Lecture 5: Cost, Price, and Price for Performance

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Computer Science 252

Spring 1996

Review From Last Time

- Given sales a function of performance relative to competition, tremendous investment in improving product as reported by performance summary
- Good products created when have:
  - Good benchmarks
  - Good ways to summarize performance
- If benchmarks/summary inadequate, then choice between improving product for real programs vs. improving product to get more sales;
  sales almost always wins!
- Execution time is the REAL measure of computer performance!
- What about cost?

Impact of Means on SPECmark89 for IBM 550

	Ratio to VAX:		Time:		Weighted Time:	
Program	*Before*	*After*	*Before*	*After*	*Before*	*After*
gcc	30	29	49	51	8.91	9.22
espresso	35	34	65	67	7.64	7.86
spice	47	47	510	510	5.69	5.69
doduc	46	49	41	38	5.81	5.45
nasa7	78	144	258	140	3.43	1.86
li	34	34	183	183	7.86	7.86
eqntott	40	40	28	28	6.68	6.68
matrix300	78	730	58	6	3.43	0.37
fpppp	90	87	34	35	2.97	3.07
tomcatv	33	138	20	19	2.01	1.94
Mean	54	72	124	108	54.42	49.99
	Geometric		*Arithmetic*		*Weighted Arith.*	
	Ratio	1.33	Ratio	1.16	Ratio	1.09

Integrated Circuits Costs

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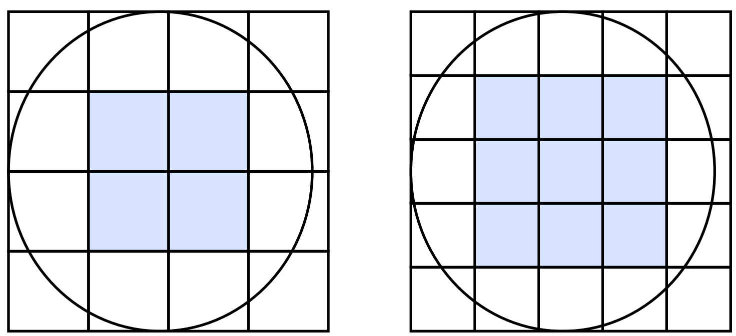
– Test dies



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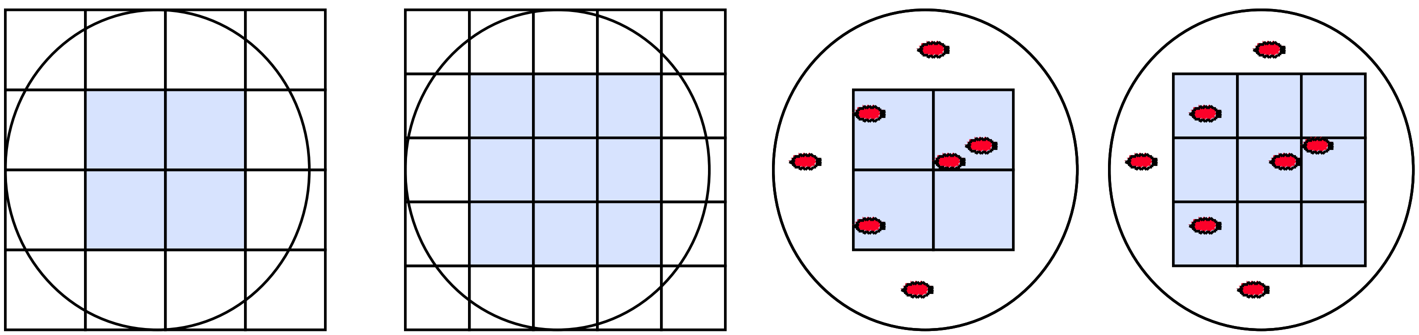

$$\text{Die Yield} = \text{Wafer yield} * \left\{1 + \frac{\text{Defects\_per\_unit\_area} * \text{Die\_Area}}{\alpha}\right\}^{-\alpha}$$

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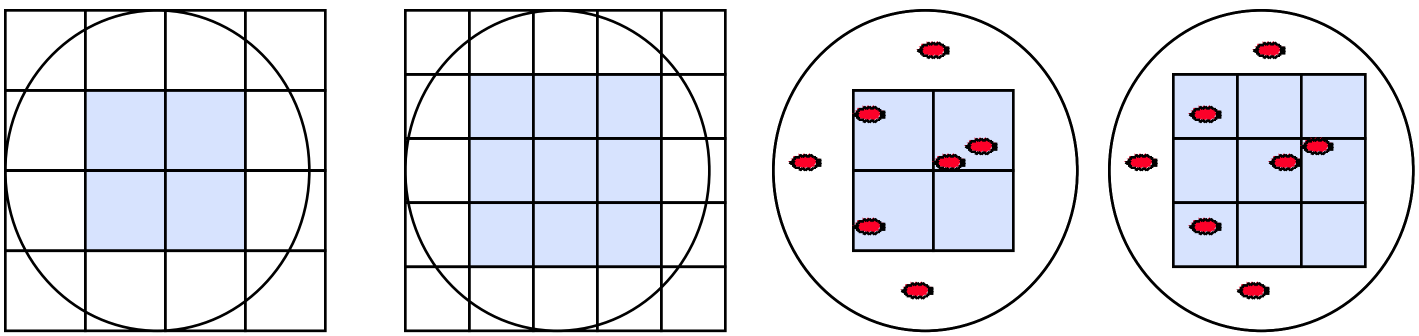

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Die Cost goes roughly with die area^4

Real World Examples

Chip	Metal layers	Line width	Wafer cost	Defect /cm²	Area mm²	Dies/ wafer	Yield	Die Cost
386DX	2	0.90	$900	1.0	43	360	71%	$4
486DX2	3	0.80	$1200	1.0	81	181	54%	$12
PowerPC 601	4	0.80	$1700	1.3	121	115	28%	$53
HP PA 7100	3	0.80	$1300	1.0	196	66	27%	$73
DEC Alpha	3	0.70	$1500	1.2	234	53	19%	$149
SuperSPARC	3	0.70	$1700	1.6	256	48	13%	$272
Pentium	3	0.80	$1500	1.5	296	40	9%	$417

– From "Estimating IC Manufacturing Costs," by Linley Gwennap, *Microprocessor Report*, August 2, 1993, p. 15

Other Costs

$$\text{Die Test Cost} = \frac{\text{Test Jig Cost} * \text{Ave. Test Time}}{\text{Die Yield}}$$

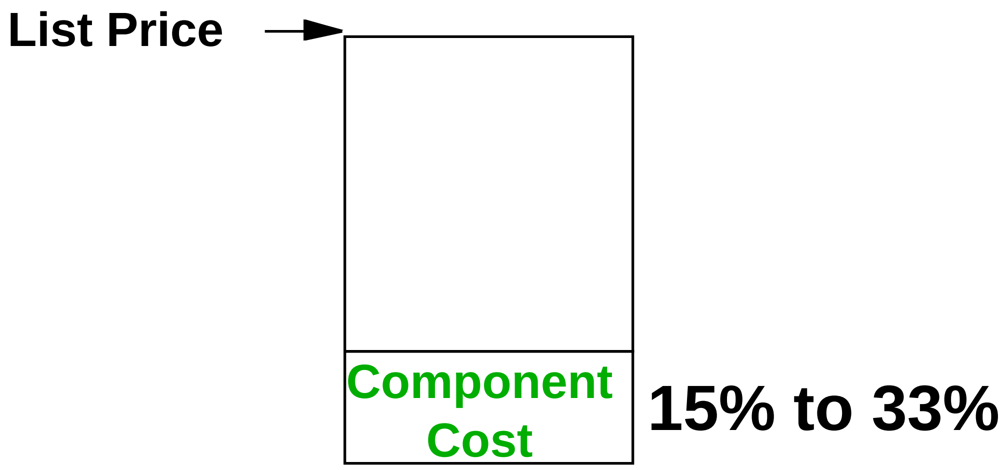
Packaging Cost: depends on pins, heat dissipation, beauty, ...

Chip	Die cost	Package pins	Package type	Package cost	Test & Assembly	Total
386DX	$4	132	QFP	$1	$4	$9
486DX2	$12	168	PGA	$11	$12	$35
PowerPC 601	$53	304	QFP	$3	$21	$77
HP PA 7100	$73	504	PGA	$35	$16	$124
DEC Alpha	$149	431	PGA	$30	$23	$202
SuperSPARC	$272	293	PGA	$20	$34	$326
Pentium	$417	273	PGA	$19	$37	$473

Cost/Performance

What is Relationship of Cost to Price?

- **Component Costs**



Cost/Performance

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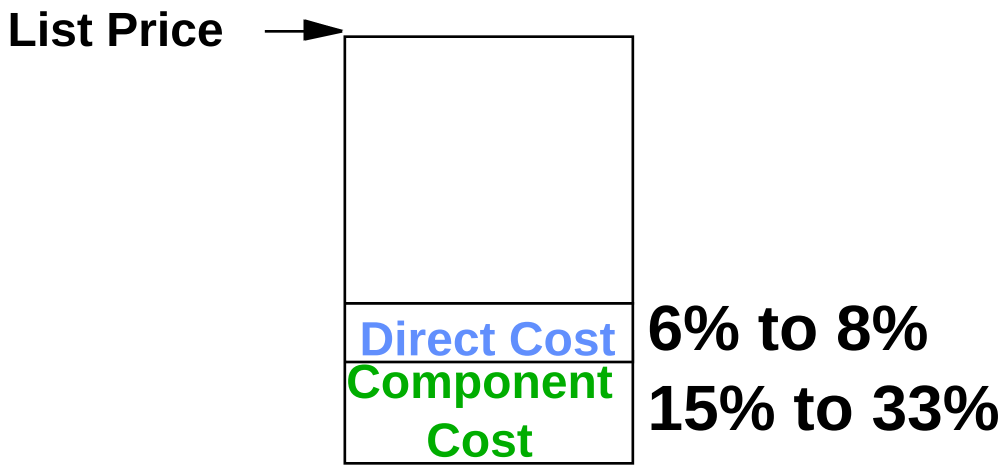
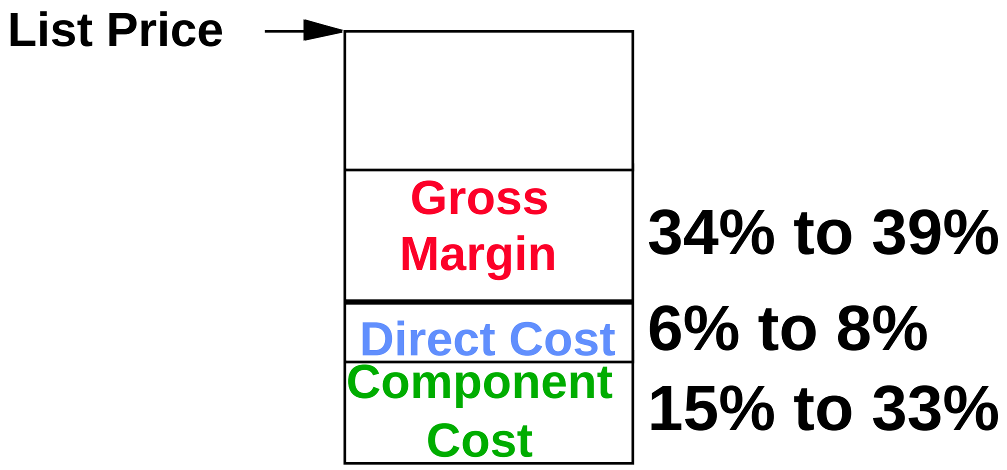


Cost/Performance

What is Relationship of Cost to Price?

- **Component Costs**
- **Direct Costs** **(add 25% to 40%) recurring costs: labor, purchasing, scrap, warranty**
- **Gross Margin** **(add 82% to 186%) nonrecurring costs: R&D, marketing, sales, equipment maintenance, rental, financing cost, pretax profits, taxes**



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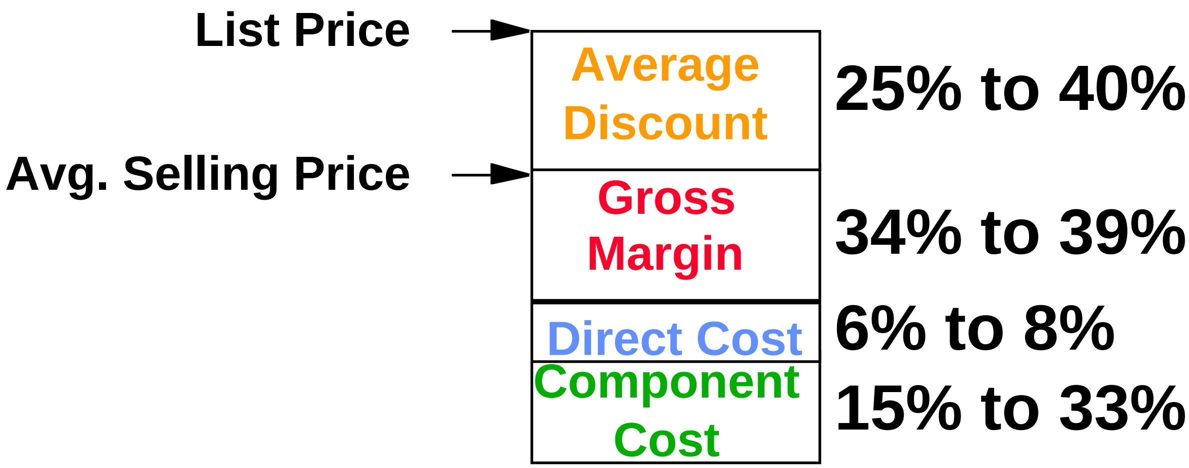
- **Gross Margin** (add 82% to 186%) nonrecurring costs: R&D, marketing, sales, equipment maintenance, rental, financing cost, pretax profits, taxes
- **Average Discount** to get List Price (add 33% to 66%): volume discounts and/or retailer markup



Chip Prices (August 1993)

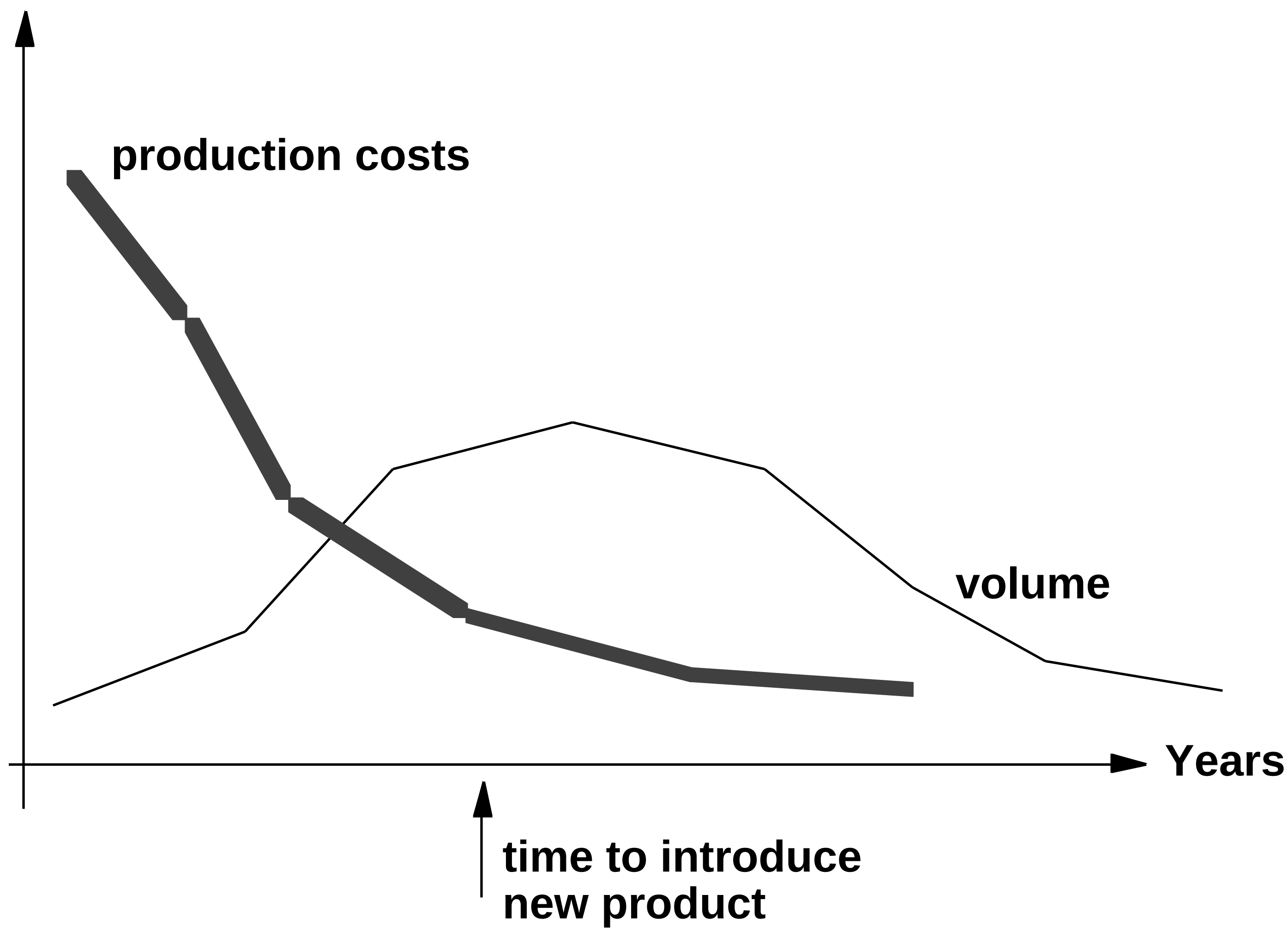
- **Assume purchase 10,000 units**

Chip	Area mm^2	Mfg. cost	Price	Multi-plier	Comment
386DX	43	$9	$31	3.4	Intense Competition
486DX2	81	$35	$245	7.0	No Competition
PowerPC 601	121	$77	$280	3.6	
DEC Alpha	234	$202	$1231	6.1	Recoup R&D?
Pentium	296	$473	$965	2.0	Early in shipments

Workstation Costs: $1000 to $3000

• **DRAM:**	**50% to 55%**
• **Color Monitor:**	**15% to 20%**
• **CPU board:**	**10% to 15%**
• **Hard disk:**	**8% to 10%**
• **CPU cabinet:**	**3% to 5%**
• **Video & other I/O:**	**3% to 7%**
• **Keyboard, mouse:**	**1% to 2%**

Learning Curve



Volume vs. Cost

- **Rule of thumb on applying learning curve to manufacturing:**

  "When volume doubles, costs reduce 10%"

  A DEC View of Computer Engineering **by C. G. Bell, J. C. Mudge, and J. E. McNamara, Digital Press, Bedford, MA., 1978.**

- **40 MPPs @ 200 nodes = 8,000 nodes/year vs. 100,000 Workstations/year**

  $$12.5X \approx 2^{3.6} \Rightarrow (0.9)^{3.6} = 0.68$$

  Cost should be 1/3 less for same components

- **What about PCs vs. WS?**

Volume vs. Cost: PCs vs. Workstations

	1990	1992	1994	1997
PC	23,880,898	33,547,589	44,006,000	65,480,000
WS	407,624	584,544	679,320	978,585
Ratio	59	57	65	67

- **65X ≈ $2^{6.0}$ => $(0.9)^{6.0}$ = 0.53**
  - ≈ 50% costs for whole market for PCs vs. Workstations

Single company: 20% WS market vs. 10% PC market

Ratio	29	29	32	33

- **32X ≈ $2^{5.0}$ => $(0.9)^{5.0}$ = 0.59**
  - ≈ 60% costs for single company for PCs vs. Workstations

High Margins on High-End Machines

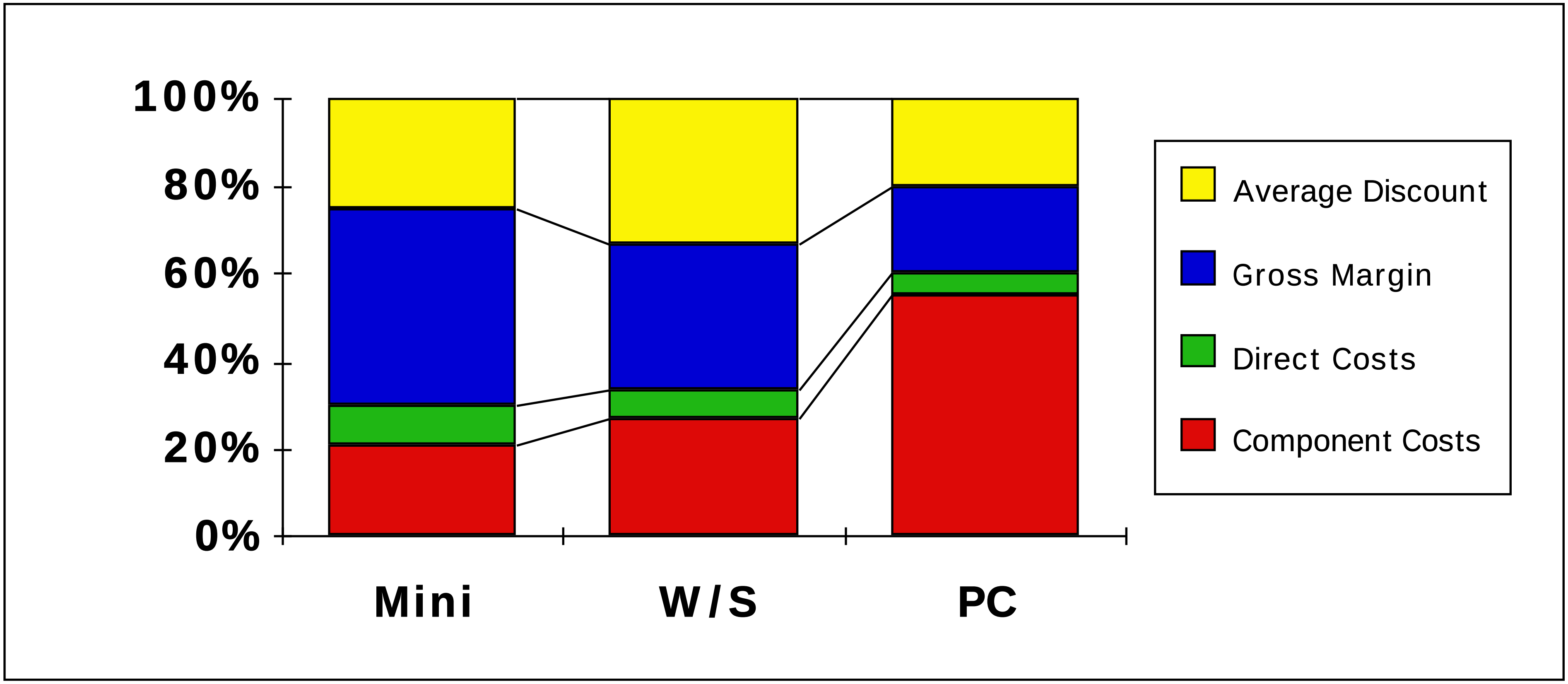
- **R&D considered return on investment (ROI) ≈10%**
  - **Every $1 R&D must generate $7 to $13 in sales**
- **High end machines need more $ for R&D**
- **Sell fewer high end machines**
  - **Fewer to amortize R&D**
  - **Much higher margins**
- **Cost of 1 MB Memory (January 1994):**

PC	**$40**	**(Mac Quadra)**
WS	**$42**	**(SS-10)**
Mainframe	**$1920**	**(IBM 3090)**
Supercomputer	**$600**	**(M90 DRAM)**
	$1375	**(C90 15 ns SRAM)**

Recouping Development Cost on Low Volume Microprocessors?

- Hennessy says MIPS R4000 cost $30M to develop
- Intel rumored to invest $100M on 486
- SGI/MIPS sells 300,000 R4000s over product lifetime?
- Intel sells 50,000,000 486s?
- Intel must get $100M from chips ($2/chip)
- SGI/MIPS can get $30M from margin of workstations vs. chips vs. $100/chip
- Alternative: SGI buys chips vs. develops them

Price/Performance
Gross Margin vs. Market Segment



Price/Performance
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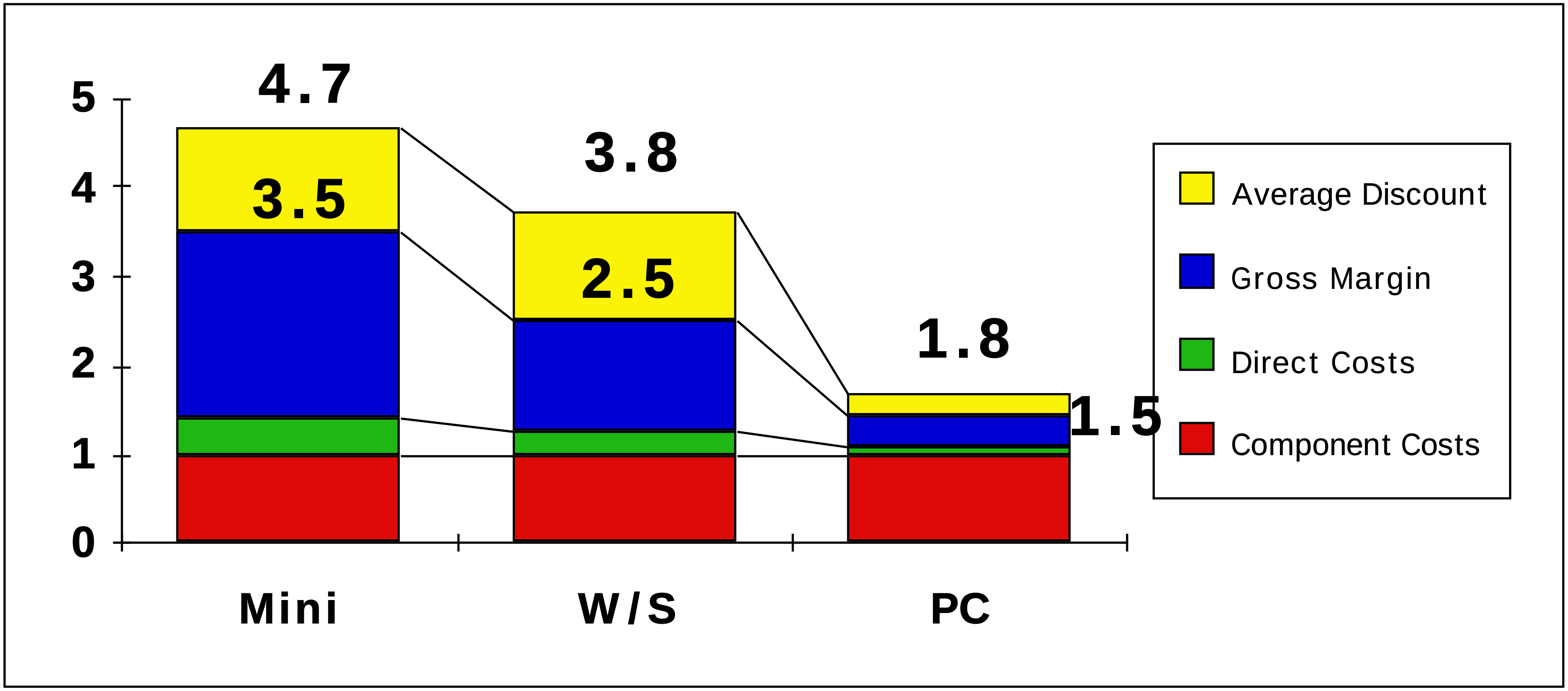
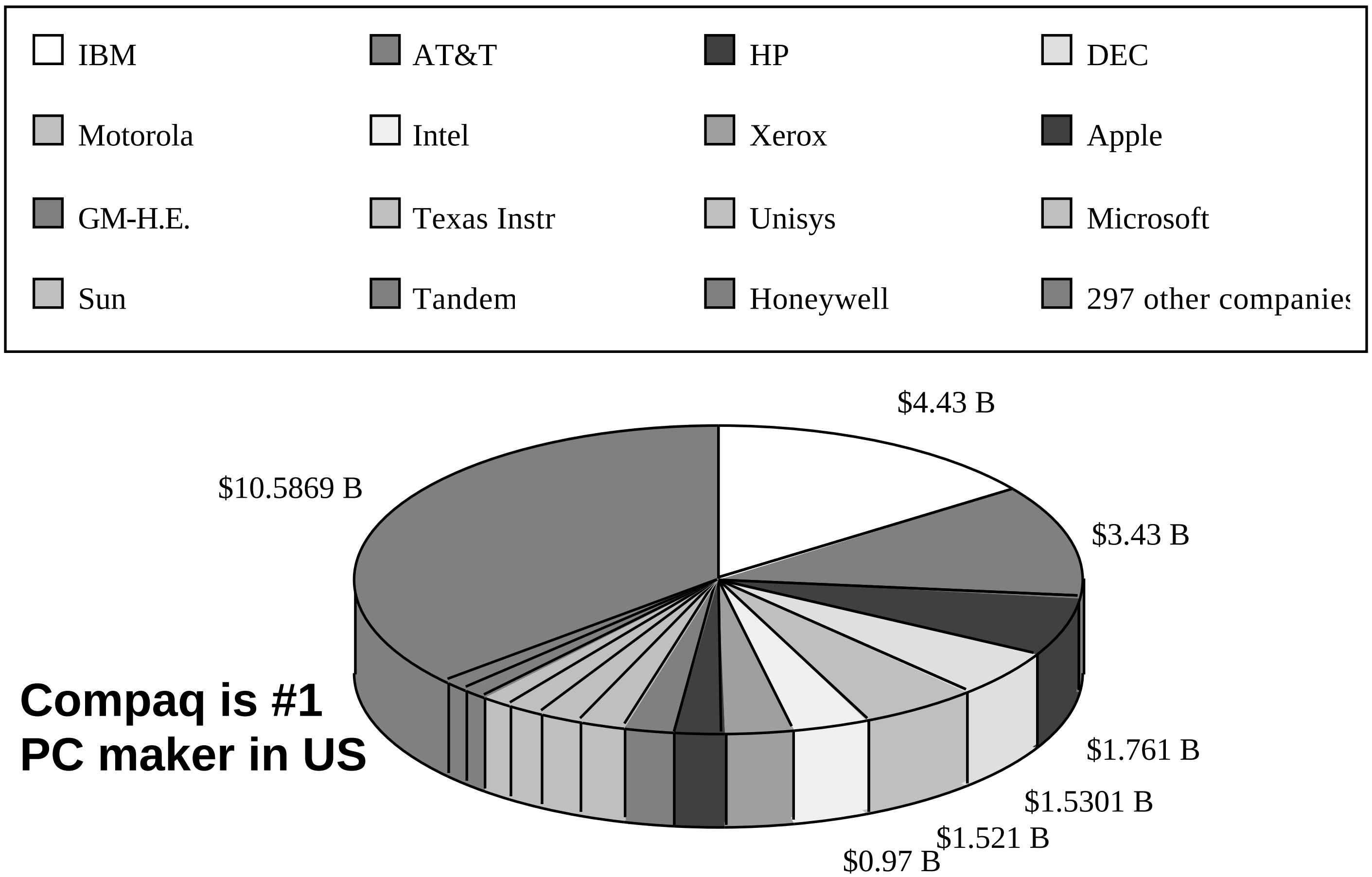


Impact of Margin Shrink on Society/Computer Industry

- **Economy?**
- **Research Labs?**
- **Future Products?**
- **Your jobs?**

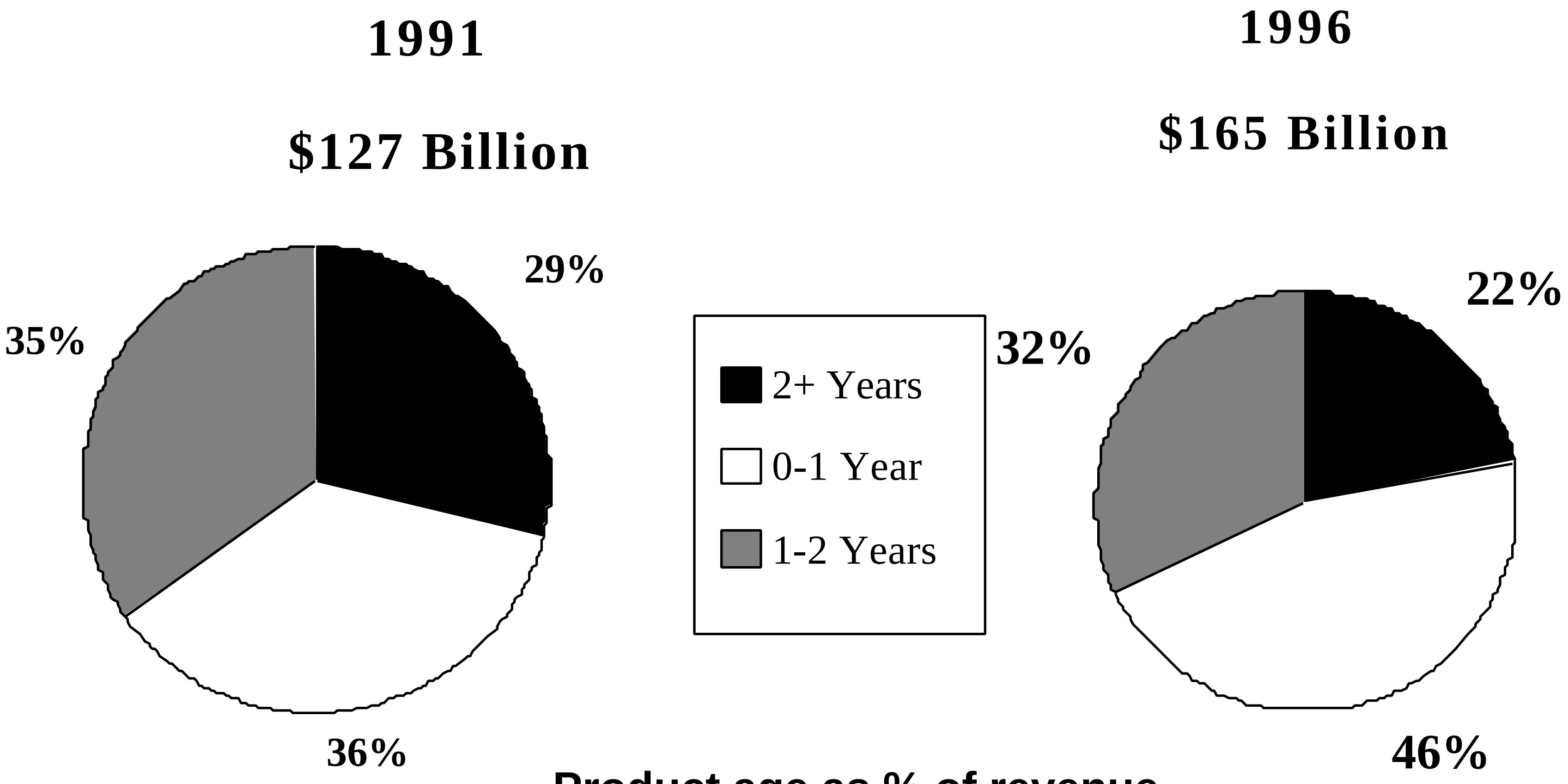
Information Technology R&D

U.S. IT's Biggest R&D Spenders in 1993: Total $29.2 billion



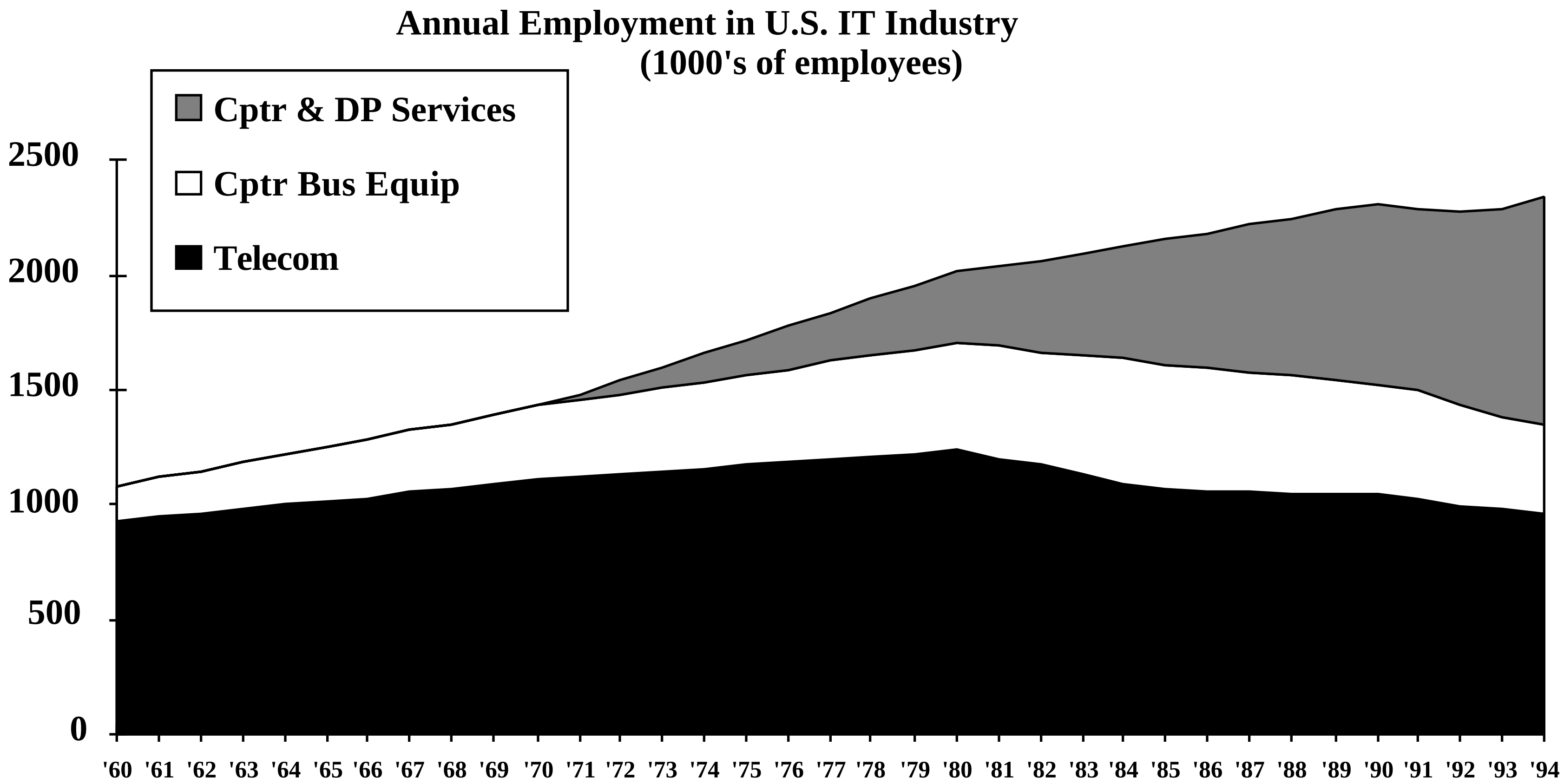
Compaq is #1
PC maker in US

Accelerating Pace of Product Development

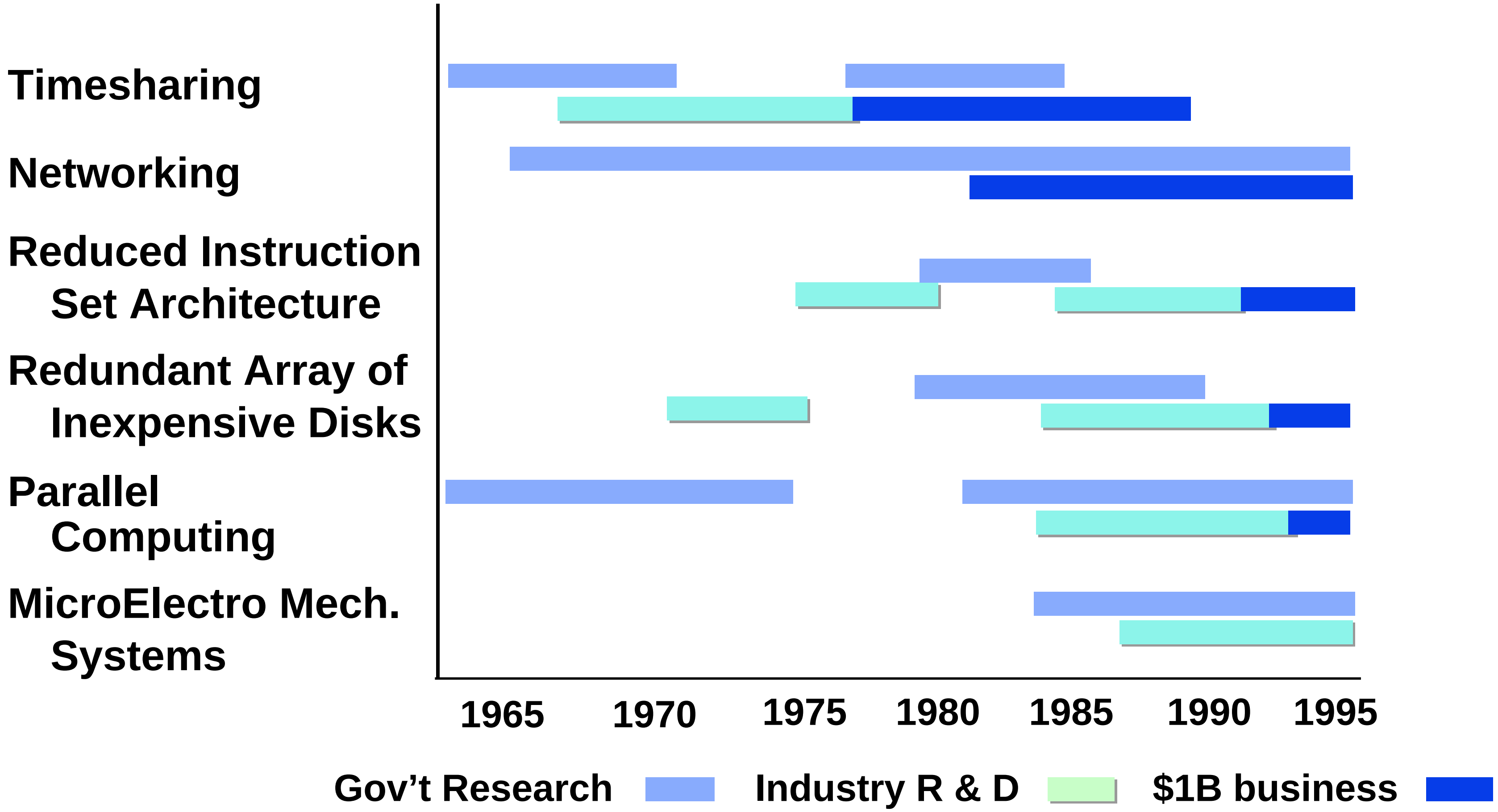


Product age as % of revenue

Shift in Employment Towards Software and Services



Long Term R&D Investments Take Time to Payoff



US IT Trade Balance
(It's Negative!)