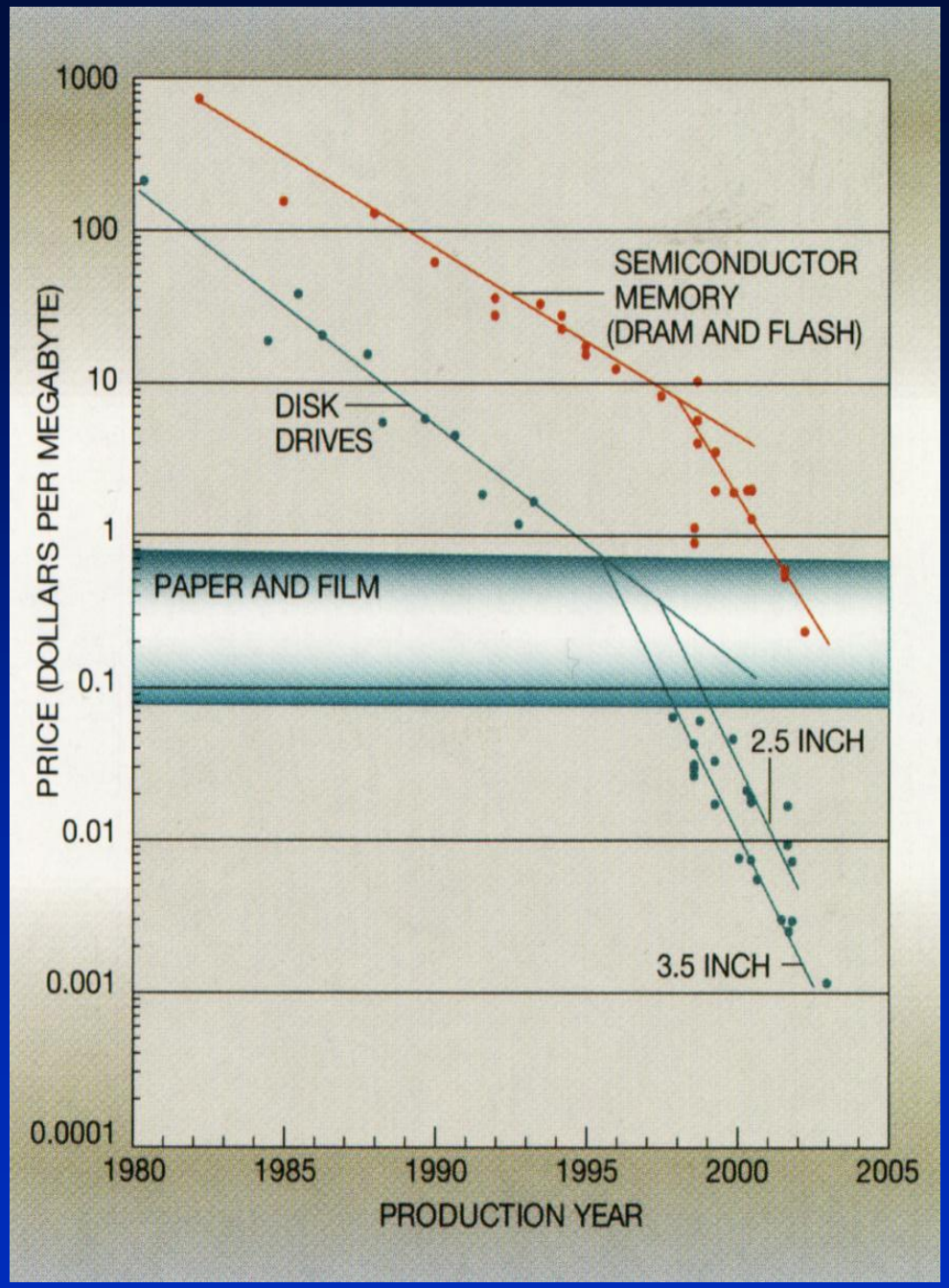
E. Grochowski, R.D. Halem. "Technological impact of magnetic hard disk drives on storage systems," IBM Systems Journal, vol. 24, no. 2, 2003 p. 339.

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



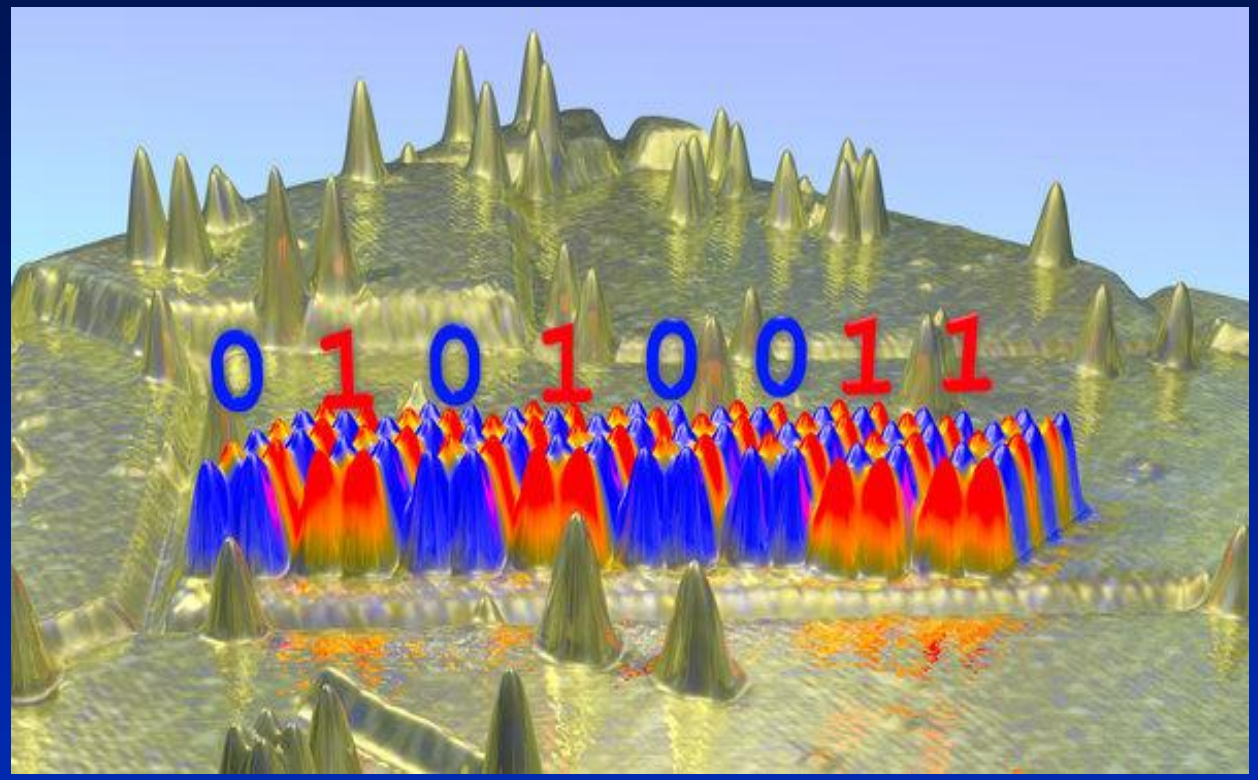
E. Grochowski, R.D. Halem. "Technological impact of magnetic hard disk drives on storage systems," IBM Systems Journal, vol. 24, no. 2, 2003 p. 339.

Solid State Storage 2017

1 TB Hard drive ~ $40-50

1 TB SSD ~ $200 - $300

Miniaturized Data Storage at Atomic Scale

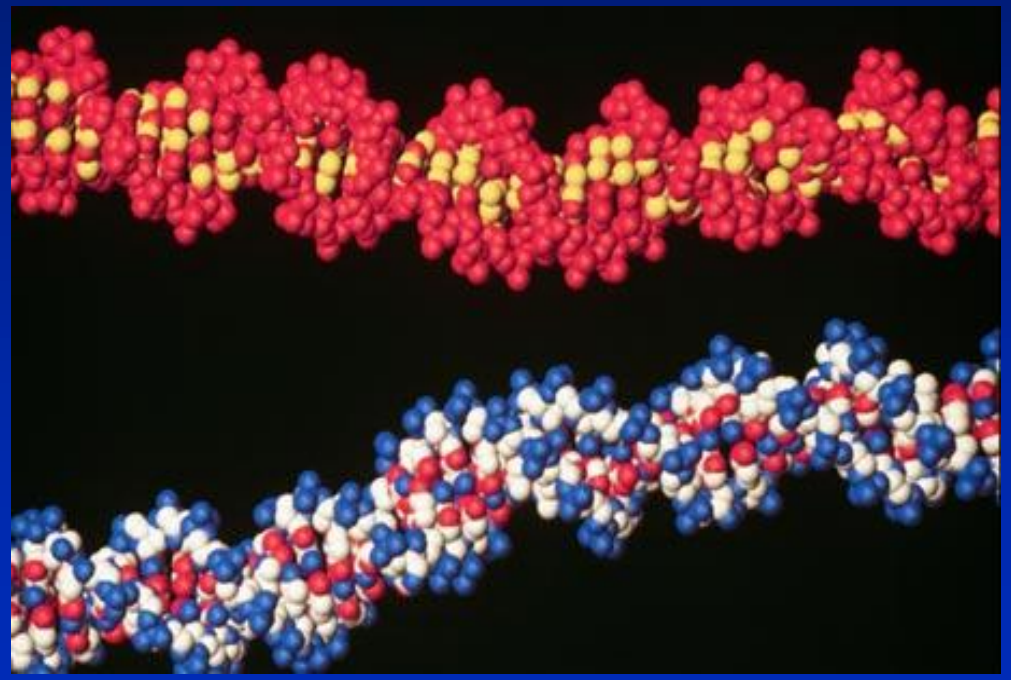


IBM researchers have stored and retrieved digital data from an array of just 12 atoms

New York Times,
1/12/12

DNA Storage

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



Science, August 19, 2012

Disruptive Technologies

- What is typical management and marketing dogma?
- Stay close to your customers!

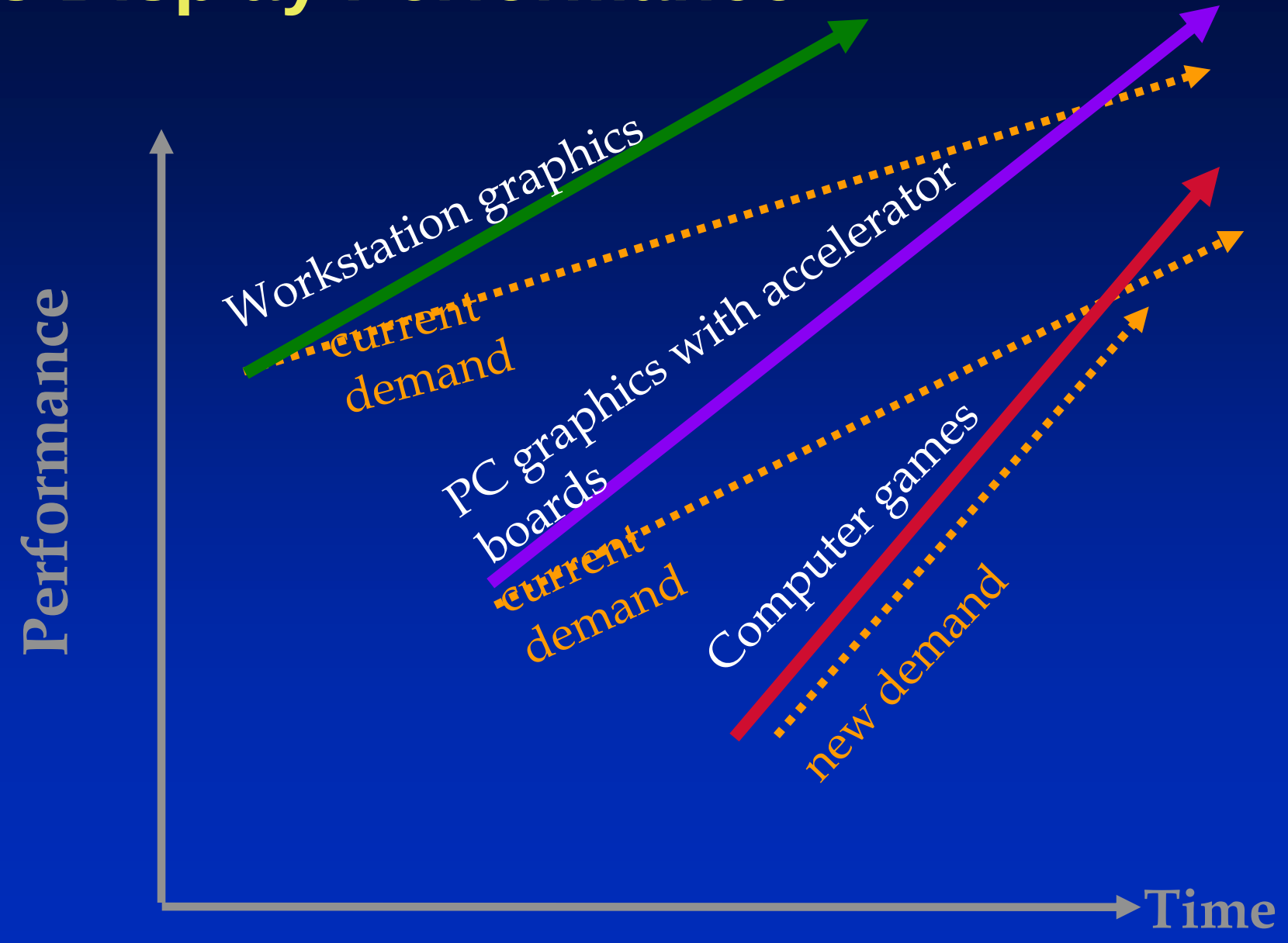
Disruptive Technologies

- 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

Graphics Display Performance



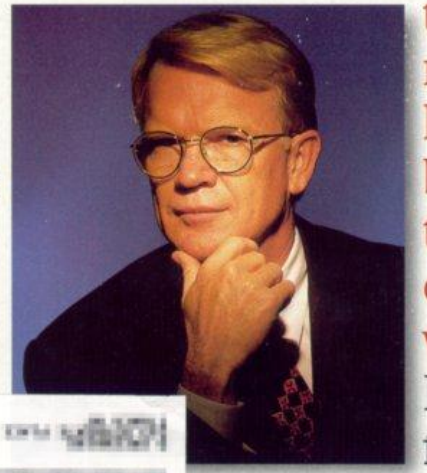
HOW DICK GRASSO IS TRANSFORMING THE NYSE

BusinessWeek

AUGUST 4, 1997 A PUBLICATION OF THE McGRAW-HILL COMPANIES $3.50

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?

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

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

SPECIAL REPORT THE BEST IN EXECUTIVE EDUCATION

BusinessWeek

OCTOBER 20, 1997 A PUBLICATION OF THE McGRAW-HILL COMPANIES $3.50

CAN GEORGE FISHER FIX KODAK?

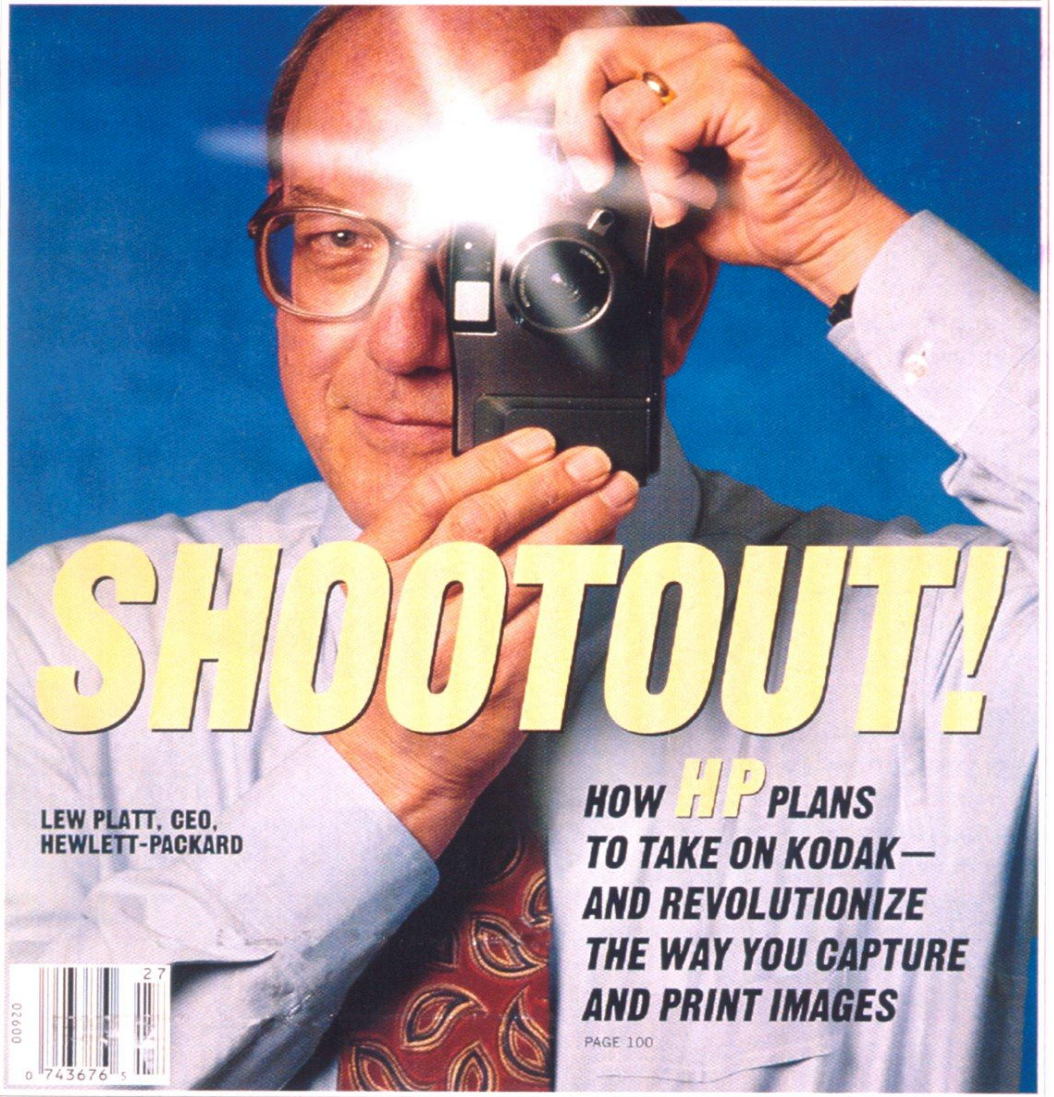
PAGE 116

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

GLOBAL 1000 THE TOP COMPANIES **TOBACCO** HOW THE DEAL WILL CHANGE **U.S. ECONOMY** NEW NUMBERS, ROSIER VIEW

BusinessWeek

JULY 7, 1997 A PUBLICATION OF THE McGRAW-HILL COMPANIES $3.50



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

http://www.bloomberg.com/news/2010-07-19/redbox-plots-internet-movie-strategy-in-challenge-to-netflix-on-home-turf.html

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. . .